African Swine Fever Cross-Border Risk Assessment: South-East Asia Scientific Report

OIE SUB-REGIONAL REPRESENTATION FOR SOUTH-EAST ASIA (SRR-SEA)

C/O Department of Livestock Development, 69/1 Phayathai Road, Bangkok 10400 Thailand

Tel: (+66 2) 653 4864 * Fax: (+66 2) 653 4904 * Email: srr.seasia@oie.int

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Executive summary

Following the first report and the spread of African swine fever virus in East and South-East Asia in 2018, preventing the introduction or re-introduction of the virus in their countries became a priority of national veterinary services. The World Organisation for Animal Health (OIE) supports the national governments by developing training and capacity building for risk analyses (including risk assessment, risk communication and risk management). As a first step, a training on cross-border risk assessment of African swine fever virus was organised with the help of the City University of Hong Kong (Center for Applied One Health Research and Policy Advice, OHRP). The original plan included the organisation of a face-to-face workshop and the compilation of a manual in order to initiate national cross-border risk assessments of African swine fever. However, due tothe SARS-CoV-2 pandemic and the subsequent travel restrictions, the OIE team and the OHRP consultancy team decided to change the format of the training into a series of online webinars.

The webinar series ran from September 2020 to May 2021. The participants include members of national veterinary services from twelve countries (Cambodia, China, Indonesia, Lao PDR, Malaysia, Myanmar, Papua New Guinea, Singapore, Thailand, The Philippines, Timor-Leste, Vietnam). The webinars combined presentations about risk assessment and discussions with and between participants (through country presentations, group discussions, exercises). Each participant was assigned with one mentor from the OHRP consultancy team, who provided support in risk assessment methodology between the webinars. The OHRP consultancy team also assisted with writing of national reports to be shared with national authorities.

Outputs of the project encompass a desk review about African swine fever in the region (South-East Asia plus China, Papua New Guinea and Timor Leste), a manual to perform a cross-border risk assessment of African swine fever and the present report that includes a discussion of the data retrieved during the webinars and recommendations on risk mitigation measures and capacity building. Only four of the country risk assessment teams (CRATs) reached the step of risk estimation. Moreover, almost all reports are incomplete as some risk pathways were eluded without relevant explanation. One of the main components of risk assessment is the transparency of the process and the clear explanation of each decision made in the report. Unfortunately, this objective was not achieved for most of the country reports.

The epidemiology of African swine fever and the risk of introduction of the virus in a country were discussed with participants during the webinars and through one-to-one discussions with the mentors. During these discussions, most of the participants focused on the pig product trade (illegal freight, individual travellers, or swill trade). Two other risk pathways were noted as relevant for the region by the OHRP consultancy team: the fomites and the wild boar population. These two risk pathways were rarely studied by participants as there is a lack of data for the wild boar population and the concept of fomites (without the presence of live pigs or pork products) might be misunderstood. The OHRP consultancy team recommends that national risk mitigation should focus on these three risk pathways.

This first regional training on cross-border risk assessment of African swine fever was successful in initiating capacity building and communication between countries. The national and international stakeholders are encouraged to extend the present training to more participants from different departments of the national authorities.

List of accronyms

ASF: African Swine Fever

ASFV: African Swine Fever Virus

CRAT: Country Risk Assessment Team

CRISPR: Clustered Regularly Interspaced Short Palindromic Repeats

ELISA: Enzyme-Linked Immunosorbent Assay

FAO RAP: Food and Agriculture Organization Regional Office for Asia and Pacific

LAMP: Loop-mediated isothermal amplification

OHRP: Centre for Applied One Health Research and Policy Advice

OIE: Office Internationale des Epizooties (World Organisation for Animal Health)

OIE-WAHIS: OIE World Animal Health Information System

P: Pathway

PNG: Papua New Guinea

PCR: Polymerase Chain Reaction

RPA/RAA: Recombinase-based isothermal assays

U.S.: United States of America

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We are also thankful to Dr. Lorraine Chapot for her review of this report.

Introduction

Since African swine fever virus (ASFV) was first reported in China in August 2018, the virus has continued to spread throughout China and to countries in South-East Asia. Despite that some entire countries as well as some areas inside countries in South-East Asiahad remained free of the virus in 2020, virus introduction in some countries had led to devastating consequences for the pig industry due to the loss of production and the resulting trade bans. Moreover, most South-East Asian countries are low- or medium-income countries and, therefore, have limited capacity of veterinary services. Their pig production largely depends on smallholder farming commonly characterised by poor biosecurity and the absence of animal health and movement records, making the effective and efficient surveillance, prevention and control of ASF difficult.

Since the beginning of the ASF outbreak in East and South-East Asia, there have been continued regional efforts to develop coordinated and multidisciplinary approaches for ASF control and prevention across governments and the private sector. Considering that risk analysis is a pillar of developing local, national, and regional sustainable ASF prevention and control strategies, capacity building in risk assessment for veterinary services in South-East Asian countries, plus China, Timor-Leste, and Papua New Guinea was identified as one of the first essential steps.

Objectives and scope

The present ASF cross-border risk assessment project aimed to build capacity of OIE Members from South-East Asia plus China, Papua New Guinea (PNG) and Timor Leste in conducting cross-border risk assessments, using the example of ASFV. Therefore, the project also provided an opportunity to inform stakeholders of the regional ASF situation, along with the concepts, methodologies, and results of value chain analyses, and risk analyses.

The present scientific report discusses the work and the data collected by the country risk assessment teams (CRAT) and the Centre for Applied One Health Research and Policy Advice (OHRP) consultancy team during the training. The OHRP consultancy team facilitated the CRAT work by providing guidance, training and one-to-one support throughout the project. . While the CRATs were encouraged to produce a simple cross-border risk assessment for their internal reference, the present scientific report is not a national or South-East Asia regional cross-border risk assessment. By extension, itwill discuss the outputs generated by the project activities and recommend risk-mitigation measures. The CRAT reports shall remain confidential and will not be publicly available. The use of national data provided in the present scientific report has been agreed upon by the CRATs and are presented to support recommendations about capacity building in conducting risk assessment and developing prevention and control strategies in South-East Asia.

Method

The project's overall goal is to build national veterinary services' capacity in conducting ASF cross-border risk assessment. The original plan was to organise a face-to-face workshop on cross-border risk assessment for national veterinary services, using the example of ASFV. However, due to the SARS-CoV-2 pandemic and the subsequent travel restrictions, the decision to organise online webinars was made by the OHRP consultancy team in discussion with the OIE. At least one representative of the veterinary services from each participating country was nominated to attend the training. In the rest of this document, these country representatives will be referred as CRATs (country risk assessment teams). The project was divided into three phases.

The first phase consisted of a desk review of the literature on ASF situations in South-East Asia plus China, Timor-Leste, and Papua New Guinea. Based on this review, generic cross-border risk pathway diagrams for ASFV were created. These diagrams were shared and discussed with the CRATs for their relevance to each national context.

In the second phase, a series of 15 webinars was organised over 9 months. Inception with all CRATs was organised on the 31st of August 2020. The training presentations focused on providing background knowledge and technical skills required for conducting cross-border risk assessment, including conducting value chain analysis, identifying risk pathways, developing risk pathway diagrams, collecting data, and estimating the entry risk for ASFV (re)introduction. The CRATs also had the opportunity to describe the situation of ASF in their countries. Moreover, the OHRP consultancy team actively collected relevant information during the group discussions, which were either plenary or in small groups with facilitators. While qualitative risk assessment was preferable due to the limited data availability in the region, a separate webinar was organised to introduce semi-quantitative and quantitative approaches. In addition to the CRATs, the webinar invitation was extended to other members of the national veterinary services.

The last phase of the project focused on facilitating ASF cross-border risk assessment by each CRAT. The CRATs were given a manual to guide them during this phase. Each country was assigned a mentor from the OHRP consultancy team (Annex 1), who assisted the CRATs with conducting the following tasks.

- Collect provincial data of pig production and wild boar population (Annex 2)
- Describe regional and international trade (Annex 3)
- Review of the generic risk pathways
- Estimate risk pathway diagram event likelihoods (Annex 4)
- Fill up a standardised questionnaire (Annex 5): the OHRP consultancy team developed a standardised questionnaire to help the CRAT with the data collection. Questions focused on the following topics: 1) trade of pigs and pig products, 2) trade of wild boars and wild boar products, 3) human activities and fomites, and 4) wild and free-roaming animals.

Outputs

Study design

Prior to the webinar series, the study design of the project was written. The document was not previously published but it is included in Annex 6 for reference. The study design set out the objectives of the project as follows:

1. To review existing knowledge about ASFV epidemiology in countries participating in the study.
2. To identify the major entry risk pathways for ASFV (re) introduction to each country.
3. To develop and strengthen risk assessment capacity of national veterinary services.
4. To develop practical recommendations on risk mitigation measures in the region.

The hazard of the cross-sectional risk assessment was identified as part of formulating the study design and presented to all CRATs at the beginning of this project. The hazard for the present RA is specified as the African swine fever virus (ASFV). The virus is an enveloped double-stranded DNA virus of the Asfarviridae family. There are 26 identified genotypes in the world. However, ASFV isolates detected in China and Vietnam all belong to the genotype II (p72). For the present risk assessment, all genotypes will be considered. Susceptible species include domestic pigs and wild species of the Suidae family (as warthogs or wild boars). Transmission between susceptible animals occurs via direct or indirect contact (e.g. through the environment, human activities as swill feed trade, or vector-borne).

Desk review

A desk review on the situation of ASF in the region prior to the project was produced. The document is attached in Annex 7. The review was provided to the CRATs to facilitate data collection in their own countries. It was expected that each country would collect the national data in order to start their own risk assessment.

Since the latest update of the desk review (October 2020), the ASFV has spread further in the region. The new information is described in Table 1 (up to September 2021).

Table 1: Updated information of the desk review up to the September 2021

Section in desk review	Update
History and current situation of African swine fever	**Cambodia** - As of February 2021, all the previous outbreaks were reported as resolved and no cases of ASFV were reported in Cambodia in 2021 [1,2]. **China** - In February 2021, 21 outbreaks, affecting both domestic and wild pigs, in 10 different administrative divisions were reported and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2]. **Hong Kong SAR** - One new outbreak in farmed swine was reported in February 2021 [1,2]. **Indonesia** - A total of 443 new outbreaks in backyard swine were reported in February 2021 and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2]. **Korea (Rep of)** - A total of 66 new outbreaks affecting wild boar were reported in February. The outbreaks affecting both domestic and wild boars were notified until April 2021, and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2]. **Malaysia** Introduction of AVSFV in Malaysia on the 19th of February 2021. First detection was in dead wild boar in the province of Sabah. The ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1–5]. **Myanmar** - On 7th November 2020, the recurrence of the disease in Sagaing has been reported in backyard swine and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2]. **Philippines** - In February 2021, a total of 171 new outbreaks in backyard swine were reported and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2].

Section in desk review	Update
	Thailand - No ASF outbreak has been notified as of September 2021 [1,2]. **Timor-Leste** - In February 2021,126 outbreaks were notified and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2]. **Vietnam** - A total of 1,336 outbreaks were reported as ongoing in February 2021 and the ongoing outbreak is still notified in the semester of July-December 2021 in OIE-WAHIS [1,2].
African swine fever virus	- A new strain of ASFV has been detected in China in 2020. This strain is less virulent and lead to less severe clinical signs in the pigs [6]. The rumour pointed the use of illegal live vaccine even though there is no scientific evidence. The use of illegal ASF vaccination was reported in China and the China's Ministry of Agriculture and Rural Affairs strictly crackdown the use of the vaccine in pig production [7–11]. - A publication identified the strain circulating in Vietnam in 2019: VN/Pig/HN/19 is part of the genotype II and serogroup 8 and is closely related to Eastern European and Chinese strains [12].
Virus tenacity	- Both ASFV genome and infectious virus were detected in spleen or muscles at −20 °C and in blood stored at 4 °C kept for 24 months. ASFV genome and infectious virus were detected in bones stored at −20 °C, for up to three months and at 4 °C for up to one month and at room temperature (RT), no infectious virus could be recovered after one week. Skin at −20 °C, 4 °C and RT remained infectious for up to three, six and three months. In urine and faeces, no infectious virus was recovered after one week [13]. - A study tested the stability of ASFV in species originated from soil. ASFV was demonstrated in specimens from sterile sand for at least three weeks, beach sand for up to two weeks, yard soil for one week, swamp soil for three days [14].
Virus resistance	- Sodium hypochlorite, glutaraldehyde, caustic soda and potassium peroxymonosulfate showed the best ASFV inactivation rates [15]. - "DZPT-2" disinfectant is effective to be used during anti-epizootic measures regarding the ASF and could effectively prevent and force the disinfection of livestock and veterinary control facilities [16]. - Antimicrobial RM E Liquid has a strong effect against ASFV replication [12].

Section in desk review	Update
	- ASFV in tissues could remain infectious for 353–713 days at −20 °C, 35–136 days at +4 °C, and from 9 to 17 days at +23 °C [17]. - A study also shown that either 3.5% or 7.5% of citric acid and calcium hydroxide by soil weight were noted as agents that can effectively inactivate the virus after one hour of using on virus-spiked soil samples [14].
Clinicopathology	- According to one study that analysed the clinical signs and pathological features of the first outbreaks of ASF in Vietnam in 2019, genotype II (p72), the disease onset was a peracute to acute clinical form with high mortality. Some animals showed very unspecific clinical signs with severe hyperthermia, respiratory distress, diarrhea, or vomit. In postmortem examination, hemorrhagic splenomegaly and lymphadenitis were noted and histopathological lesion of the lymphoid depletion and multiorganic hemorrhage while monocyte-macrophages were identified in immunohistochemical methods [18]. The liver showed the highest viral loads, and ear tissue also exhibited high viral loads among 11 tissues obtained from dead pigs [19]. - According to one of the study conducted in Spain, the enlargement of liver and spleen; serosanguinous effusion in body cavities; and multiple hemorrhages in lungs, endocardium, brain, kidneys, urinary bladder, pancreas, and alimentary system were seen from the postmortem examination of wild boars infected with ASFV genotype II [20].
Laboratory detection and diagnostic tests	The use of several diagnostic tests was reported in the literature: - Rope-based oral fluid collection method (Vietnam) [19] - Real-time PCR Assay (Thailand, Laos, Cambodia, Vietnam) [21–23] - Portable magnetofluidic device (China) [24] - Loop-mediated isothermal amplification assay (Timor-Leste, Thailand) [25,26] - ASF antigen detection pen-side rapid diagnostic tests from Shenzhen Lvshiyuan Biotechnology Co. Ltd (Laos) [27] - Two Recombinase-Based Isothermal Amplification Assays (RPA/RAA) (China) [28] - Automatic Insulated Isothermal PCR System (Vietnam) [29] - Duplex TaqMan real-time PCR assay (China) [30] - Direct colorimetric loop-mediated isothermal amplification (LAMP) assay (Vietnam) [31]

<table>
<tr><th>Section in desk review</th><th>Update</th></tr>
<tr><td></td><td>- Hive-Chip and direct LAMP (China) [32]
- Horseradish peroxidase-conjugated-nanobody-based blocking ELISA (China) [33]
- CRISPR/Cas12a technology combined with immunochromatographic strips (China) [34]</td></tr>
<tr><td>Pig production system</td><td>China
- According to one of the review articles published in 2020, ASF outbreakcaused a number of issues in pig production: counterfeit drug and vaccine sales, insufficient pork supply, and panic among pig farmers [35].
- With the aim of supporting small-scale farms in resuming pig production, the quadruple protection procedure, which takes care of the farms' construction, environmental disinfection, regular immunisation, and feed quality was tested in small farms which had been confirmed with ASFV [36].
- Between April and June 2021 excess pork production has lowered pork prices, caused small and medium producers to liquidate farm inventories, and limited piglet restocking [37].
- Keeping their pigs in multi-storey buildings in an attempt to fulfil their nation's appetite for pork has been a revolution of new chapter in pig production [38–40].
CRATs data: the following data have been reported by the CRATs during webinar presentations [41].
Cambodia
- Majority (70%) of small scale farmers raised up to 50 heads per farm which reflected a total population of 2 million heads of pig within the country.
- Commercial farms raised more than 200 heads per farm.
Indonesia
- The majority of farmers (>95%) are smallholder farmers, 38.56% owned less than 5 pigs, 48.84% owned 5-20 pigs and 12.6% owned more than 20 pigs.
- Several big commercial farms are present in Indonesia aimed for export and breeding.
Thailand
- Native, fattening and breeding pigs are raised. The common farming systems are farrow-finish, nursery and finishing farms.</td></tr>
</table>

<table>
<tr><th>Section in desk review</th><th>Update</th></tr>
<tr><td></td><td>Myanmar
- Over two million holdings raised 5.8 million pigs with an average of nearly three pigs per holdings.
- Nationally, 27% of holdings raised pigs.</td></tr>
<tr><td>Value chain and trade of live pigs and pork products</td><td>Thailand
- While no cases have been detected in Thailand, Vietnam implemented a ban on trade of live pigs coming from this country [21,42–45].</td></tr>
<tr><td>Ecology of wild boar and cases in wild boar</td><td>Malaysia
- Wild boar mortality was also involved as one of the first reported case. There was additional suspicion of wild boar deaths with ASF, which tested negative with conventional PCR by Sabah Department of Veterinary Services Laboratory) [1–4,46,51].
Cambodia, Laos, Vietnam
- No study reported ASF in wild boar [22,46].
Indonesia
- Media reported that deaths of wild boars were reported in several national parks. The ASFV circulation in the wild boar population may threaten some endangered wild pig species [1].
Korea
- Since 9 October 2019 as of 16 August 2021, a total of 1 552 wild boars were confirmed to be infected by ASFV. From the report, it was noted that the sources of event or the origin of infection in wild boars was unknown [1,5,47–50].
Hong Kong SAR
- In September 2021, The Agriculture, Fisheries and Conservation Department (AFCD) confirmed one wild boar carcass tested positive for ASFV [52].</td></tr>
</table>

Manual

During the process, a user-friendly manual was created to summarise the different steps of the cross-border risk assessment. The manual is published separately from this report and can be found here:

Anne Conan, Younjung Kim, Dan A Yang, Tu Tu Zaw Win, Omid Nekouei, Dirk U Pfeiffer. - African Swine Fever Cross-border Risk Assessment Manual: South-East Asia. World Organisation for Animal Health (OIE) Sub-Regional Representation for South-East Asia, Bangkok, Thailand, 29 pp

National cross-border risk assessment in South-East Asia

Introduction

The CRATs were given the opportunity to perform a national cross-border risk assessment that would be reviewed by the OHRP consultancy team. These reports aim to serve as an exercise for the CRATs to conduct cross-border risk assessment for internal reference. In the presentl report, each risk pathway identified as relevant by the CRATs is discussed in the following order: i) Risk pathway; ii) Available data; iii) National risk estimations; 4) OHRP consultancy team conclusion.

The results are presented by risk pathways identified by the OHRP consultancy team, i.e.:

- Origin from domestic pig farms
    - Trade of live domestic pigs
    - Trade of semen and genetic materials of domestic pigs
    - Trade of domestic pig products
    - Fomites associated with domestic pig farming
    - Non-commercial domestic pig movements
    - Trade of contaminated feed and infected ingredients
- Origin from wild boar farms
    - Trade of live wild boars
    - Trade of semen and genetic materials of farmed wild boars
    - Trade of wild boar products
    - Fomites associated with wild boars
    - Non-commercial wild boar movement
- Origin from wild boar population
    - Cross-border movement of wild boar
    - Movement of hunters
    - Trade of wild boar meat

Summary of pathways by country

Based on the generic risk pathway diagrams provided by the OHRP consultancy team (Figure 1 to 14), 6 participating countries developed their own risk pathway diagrams, namely Cambodia, Malaysia, Myanmar, Singapore, Thailand, and the Philippines. Timor Leste and Papua New Guinea provided comments on the generic risk pathway diagrams. China and Indonesia presented their own risk pathway not derived from the generic risk pathway diagrams. Table 2 summarises the risk pathways reported as relevant by the countries. However, the information was not available from other countries.

Table 2: Risk pathways considered relevant by participating countries (blue cells)

Risk pathways	Cambodia	China*	Indonesia*	Malaysia	Myanmar	Singapore	PNG	Thailand	Timor Leste	The Philippines
P1. Trade of live domestic pigs	■	■	■		■	■	■	■	■	■
P2. Trade of semen & genetic materials of domestic pigs		■	■				■	■		■
P3. Trade of domestic pig products	■	■	■	■	■	■	■	■	■	■
P4. Fomites associated with domestic pig farming			■		■	■	■		■	
P5. Non-commercial domestic pig movements	■						■		■	
P6. Trade of contaminated feed & infected ingredients	■	■	■		■		■		■	
P7. Trade of live wild boars										
P8. Trade of semen & genetic materials of wild boars										
P9. Trade of wild boar products							■			
P10. Fomites associated with wild boars							■			
P11. Non-commercial wild boar movements							■			
P12 Cross border movement of wild boars	■	■	■	■		■	■	■	■	
P13 Hunters crossing borders							■	■	■	
P14 Trade of wild meat					■		■	■	■	

*China and Indonesia also mentionedanother risk pathway: "Soft ticks introduction by imported goods". As no other information was collected for this risk pathway, it is not mentioned later in the present report

Pathway 1: Trade of live domestic pigs

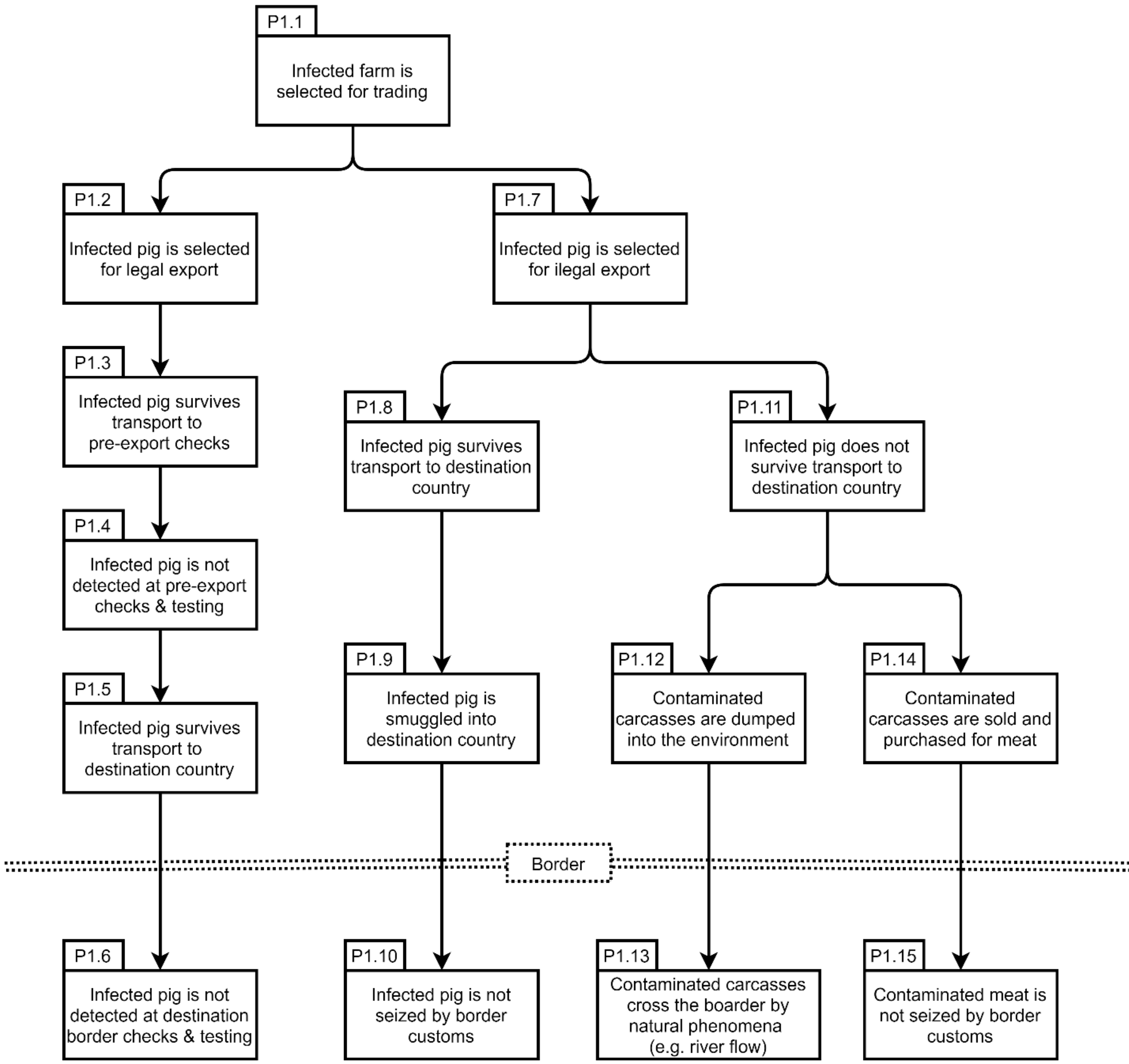

Figure 1 Generic risk pathway diagram for ASFV introduction through trade of live domestic pigs

Risk pathway: Although not all CRATs provided a diagram for the risk pathway through trade of live domestic pigs, all the ones who worked on risk pathways (except Malaysia) reported that they considered this risk pathway as relevant for ASFV cross-border introduction. However, most of the CRATs took into consideration legal trade only, except for China, Indonesia, Myanmar, and the Philippines, who included both legal and illegal trade of live domestic pigs in its risk pathway diagram.

Available data:

- The trade of live domestic pigs was frequent between participating countries as well as from countries outside South-East Asia (Table 3). Transport of pigs included terrestrial (e.g. Myanmar), by sea (e.g. Singapore), or by air (e.g. origin from the U.S. or Europe) modes.
- Most CRATs reported that regulations on the importation of live domestic pigs were in place. Some countries, such as Singapore or Thailand, reported accreditation systems where the origin farms and/or the origin countries were selected considering their ASF status. While live domestic pigs were imported mainly from ASF-free countries, the terrestrial trade was also made between countries with ASF cases, such as from Vietnam to Cambodia. It is important to note that several trade bans were imposed throughout the course of this project due to the changes in the regional ASF situation
- For most countries, available information on the quarantine of imported pigs was partial. China imposed a quarantine period of 45 days for all ports of entry. Malaysia reported that quarantine measures were in place for imported pigs. Thailand reported importing only breeder pigs from European countries. The Philippines mentioned the importation of breeder pigs, but this risk pathway was combined with the risk pathways through semen and genetic materials of domestic pigs. In Singapore, imported pigs were inspected for ASFV infection via ante and post mortem examination after they were directly transported to the slaughterhouse upon entering the country. In Cambodia pigs are sampled and tested for ASFV if they show clinical signs. However, laboratory tests at the customs and health certificate information were not reported by the CRATs.
- Regarding illegal importation, it should be noted that Indonesia had indicated possible illegal pig imports from Malaysia, Cambodia, PNG, and Timor Leste.

Table 3: Reported legal trade of live domestic pigs inside and outside the region (dark blue cells). Information is not exhaustive and the legal trade may have changed over the year. The known bans are reported in light blue cell with the year of the ban

	IMPORTER											
	Cambodia	China*	Indonesia	Lao	Malaysia	Myanmar	PNG	Singapore	Thailand	The Philippines	Timor Leste	Vietnam
Region trade												
Indonesia												
Malaysia												
Thailand												2021
Vietnam	2020											
International trade												
Australia												
Belgium												
Canada												
Denmark												
France												
Germany												
Netherlands												
UK												

* Importation from 64 countries (from 2018 to 2020) outside of South-East Asia

National risk estimation: After reviewing the collected data, Thailand and Singapore considered that the overall risk for ASFV introduction through the trade of live domestic pigs was "negligible" with "low" and "medium" uncertainty, respectively, while Myanmar reported a "very high" risk with "low" uncertainty. The Philippines supported a "negligible" risk with "low" uncertainty for legal trade. But the risk with illegal importation is "very low" with "high" uncertainty.

OHRP consultancy team conclusion: In general, the CRATs considered that their national ASF prevention and control programmes (for example, the application of trade bans upon reporting of ASF outbreaks in exporting countries) were sufficient for maintaining the overall risk by this risk pathway below or to the agreed acceptable level. Therefore, they did not see the need for introducing additional risk mitigation measures for importing live domestic pigs. However, no CRATs provided information on how their national ASF prevention and control programmes were evaluated**.**

Pathway 2: Trade of semen and genetic materials of domestic pigs

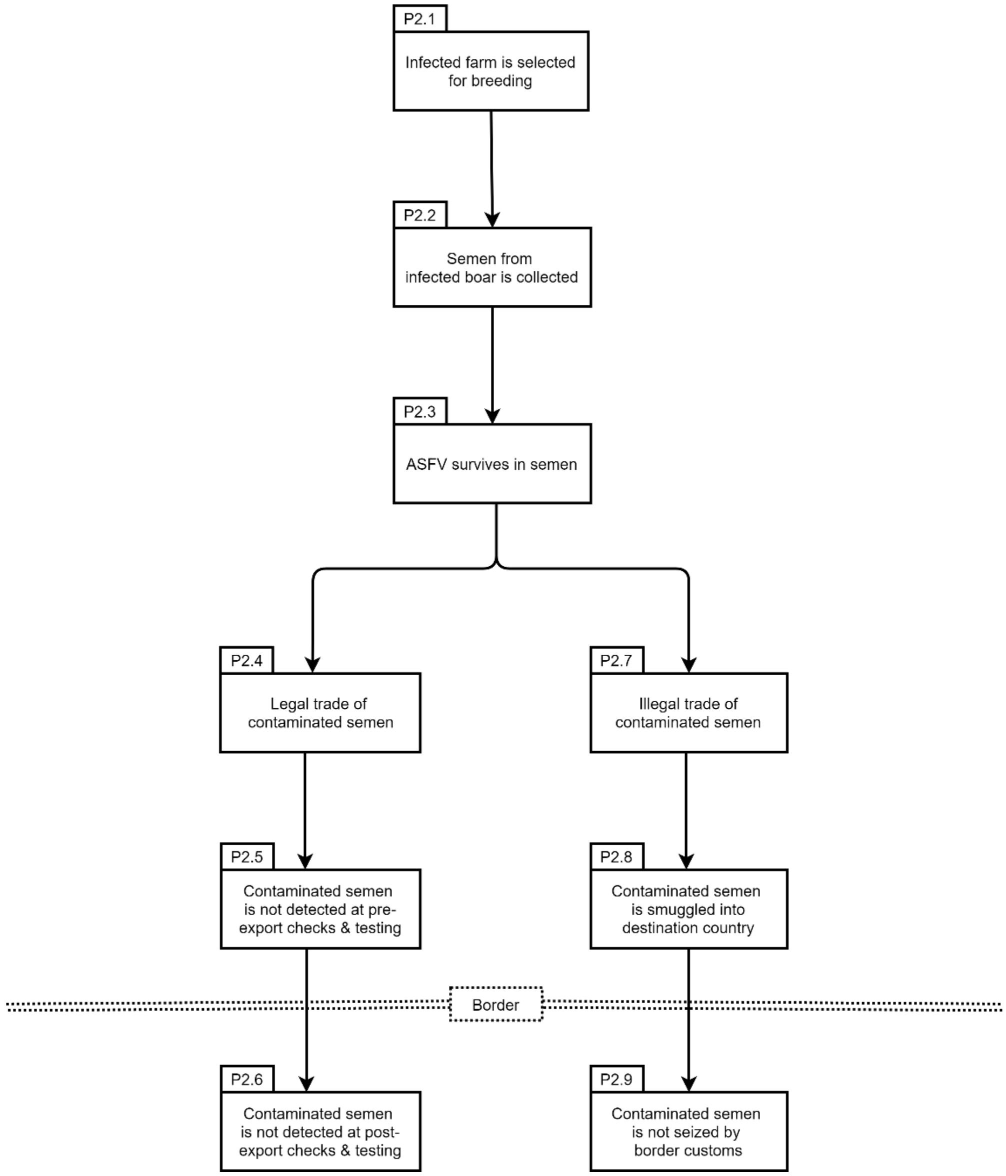

Figure 2 Generic risk pathway diagram for ASFV introduction through trade of semen and genetic materials of domestic pigs

Risk pathway: China, Indonesia, PNG, Thailand and The Philippines considered that the risk pathway through legal trade of genetic material of domestic pigs was relevant for ASFV introduction. Illegal trade of genetic materials of domestic pigs was only mentioned by The Philippines.

Available data: For PNG, the importation of genetic materials of domestic pigs was only allowed from Australia, one of ASF-free countries. Yet, the CRAT did not exclude the possibility of smuggling these commodities from countries other than Australia. The Philippines also indicated in the CRAT report that although there were no records of illegal importation of these commodities, possibly due to the special requirements for transporting these commodities (e.g. a cold chain), the risk pathway should still be considered. The conditions for selecting origin farms or countries and laboratory diagnostic testing of these commodities at border were not reported. However, Thailand and The Philippines indicated in the CRAT report that regulations were in place, including questionnaires, auditing and testing. Timor Leste mentioned there was no trade of these commodities because all their production was backyard.

National risk assessment: Thailand and the Philippines estimated that the risk associated with legal importation is "negligible" with "low" uncertainty. The Philippines mentioned that risk associated with illegal importation is "very low" with "high" uncertainty.

OHRP consultancy team review: The trade of genetic materials of domestic pigs was considered as well regulated by the CRATs. In general, the commodities pose relatively low risk for ASF cross-border introduction because domestic pigs providing the genetic materials are raised under strengthened biosecurity. However, these data were not reported, possibly due to the dominance of backyard farming and therefore infrequent trade of the genetic materials in the region. Some of the CRATs, including Vietnam, Cambodia, Myanmar, Thailand, mentioned that commercial farming has increased since 2020, which may lead to an increase in the trade of the genetic materials in the foreseeable future. Therefore, this risk pathway should not be underestimated in the future. It should be noted that the Philippines added the importation of breeder pigs as part of this risk pathway, and the result was reported in the live domestic pig risk pathway (Pathway 1).

Pathway 3: Trade of domestic pig products

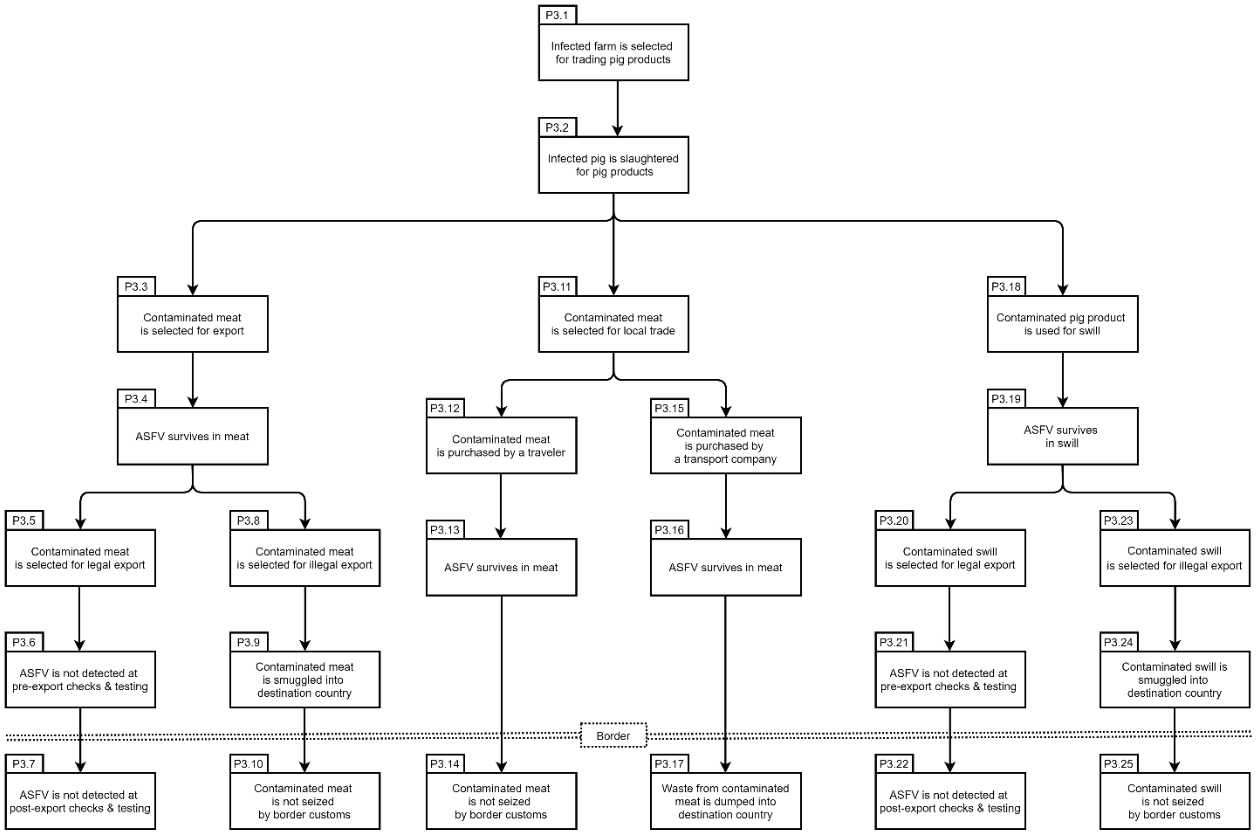

Figure 3 Generic risk pathway diagram for ASFV introduction through trade of pig products

Risk pathway: Most CRATs, including Cambodia, China, Indonesia, Malaysia, Myanmar, PNG, Singapore, Timor Leste and Thailand, identified trade of domestic pig products as a potential risk pathway for ASFV introduction. While Malaysia, the Philippines, and Myanmar included steps associated with swill in the risk pathway, Singapore (no domestic pig farms) and Thailand did not. Singapore and The Philippines divided the risk pathway into legal and illegal importation. China, Indonesia and The Philippines separated illegal importation and combined it with the ‘smuggling of live pig’ risk pathway as well as ‘swill from international transpor’t and ‘pig products carried by international travellers’ pathways. PNG did not develop a diagram for this risk pathway, but stated that although the importation of pig products, including swill feed, was not allowed, the possibility of smuggling should not be ruled out.

Available data: Origin of pig products was available for most countries. As an example, China imported pig products from Lao, Malaysia, Myanmar, Singapore and the Philippines. Timor-Leste mentioned the importation of pig products from China, Indonesia, The Philippines and Vietnam. Internationally, the Philippines import pig products from Australia, several European countries, New Zealand and the U.S. Thailand also reported having intercepted contaminated pig products with tourists entering the country. In general, three routes (i.e. land, sea and air) were reported for both legal and illegal importation of pig products. However, the risks between the three routes were likely different. Limited information about the ASFV testing of legally imported pig products was reported. Myanmar mentioned the use of real-time PCR. In Cambodia, pig products are not tested at the border.

Swill Feeding: In Thailand, smallholder and backyard pig farms still practise swill feeding, particularly in the northeastern and northwestern regions. Myanmar and the Philippines indicated in the CRAT report that swill feeding trade and use were widespread. The latter also suspected swill feeding to be the major source of ASFV introduction into infected farms. Indonesia also suspected that ASFV was introduced into North Sumatra by swill feeding and then spread into the pig population by fomites.

National risk assessment: Thailand estimated that the overall risk associated with legal trade of domestic pig products was “negligible” with “low” uncertainty. In contrast, the country estimated that illegal trade of domestic pig products, including those brought by travellers, posed “high” risk with “high” uncertainty. Singapore considered that the risk pathway posed “negligible” risk with “medium” uncertainty for legal trade and “very low” risk with “high” uncertainty for illegal trade. Myanmar reported an overall risk of “moderate” with “medium” uncertainty. The Philippines gave risk estimation for five risk pathways: 1) “very low” for legal importation of large volume of meat and meat products ("low” uncertainty); 2) “medium” for illegal importation of large volume of meat and meat products ("high” uncertainty); 3) “negligible” for legal importation of hand-carried of meat and meat products ("low” uncertainty); 4) “medium” for illegal importation of hand carrier of meat and meat products ("high” uncertainty); 5) “medium” for left over meat products from foreign vessel/aircraft ("high” uncertainty).

OHRP consultancy team conclusion: The risk pathway of the pig products is considered as a major one for ASFV introduction by most of the countries. Most of the CRATs indicated their concern about the illegal importation of pig products either by tourists, by nationals traveling abroad or by illegal trade. Unfortunately, the criteria for seizing and testing at the borders are unknown. It is recommended that the CRATs investigate more thoroughly these criteria. Moreover, following the importance of this risk pathway, it would be relevant to separate the risk pathway into different routes or actors of the importation. It is likely that the risks are different between the aerial, terrestrial and sea routes as well as between the tourists and the illegal trade. We would also recommend separating the risk pathway of swill importation.

Pathway 4: Fomites associated with domestic pig farming

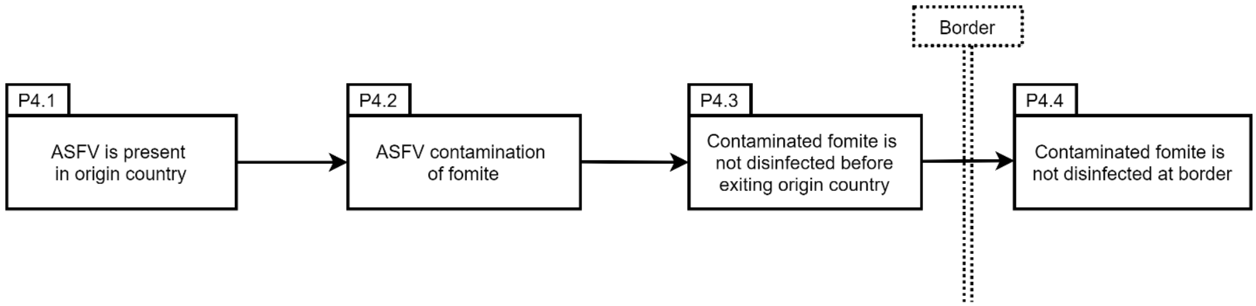

Figure 4 Generic risk pathway diagram for ASFV introduction through fomites

Risk pathway: Indonesia, Myanmar, Singapore and Timor Leste considered that the risk pathway through fomites was relevant for ASFV introduction.

Available data: In Singapore, ASFV introduction by fomites could occur via two bridges connected with Malaysia. While there was a lot of traffic on the sea route, fomite transmission via sea vessels and non-pig animals on these vessels was not considered to pose the risk for ASFV introduction. In Myanmar, the vehicles were disinfected before and after crossing the various borders from Thailand, China, Laos, Bangladesh, and India.

National risk assessment: Singapore estimated the risk as "very low" with "high" uncertainty. Myanmar combined the fomites with the feed for the risk pathway and considered a "moderate" overall risk with "medium" uncertainty.

OHRP consultancy team conclusion: Interestingly, although most CRATs mentioned that the movement of vehicles and people posed the risk for ASFV introduction and spreading into the country, only a few CRATs identified fomite transmission as a risk pathway for ASFV introduction. One of the hypotheses is the mis-conception of the 'fomites' principle and the inclusion of this factor in risk pathways as live pig or pork product transport. This mis-conception should be investigated further.

Pathway 5: Non-commercial domestic pig movements

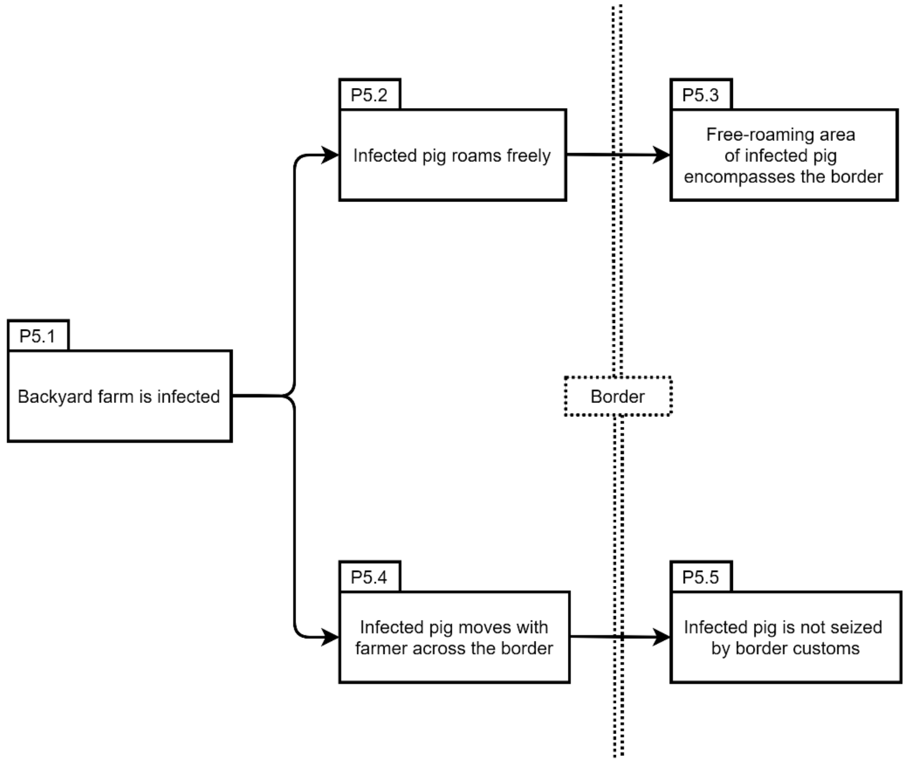

Figure 5 Generic risk pathway diagram for ASFV introduction through movements of domestic pigs not due to commercial trade

Risk pathway: Cambodia, PNG and Timor Leste considered that the risk pathway through non-commercial movements of domestic pigs was relevant for ASFV introduction. PNG also mentioned that cross-border exchange of live domestic pigs could be considered non-commercial movements depending on the context.

Available data: Cambodia indicated that backyard pigs could cross the border of Vietnam and Laos freely. PNG also mentioned movements through a barter system, where pig owners visit their families in Indonesia and return, were unmonitored.

National risk assessment: No risk was estimated for this risk pathway.

OHRP consultancy team conclusion: The abovementioned type of movement was mainly associated with backyard farming. While the CRATs reported this practice, it occurred in remote areas where an appropriate surveillance system may not be in place with very limited data available. As backyard farming remains the dominating pig production in the region, it is in the OHRP consultancy team opinion that risk should be estimated and mitigation measures should be considered.

Pathway 6: Trade of contaminated feed and infected ingredients

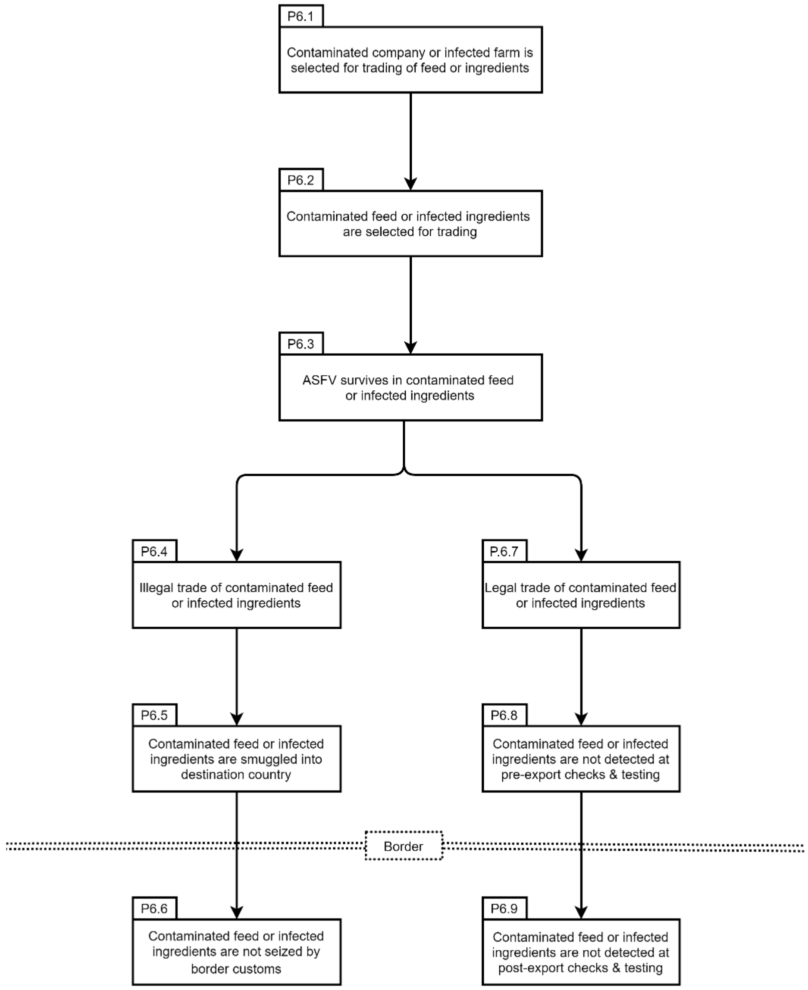

Figure 6 Generic risk pathway diagram for ASFV introduction through trade of contaminated feed and infected ingredients

Risk pathway: Cambodia, China, Indonesia, PNG and Timor Leste considered a risk pathway diagram for trade of contaminated feed and infected ingredients (e.g. plasma). Myanmar also considered it relevant for ASFV introduction but combined this diagram with the fomite risk pathway diagram. PNG mentioned that while these commodities were imported only from Australia, which was free of ASFV during the project, illegal importation should still be considered.

Available data: Myanmar reported importation of feed and ingredients by terrestrial route from China. Aerial route (e.g. from Argentina, Australia, Brazil, India or the U.S.) was also mentioned by Malaysia and Myanmar. In PNG, while all feed and ingredients were imported from Australia, illegal smuggling of these commodities was also deemed possible. Timor Lest indicated feed trade from Indonesia, while Cambodia imported food from Thailand and Europe (no specific country mentioned).

National risk assessment: For Myanmar, risk estimation was combined with the fomites and estimated as “moderate” with “medium” uncertainty.

OHRP consultancy team conclusion: Feed and ingredients for pigs as entry risk pathway looks like a minor practice in the region. We would recommend that the countries keep this pathway in mind, especially when the pig production moves towards intensive farming where commercial trade of feed and ingredients would become a more common practice.

Pathway 7: Trade of live wild boars

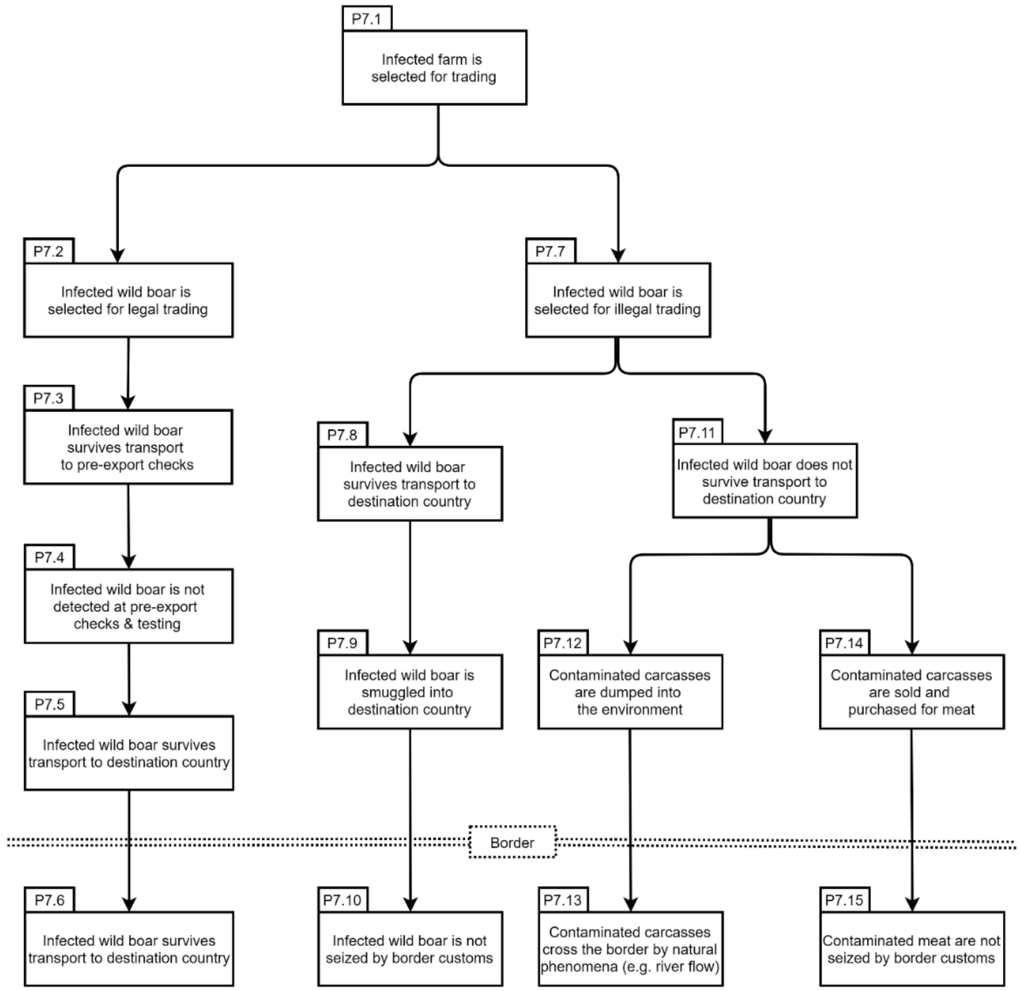

Figure 7 Generic risk pathway diagram for ASFV introduction through trade of live wild boars

Risk pathway: No CRATs considered that the risk pathway through trade of live wild boars relevant for ASFV introduction. However, PNG, Cambodia, Timor Leste indicated in the webinars and discussions with the OHRP consultancy team that illegal trade of live wild boars into their countries was suspected.

OHRP Consultancy team conclusion: There is no legal trading of live wild boars reported in the region. However, illegal trade of infected wild boars and movement of contaminated carcasses should be kept in mind considering that they were considered to have happened in the region.

Pathway 8: Trade of semen and genetic materials of farmed wild boar

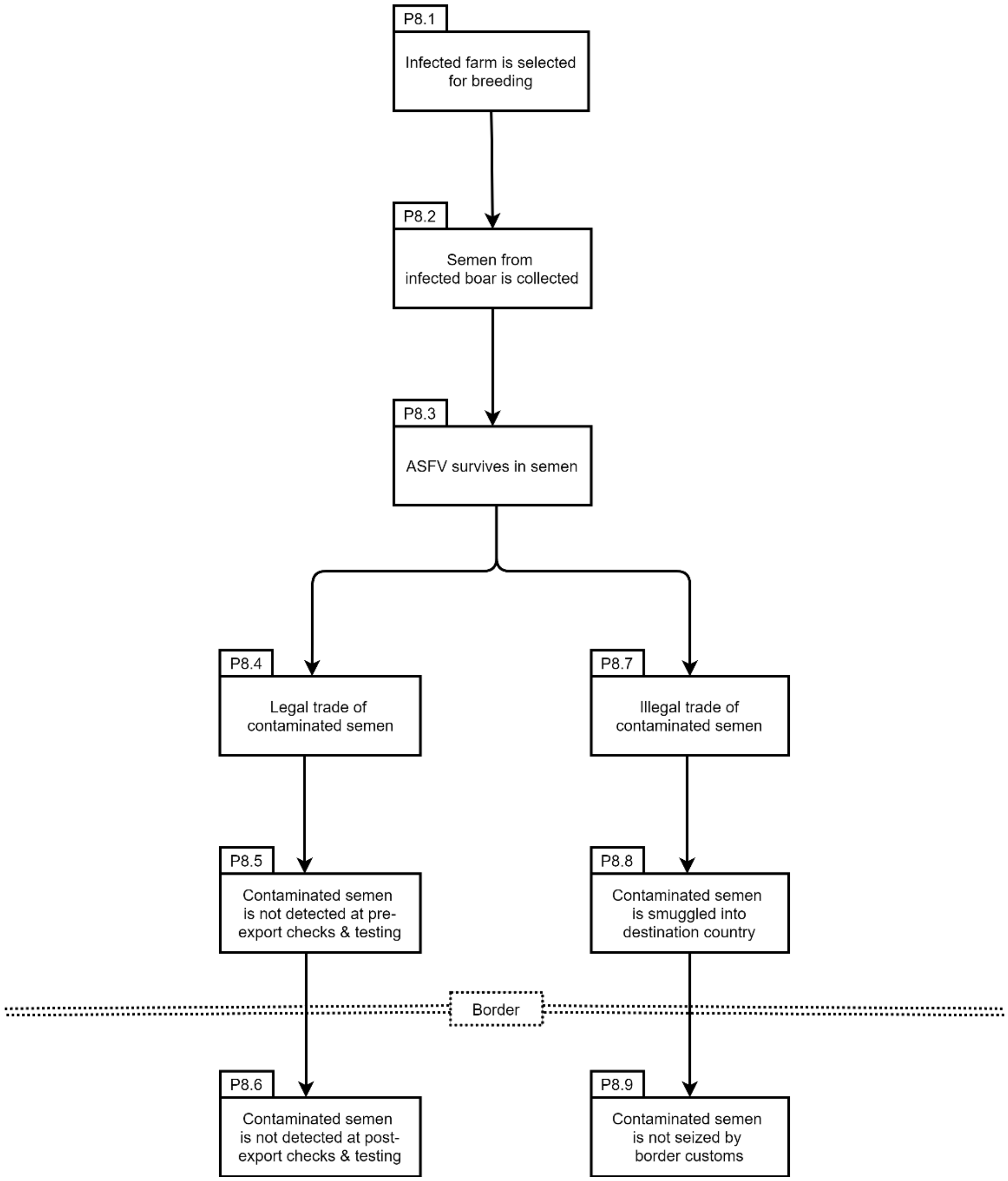

Figure 8 Generic risk pathway diagram for ASFV introduction through trade of semen and genetic materials of farmed wild boars

Risk pathway: No participating country considered that the risk pathway through trade of semen and genetic materials of wild boars relevant for ASFV introduction. Therefore, no CRAT proceeded with data collection and risk estimation for this risk pathway.

OHRP consultancy team conclusion: This pathway was developed for consistency with the live pig production. After discussion with the CRATs, there is no data to support the existence of activities associated with this particular pathway.

Pathway 9: Trade of wild boar products

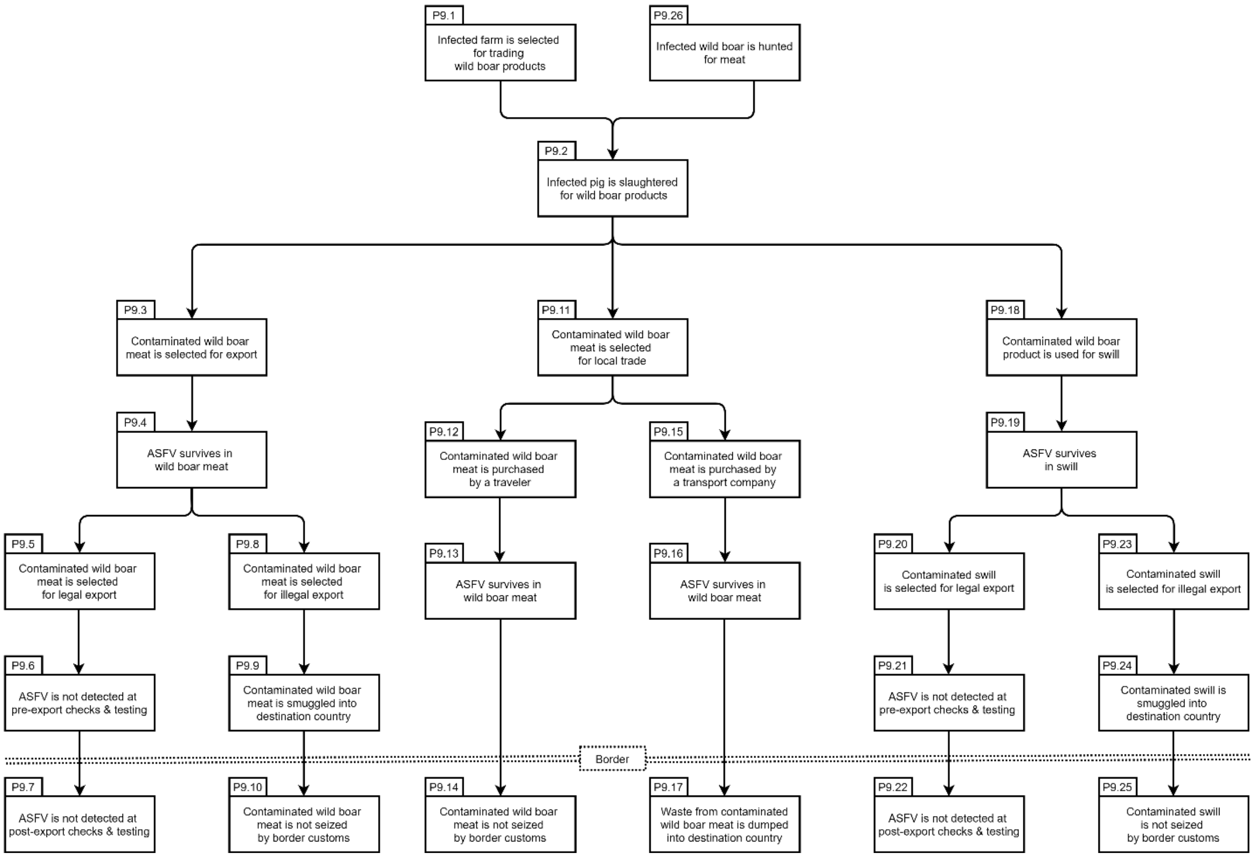

Figure 9 Generic risk pathway diagram for ASFV introduction through trade of wild boar products

Risk pathway: PNG mentioned the possibility of ASFV introduction through illegal trade of wild boar products. No other CRATs considered that the risk pathway through trade of live wild boar products relevant for ASFV introduction.

OHRP consultancy team conclusion: There is no legal trading of live wild boar products reported in the region. However, illegal trade should be kept in mind as a possibility.

Pathway 10: Fomites associated with farmed wild boars

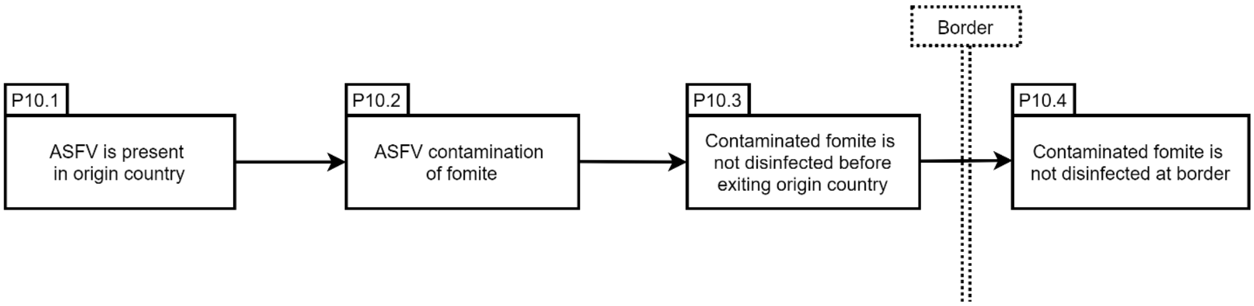

Figure 10 Generic risk pathway diagram for ASFV introduction through fomites associated with farmed wild boars

Risk pathway: PNG reported the possible imported construction equipment and machinery as possible fomites associated with farmed wild boars. No other CRATs considered that the risk pathway through trade of live wild boars relevant for ASFV introduction.

OHRP consultancy team conclusion: There is no data supporting the risk pathway through fomites associated with farmed wild boars. This pathway could be combined with the risk pathway of fomites associated with farmed domestic pigs.

Pathway 11: Non-commercial wild boar movements

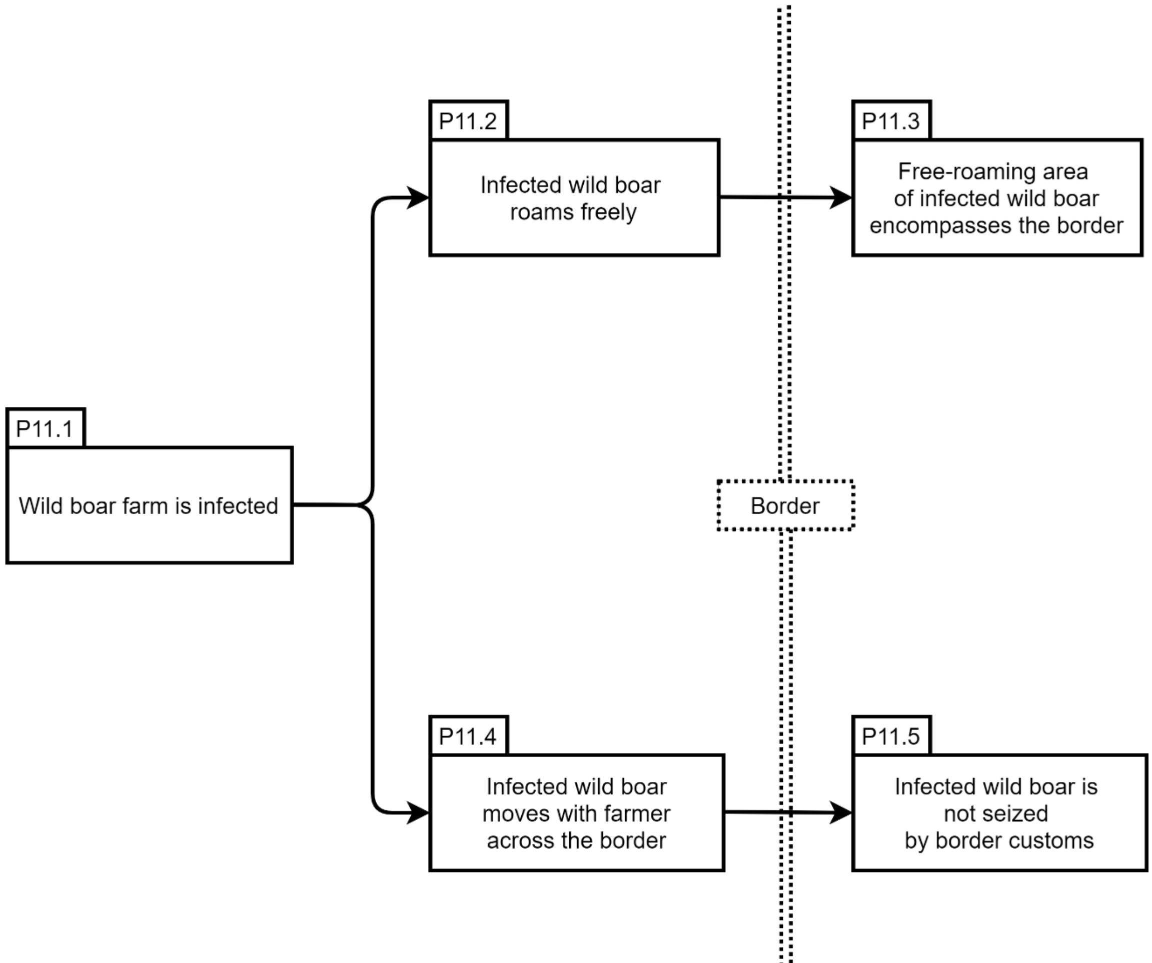

Figure 11 Generic risk pathway diagram for ASFV introduction through non-commercial wild boar movements

Risk pathway: PNG reported the possible movement of farmed wild boar through the border. In Malaysia, it has been reported that some communities would feed wild boars, which would then return to the forest in East Peninsula. However, no border crossing was reported

OHRP consultancy team conclusion: This risk pathway is possible but remains minor in participating countries.

Pathway 12: Cross border movement of wild boars

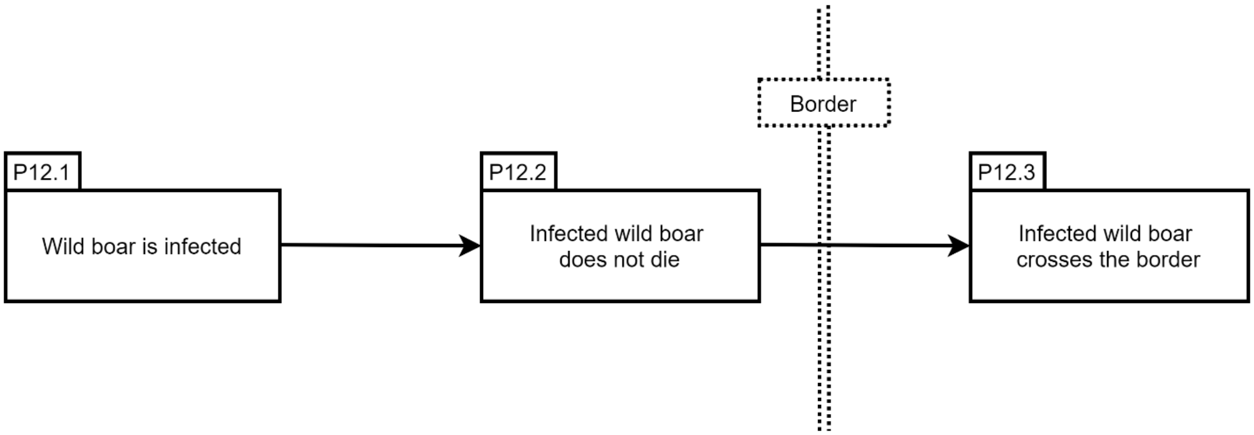

Figure 12 Generic risk pathway diagram for ASFV introduction through cross border movement of wild boars

Risk pathway: Cambodia, China, Indonesia, Malaysia, PNG, Thailand and Timor Leste considered that the risk pathway for movement of wild boars is relevant for ASFV introduction.

Available data: Data on the regional wild boar populations were scarce. While *Sus scrofa* was considered to dominate the wild boar populations in the region, the presence of other local species such as *Sus barbatus, Sus philippinesis, Sus cebifrons, Sus oliveri and Sus aheonobarbus* were evident in some countries, including Malaysia and the Philippines. In addition, PNG mentioned a "New Guinea Native" upon communication with the OHPR consultancy team. In Thailand, interviews with local people and officers at the border suggested that the cross-border wild boar movements were deemed uncommon. Despite not considering this risk pathway as relevant for ASFV introduction, Singapore mentioned the presence of wild boar in vegetated areas and did not exclude movements from Malaysia and Indonesia. Countries like Timor Leste did not take the risk pathway into consideration. Wild boars were believed to be present in all provinces except one.

National risk assessment: In Thailand, the overall risk associated with this risk pathway was estimated "low" with "high" uncertainty, while Singapore considered the introduction via local wild boar "very low" with "low" uncertainty.

OHRP consultancy team conclusion: In our opinion, this important risk pathway is overlooked by most of the CRATs. The main reason is the absence of (official) data on wild boar populations. However, there is evidence showing the presence of wild boars at various borders and can therefore cross this border with ASFV.

Pathway 13: Hunters crossing borders

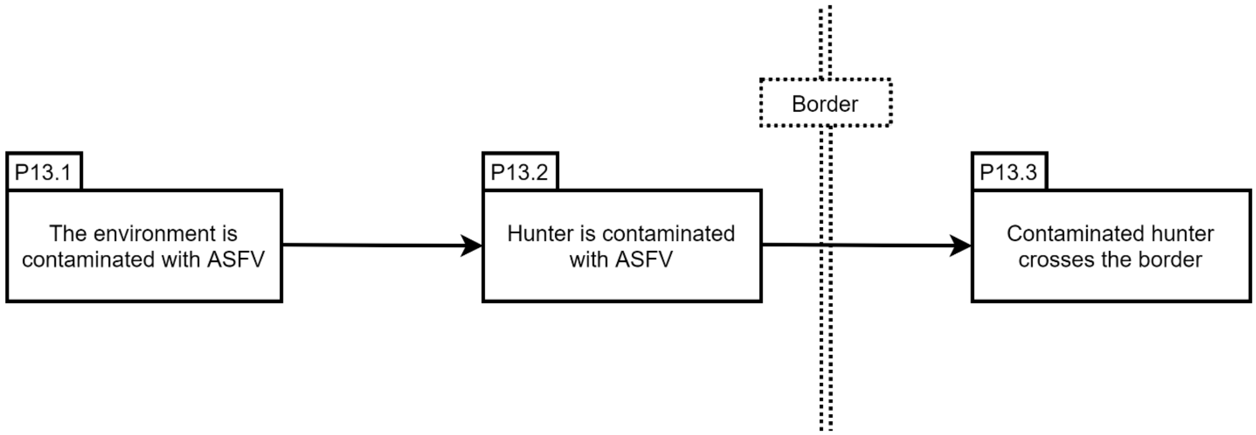

Figure 13 Generic risk pathway diagram for ASFV introduction through hunters crossing borders

Risk pathway: Malaysia, PNG, Thailand and Timor Leste considered that the risk pathway through hunters is relevant for ASFV introduction, mainly linked to hunting activities. While Malaysia took the scenario that hunters in the country contact infected wild boars that crossed the border into consideration of the risk pathway, Thailand took the scenario that hunters crossing the border after contacting infected wild boars into consideration of the risk pathway. Myanmar also reported the possibility of hunters crossing the border to hunt bushmeat but did not consider the risk pathway as relevant.

Available data: The CRAT in Thailand communicated with the border local officers to evaluate the risk of contact between hunters and contaminated wild boars.

National risk assessment: In Thailand, the risk of hunters contacting infected wild boar and the risk of hunters crossing the border were estimated to be “low” as these events were considered uncommon. The uncertainty associated with this risk pathway was considered “high”.

OHRP consultancy team conclusion: While the movement of hunters may occur, this risk pathway may not be relevant for a lot of countries. We recommend combining it with the risk pathway through fomites.

Pathway 14: Trade of wild meat

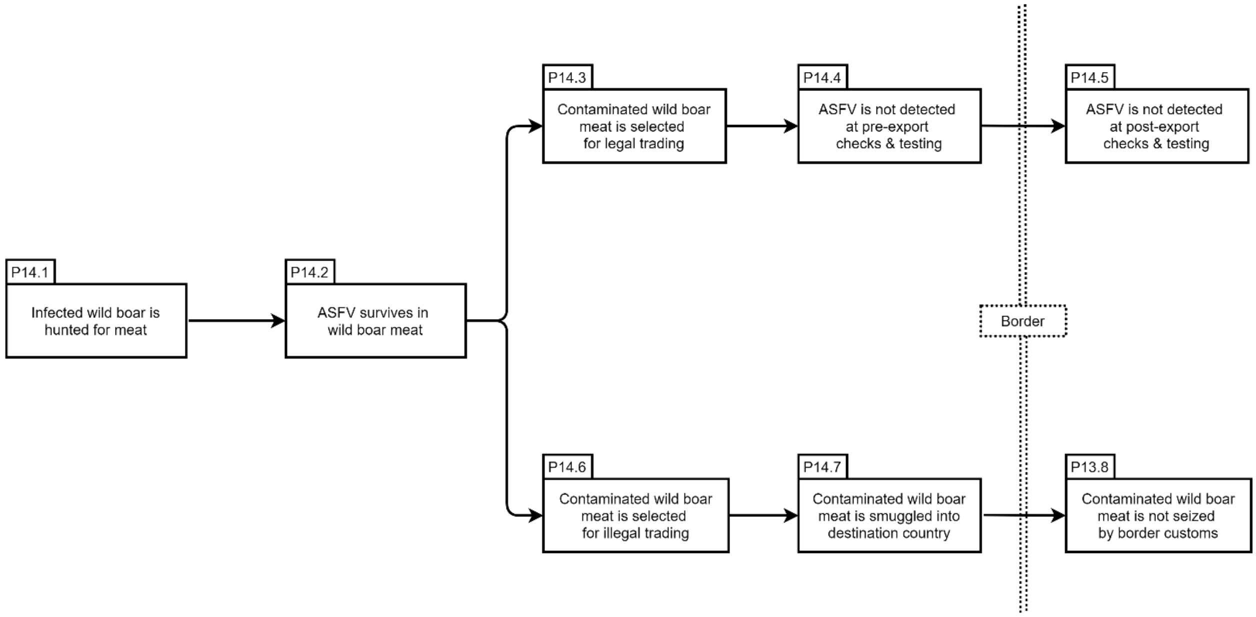

Figure 14 Generic risk pathway diagram for ASFV introduction through trade of wild meat

Risk pathway: Myanmar, Thailand and Timor Leste considered the risk pathway through trade of wild boar products relevant for ASFV introduction. Note that PNG did not develop a diagram for this risk pathway, but reported that while trade of wild boar products was not accepted, illegal smuggling of wild boar products was possible.

Available data: Myanmar identified and collected published literature indicating the presence of wild boar and trading of their associated products within the country. They mentioned the practice might occur at the terrestrial border. Myanmar reported that wild boar products were sold for medicinal use, meat consumption, clothing, or as pets. Thailand reported that trade of wild boar meat was uncommon but could occur.

National risk assessment: The risk of ASFV entering Thailand through wild boar meat was estimated to be “low” with “high” uncertainty, while Myanmar considered this risk as “very low” with “high” uncertainty.

OHRP Consultancy team conclusion: While this risk pathway looks minor, its occurrence should not be disregarded due to the traditional use of wild boar products in some areas of the region.

OHRP Consultancy team conclusions and recommendations on risk mitigations

The following section describes some risk mitigation measures recommended at the regional level. They are, however, not exhaustive as the collected data showed a high level of uncertainty. The OHRP consultancy team identified three pathways of interest for risk mitigation: trade of pork products, wild boars, and fomites.

The trade of pork products is the main risk pathway noticed by the CRATs in this study. Firstly, the trade of swill should be banned. In addition, personal transport of pork products should also be banned. While there was no seizing and testing reported by CRATs, strengthening testing capacity at the borders (terrestrial, aerial, and marine) is recommended.

There is evidence showing the presence of wild boars at various locations in all countries and can therefore cross the borders with ASFV. Recommendations are to strengthen the collaboration between the departments taking care of wildlife and pig farming to improve the early detection of border crossing by wildlife and collect more data about this possible pathway to have a more accurate risk estimate.

While the fomite pathway was rarely taken into account, it may be due to a misunderstanding of one concept: the virus can be transported on fomites in the absence of live pigs or pork products. To decrease the risk of terrestrial introduction, we recommend disinfection of the long travel vehicles (trucks, cars, motorbikes) at the border.

The trade of live pigs does not seem to be a pathway at risk. However, the OHRP consultancy team did not have access to the laboratory and importation regulations in any country. While most of the countries import from ASF-free zone, we encourage the use of questionnaires to the origin farms to assess the prevention measures and the risk of ASFV in the pigs of these farms.

Finally, with the intensification of farming, it is important to increase the surveillance of the trade of genetic material and feed. While the trade of genetic material and is currently negligible, it is almost certain that the market will expand, leading to an increased risk of importation of the virus.

Discussion and recommendation for capacity building

In this section, the OHRP consultancy team will discuss and recommend key points for improving risk assessment processes and training of the veterinary services in South-East Asia

1) It is essential to identify and describe all risk pathways relevant to ASFV epidemiology and pig value chains before proceeding with subsequent risk assessment processes. In the current project, some CRATs often concluded that particular risk pathways were irrelevant before identifying and describing them as diagrams or scenario trees. This was mainly because they considered that the risk of ASFV introduction from these risk pathways was negligible or zero or that information on these risk pathways was not available. However, it should be noted that the risk is unlikely zero unless it is proven otherwise. Moreover, the absence of information does not indicate the absence of risk. Also, there were some confusions between describing risk pathway diagrams and performing value chain analysis. Value chain analysis should be performed before describing risk pathway diagrams to help identify the epidemiological probability events leading to the ASFV introduction.

⇨ ***Recommendation:*** Identification and description of risk pathways are the critical processes of risk assessment. The CRATs should discuss them from the beginning of any risk assessment based on ASFV epidemiology and pig value chains before describing them as diagrams. We also recommend that disease experts identify the risk pathways for a particular disease at the regional level. We report here the 11 cross-border risk pathways for African swine fever virus in South-East Asia. The same type of list could be created for other hazards and made available to OIE Members.

⇨ ***Recommendation:*** Future training should focus more on the distinction of risk pathways and value chain analysis. Consistency in scientific concepts and terminology should be ensured. For example, we would recommend avoiding the word "pathway" when speaking about value chain analysis. Following the literature and expert opinion, we would like to propose the use of "distribution channels" instead to describe the route of the commodity along the value chain.

2) Data should be identified and collected from various sources. Most CRATs made good use of government databases for collecting data for risk pathways through, for instance, legal trade of pigs and pork products and illegal smuggling of pork products. Some CRATs also sourced data from peer-reviewed publications when they were not attainable from government databases. When relevant data could not be obtained from government databases and peer-reviewed publications, participatory surveys, as well as grey literature and expert opinions, could be alternative data sources. Regardless of the type of data source, the process of data identification and collection should be conducted and described in a systematic and transparent manner. However, such process was rarely described in most CRAT reports. Moreover, data completeness and accuracy should be assessed and described in a systematic and transparent manner. While some CRAT proceeded with data collection and risk estimation, it was unclear how the risk and its uncertainty were estimated for each step along the risk pathway.

⇨ ***Recommendation:*** In addition to government databases and peer-reviewed publications, the CRATs should make use of various other sources for data identification and collection, such as participatory surveys, grey literature, and expert opinions. In particular, the CRATs should describe the process of data identification and collection. Also, data sources should be properly referenced. The method of participatory surveys should also be described. If expert opinions are sought, the CRATs should describe who are these experts, how they are selected, and how opinions are obtained from them.

⇨ ***Recommendation:*** As part of the training, more presentation and group exercises should focus on the concept of "uncertainty".

3) The effectiveness of prevention and control measures in reducing the risk of ASFV introduction should be evaluated and described as part of risk assessment. However, none of the CRATs described such evaluation in detail in their report. For example, most CRATs considered that the risk from legal trade of live domestic pigs was low as they assumed that appropriate prevention and control measures were in place. However, no information on the evaluation of such measures was provided to their country report.

⇨ ***Recommendation:*** We believe the integration of risk assessment in the concept of risk analysis and the link with risk management as well as the concept of continuity of the risk assessment may not be clear. It would be valuable to organise follow up webinars with the trained CRATs to help with the update of the risk assessment.

4) The structure of the webinars did not fit objectives of the training. Some CRATs mentioned eventually that the sessions were not frequent enough for them to keep a good track of the taught content.

⇨ ***Recommendation:*** We suggest that online training should be organised over a shorter period of time, with longer and more frequent sessions (as example, the present training could take 4 sessions of 3 hours over 4 weeks). Exercises with CRAT should also be facilitated during these sessions instead of asking for 'homework'. The use of technological tools such as Klaxoon, Padlet or Miro would also be beneficial.

The regional training approach provided a unique platform to communicate and exchange useful information on challenges commonly faced by countries when mitigating ASF such as management of dead carcasses, spreading by fomites etc. Throughout the project, the disparity in available resources and capacity of different veterinary services were highlighted, and specific recommendations and mentoring to the countries by the OHRP consultancy team were provided and were found to be beneficial to the CRATs. While regional training was proven exceptionally valuable, the possibility of having tailored training for individual countries as a next step should be explored.

Limitations

The major limitation that the OHRP consultancy team faced was caused by the SARS-CoV-2 situation. The initial plan of the project was to run a face-to-face workshop that consisted of lectures and group exercises. However, due to the SARS-CoV-2 situation, the workshop was replaced with a series of virtual webinars.

Through the discussion with the OIE, the OHRP consultancy team decided to organise biweekly webinars and the overall webinar attendance was satisfactory. However, some of the CRATs expressed that they had difficulties focusing on the webinar content with the biweekly format because they could not attend all the sessions on top of their work schedule . Furthermore, Western New Year and Lunar New Year contributed to longer hiatus between some sessions .

Secondly, during the course of this project, African swine fever was not the only transboundary disease striking in the region. Lumpy Skin Disease and avian influenza outbreaks were also reported in various participating countries. As such, many of the CRATs had limited time for the project while engageing in relevant outbreak responses in the field.

Finally, ASFV continued to spread in the region during the project. While ASF was already circulating in their countries, some of the CRATs might find conducting cross-border risk assessment slightly less relevant and of a lower priority in controling the existing outbreaks. During the project, the OHRP consultancy team emphasised the importance of cross border risk assessment, even when the hazard already existed in the country, as well as the potential application of the risk assessment processes to other diseases to encourage the active participation of the CRATs in the project.

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Annexes

Annex 1

List of OIE member countries, CRAT team leaders and mentors

Participating countries	CRAT Team Leaders	Mentors
Cambodia	Ms. Lim Socheat	Dr. Anne Conan
China	Dr. Xu Quangang	Dr. Aaron Yang
Indonesia	Dr. Suseno Pebi	Dr. Andrew Bremang
Laos	Dr. Souriyasack Chayavong	Dr. Veronica Yu
Malaysia	Dr. Sarah Dadang Abdullah	Dr. Younjung Kim
Myanmar	Dr. Aung Ko Ko Minn	Dr. Lisa N Kohnle
Papua New Guinea	Dr. Andy Yombo	Dr. Anne Conan
Philippine	Dr. Samuel Castro	Dr. Andrew Bremang
Singapore	Dr. Lim Hwee Ping Dr. Alwyn Tan	Dr. Aaron Yang
Thailand	Dr. Weerapong Thanapongtharm	Dr. Veronica Yu
Timor-Leste	Dr. Antonino Do Karmo	Dr. Lisa N Kohnle
Vietnam	Dr. Vo Dinh Chuong	Dr. Younjung Kim

Annex 2

Collected indicators of provincial data of pig production and wild boar population

A. Pig production

1) Are there pig raising/keeping/production activities in the province? Yes/No
2) What is the total number of pigs in the province?
3) What is the total number of pig farms in the province?
4) What is the number of farms with extensive/ backyard production system in the province?
5) What is the number of pigs raised in farms with extensive/ backyard production system in the province?
6) What is the number of farms with semi-intensive production system in the province?
7) What is the number of pigs raised in farms with semi-intensive production system in the province?
8) What is the number of farms with intensive production system in the province?
9) What is the number of pigs raised in farms with intensive production system in the province?
10) What is the number of farms engaged only in breeding activities in the province?
11) What is the number of pigs raised in farms engaged only in breeding activities in the province?
12) What is the number of farms engaged only in fattening activities in the province?
13) What is the number of pigs raised in farms engaged only in fattening activities in the province?
14) What is the number of farms engaged in both breeding and fattening activities in the province?
15) What is the number of pigs raised in farms engaged in both breeding and fattening activities in the province?

B. *Cross border value chain*

1) Does the province engage in direct import of live pigs from other countries? Yes/No

2) If yes, from where (country)?

3) Does the province engage in indirect import of live pigs from other countries? Yes/No

4) If yes, from where (country)?

5) Does the province engage in direct export of live pigs to other countries? Yes/No

6) If yes, to where (country)?

7) Does the province engage in indirect export of live pigs to other countries? Yes/No

8) If yes, to where (country)?

9) Does the province engage in direct import of pig feed from other countries? Yes/No

10) If yes, from where (country)?

11) Does the province engage in indirect import of pig feed from other countries? Yes/No

12) If yes, from where (country)?

13) Does the province engage in direct export of live pigs to other countries? Yes/No

14) If yes, to where (country)?

15) Does the province engage in indirect export of live pigs to other countries? Yes/No

16) If yes, to where (country)?

C. *Wild boar population*

1) Is there any wild boar in the province? Yes/No

2) What are the species of wild boar that are present in the province?

3) What is the total number of wild boars in the province?

4) What is the wild boar population density in the province?

4) What is the wild boar population density in the province?

Annex 3

Templates of Microsoft Excel™ spreadsheet for regional and international trade of a particular commodity

Importers / Exporters	Cambodia	China	Indonesia	Lao	Malaysia	Myanmar	PNG	Singapore	The Philippines	Thailand	TL	Vietnam
Cambodia												
China												
Indonesia												
Lao												
Malaysia												
Myanmar												
PNG												
Singapore												
The Philippines												
Thailand												
TL												
Vietnam												

Country	**Cambodia**	**China**	**Indonesia**	**Lao**	**Malaysia**	**Myanmar**	**PNG**	**Singapore**	**he Philippin**	**Thailand**	**TL**	**Vietnam**
South Korea												
Russia												
Australia												
Belgium												
Germany												
Denmark												
France												
Canada												
The Netherlands												

Note: CRATs were asked to list the countries of importation on the first column

Annex 4

Template of the table to estimate risk pathway diagram event likelihood

Step on risk pathway	Indicators/variable that we need to estimate likelihood	Indicator estimates (With reference)	Likelihood estimate	Uncertainty	Justification

Annex 5

Questionnaire template for data collection during the cross-border risk assessment of African swine fever

Country: _______________

Risk Assessment Cross Border Entry Questionnaire for Focal Points

Table of Contents

1) Trade of pigs and pig products

a) Live pigs

The following table describes the origin and characteristics of ***live pigs' legal trade***

(expand the table as necessary)

Country of origin	Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)	Annual no. imported pigs from this country	Way of transportation [multiple choice]	Comments, sources and references
			☐ Aerial ☐ Terrestrial ☐ Sea	
			☐ Aerial ☐ Terrestrial ☐ Sea	
			☐ Aerial ☐ Terrestrial ☐ Sea	

Describe the protocol of customs check at the border

- Are the live pigs subject to quarantine? ☐ Yes ☐ No
    - **If yes,** how long is the quarantine?____________________________
    - **If yes,** describe the quarantine process of the pigs:
      ____
      ____
      ____
      ____
      ____

- At the border, are the pigs sampled for ASF testing? ☐ Yes ☐ No
    - **If yes,** what proportion of the pigs are sampled?_______________
    - **If yes,** what is the sampling method? [multiple choice]

        ☐ Pigs showing clinical signs
        ☐ Simple random sampling
        ☐ Stratified sampling by batch
        ☐ Other, Specify____________________

    - What ASF laboratory test is performed on the sample? __________________________

    - What is the performance of ASF laboratory tests used (e.g. sensitivity, specificity)? __________________________

Other comments about the legal trade of pigs:

____

____

____

____

____

Describe the illegal importation of pigs

- To your knowledge, is there illegal importation of pigs to your country?
  ☐ Yes ☐ No

- What is known about the illegal importation of pigs?
  ____
  ____
  ____
  ____

The following table describes the origin and characteristics of ***the illegal importation of pigs*** *(expand the table as necessary)*

Country of origin	Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)	Annual no. illegal pigs from this country seized by the custom	Estimated annual no. illegal pigs from this country	Way of transportation [multiple choice]	Comments, sources and references
				☐ Aerial ☐ Terrestrial ☐ Sea	
				☐ Aerial ☐ Terrestrial ☐ Sea	
				☐ Aerial ☐ Terrestrial ☐ Sea	
				☐ Aerial ☐ Terrestrial ☐ Sea	

Other comments about the illegal importation of live pigs:

____

____

____

____

____

b) Pig products

Pig products encompass all products with pig origin, including (but not exhaustive): product for animal consumption (e.g. swill, blood for food), human consumption (e.g. ham), genetic products (e.g. semen), etc.

The following table describes the origin and characteristics of ***the legal trade of pig products*** *(expand the table as necessary)*

Pig product	Type of product	Country of origin	Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)	Annual no. imported pig products from this country	Way of transportation [multiple choice]	Testing at the border for ASF	% tested for ASF	Laboratory test	Comments, sources and references
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______				☐ Aerial ☐ Terrestrial ☐ Sea	☐ Yes ☐ No			
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______				☐ Aerial ☐ Terrestrial ☐ Sea	☐ Yes ☐ No			
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______				☐ Aerial ☐ Terrestrial ☐ Sea	☐ Yes ☐ No			

Other comments about the legal trade of pig products:

____

____

____

____

Describe the illegal trade of pig products

- To your knowledge, is there illegal importation of pig products to your country? ☐ Yes ☐ No

- What is known about the illegal trade of pig products?
  ____
  ____
  ____

*The following table describes the origin and characteristics of **the illegal trade of pig products** (expand the table as necessary)*

Pig product	**Type of product**	**Country of origin**	**Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)**	**Annual no. illegal pig products from this country seized by the custom**	**Estimated annual no. illegal pig products from this country**	**Way of transportation [multiple choice]**	**Comments, sources and references**
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______					☐ Aerial ☐ Terrestrial ☐ Sea	
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______					☐ Aerial ☐ Terrestrial ☐ Sea	
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______					☐ Aerial ☐ Terrestrial ☐ Sea	

- Are travellers checked at the border for the importation of pig products? ☐ Yes ☐ No
    - If yes, how many travellers enter the country by way of transportation and what proportion of travellers are checked at the border for the importation of pig products?
        - Car/motorbike/foot: N= ____________ ; proportion : ___________________%
        - Truck/train (commercial transport): N= ____________ ; proportion : ___________________%
        - Train (tourism): N= ____________ ; proportion : ___________________%
        - Boat (commercial transport)
        - Boat (tourism): N= ____________ ; proportion : ___________________%
        - Plane: N= ____________ ; proportion : ___________________%

Other comments about the illegal importation of pig products:

____

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____

2) Trade of wildboars and wildboar products

c) Live wildboars

The following table describes the origin and characteristics of ***the legal trade of wildboars*** *(expand the table as necessary)*

Country of origin	Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)	Annual no. imported wildboars from this country	Way of transportation [multiple choice]	Comments, sources and references
			☐ Aerial ☐ Terrestrial ☐ Sea	
			☐ Aerial ☐ Terrestrial ☐ Sea	
			☐ Aerial ☐ Terrestrial ☐ Sea	

Describe the protocol of customs check at the border

- Are the wildboars subject to quarantine? ☐ Yes ☐ No
  - **If yes,** how long is the quarantine?___________________________
  - **If yes,** describe the quarantine process of the wildboars:
    ____
    ____
    ____
    ____
    ____

- At the border, are the wildboars sampled for ASF testing? ☐ Yes ☐ No
  - **If yes,** what proportion of the wildboars are sampled?______________
  - **If yes,** what is the sampling method? [multiple choice]
    - ☐ Wildboars showing clinical signs
    - ☐ Simple random sampling
    - ☐ Stratified sampling by batch
    - ☐ Other, Specify____________________
  - What ASF laboratory test is performed on the sample? __________________________
  - What is the performance of ASF laboratory tests used (e.g. sensitivity, specificity)? __________________________

Other comments about the legal importation of wildboars:

____
____
____
____
____

Describe the illegal importation of wildboars

- To your knowledge, is there illegal importation of wildboars to your country?
  ☐ Yes ☐ No
- What is known about the illegal trade of wildboars?
  ____
  ____
  ____
  ____
  ____

The following table describes the origin and characteristics of ***the illegal trade of wildboars*** *(expand the table as necessary)*

Country of origin	**Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)**	**Annual no. illegal wildboars from this country seized by the custom**	**Estimated annual no. illegal wildboars from this country**	**Way of transportation [multiple choice]**	**Comments, source and references**
				☐ Aerial ☐ Terrestrial ☐ Sea	
				☐ Aerial ☐ Terrestrial ☐ Sea	
				☐ Aerial ☐ Terrestrial ☐ Sea	

Other comments about the illegal importation of wildboars:

____

____

____

____

____

d) Wildboar products

Wildboar products encompass all products with wildboar origin, including (but not exhaustive): product for animal consumption (e.g. swill, blood for food), human consumption (e.g. ham), genetic products (e.g. semen), etc.

The following table describes the origin and characteristics of ***the legal trade of wildboar products*** *(expand the table as necessary)*

Wildboar product	Type of product	Country of origin	Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)	Annual no. imported wildboar products from this country	Way of transportation [multiple choice]	Testing at the border for ASF	% tested for ASF	Laboratory test	Comments, source and references
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______				☐ Aerial ☐ Terrestrial ☐ Sea	☐ Yes ☐ No			
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______				☐ Aerial ☐ Terrestrial ☐ Sea	☐ Yes ☐ No			

Other comments about the legal importation of wildboar products:

____

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____

____

Country: _______________

Describe the illegal importation of wildboar products

- To your knowledge, is there illegal importation of wildboar products to your country? ☐ Yes ☐ No
- What is known about the illegal trade of wildboar products?
  ____
  ____
  ____

*The following table describes the origin and characteristics of **the illegal trade of wildboar products** (expand the table as necessary)*

Wildboar product	Type of product	Country of origin	Total no. ASF outbreaks reported in this country (possible source: OIE WAHIS or FAO EMPRES-i)	Annual no. illegal wildboar products from this country seized by the custom	Estimated annual no. illegal wildboar products from this country	Way of transportation [multiple choice]	Comments, sources and references
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______					☐ Aerial ☐ Terrestrial ☐ Sea	
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______					☐ Aerial ☐ Terrestrial ☐ Sea	
	☐ Animal consumption ☐ Human consumption ☐ Genetic product ☐ Other _______					☐ Aerial ☐ Terrestrial ☐ Sea	

Country: _______________

Other comments about the illegal importation of wildboar products:

____

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____

3) Human activities and fomites

Country with terrestrial border	Density of pig farm in this country before border	Density of wildboar farm in this country before border	How many vehicles cross the border per week?	Are vehicles disinfected at the border	Description of the disinfection
				☐ No ☐ Yes, before ☐ Yes, after	
				☐ No ☐ Yes, before ☐ Yes, after	
				☐ No ☐ Yes, before ☐ Yes, after	
				☐ No ☐ Yes, before ☐ Yes, after	

- Is there any wildboar hunting activities at the border?

  Please describe:

  ____

- Are hunters controlled and checked at the border?

Other comments about human activities and fomites:

____

____

____

____

____

4) Wild and free-roaming animals

- What are the locations where wildboars have been observed in your country:
  ____
- What is the type of landscape at the border? (mountain, agricultural…)
  ____
- Are there free-roaming pig or wildboar farms in the 5 km from the terrestrial border?

  ☐ Yes ☐ No

  - If yes, how many pigs are raised on these farms?__________________
  - If yes, have authorities already observed border crossing by a free-roaming pig or wildboar?

    ☐ Yes ☐ No

    Describe _____________________________

Other comments about wild and free roaming animals:

____

____

____

____

____

Annex 6

Study Design of the project: “African swine fever cross-border risk assessment – South East Asia”

September 22, 2020

African Swine Fever Cross Border Risk Assessment – South East Asia Study Design

Anne Conan, Younjung Kim, Lisa Kohnle, Veronica Yu, Jeremy Ho, Andrew Bremang, Aaron Yang, Dirk Pfeiffer
Center for One Health Research and Policy Advice, City University of Hong Kong, Hong Kong SAR
Agriculture, Fisheries and Conservation Department, Hong Kong SAR

Introduction

The first African swine fever (ASF) outbreak in the Chinese domestic pig population was reported in August 2018. Since then, the African swine fever virus (ASFV) has spread within the country but also into South-East Asia plus Timor Leste (TL) and Papua New Guinea (PNG). To date (1st October 2020), a total of 10,154 ASFV outbreaks have been reported to the World Organisation for Animal Health (OIE) from the region, including Cambodia, Indonesia, Laos, Myanmar, Papua New Guinea, Philippines, Timor-Leste, and Vietnam (OIE, 2020). The substantial adverse economic impact on these countries, the limited animal health service capacity, especially in low- and middle-income countries, and the limited knowledge about the complexity of ASFV epidemiology in the region render the prevention and control efforts unsustainable. It highlights the need for a coordinated regional interdisciplinary effort across governments and private sectors. Therefore, an understanding of the relative importance of different risk pathways for ASFV (re)introduction into South-East Asian countries plus China, TL, and PNG will help in the development of more effective and sustainable prevention and control strategies. The data used as part of the current project is based on an up-to-date review of existing knowledge about the epidemiology of ASFV in South-East Asian countries, plus China, TL, and PNG. The project aims to conduct an (re)entry risk assessment (RA) of ASFV cross-border spread between the South-East Asian countries, plus China, TL and PNG. The specific objectives are:

1. To review existing knowledge about ASFV epidemiology in countries participating in the study.

2. To identify the major entry risk pathways for ASFV (re) introduction to each country.

3. To develop and strengthen risk assessment capacity of national veterinary services.

4. To develop practical recommendations on risk mitigation measures in the region.

Study design

Study area

The project involves the following countries in the South-East Asian region (Cambodia, Indonesia, Laos, Malaysia, Myanmar, Singapore, The Philippines, Thailand, Vietnam) plus China, Timor-Leste, and Papua New Guinea (Figure 1).

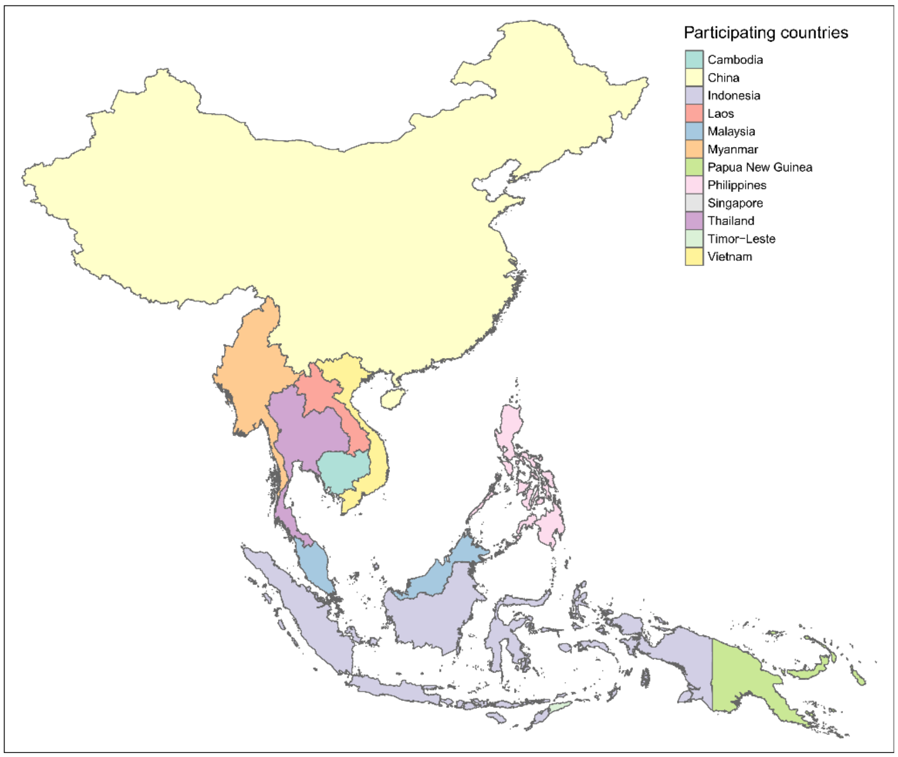

Figure 15: Participating countries in the project "African Swine Fever Cross Border Risk Assessment – South East Asia, China, Timor-Leste and Papua New Guinea"

Hazard identification

The hazard for the present RA is specified as the African swine fever virus (ASFV). The virus is an enveloped double-stranded DNA virus of the Asfarviridae family. There are 26 identified genotypes in the world. However, isolates detected in China and Vietnam all belong to the genotype II. For the present risk assessment, all genotypes will be considered. Susceptible species include domestic pigs and wild species of the Suidae family (as warthogs or wildboars). Transmission between susceptible animals occurs via direct or indirect contact (through the environment, human activities as swill feed trade, or vector-borne).

Purpose and scope

The study will be a country-specific entry RA. It will describe the likelihood of the 'entry' of ASFV into a specific country under a specified set of conditions with respect to amounts and timing, and how these might change as a result of various actions, events or measures (OIE, 2019). A qualitative RA approach will most likely be adopted in the study countries, due to limited data availability in the region. The possibility of using semi-quantitative or quantitative approaches will be explored. As part of the data collection for the RA, evaluations of veterinary services and of surveillance of the source country will be performed, as this will help with assessing the likelihood of ASFV being present in the source animal population. Due to the diversity of epidemiological situations in the region, the risk assessments will be country-specific, but it is expected that there will be broad similarities. Therefore, the same methodology will be used for all countries (see 'Risk estimation'). Exposure and consequence assessments will not be conducted. The final report will summarize the findings from all country-specific entry risk assessments.

Risk questions

The risk questions will be transmission route specific and follow the model": "What is the likelihood of introducing or reintroducing viable ASFV of a given genotype through a given transmission route from a given countries into the country X per year?"

Roles of consultancy team, country focal points (FPs) and the World Organisation for Animal Health (OIE)

Each country will nominate at least one person as a focal point (FP). They will be responsible for identifying relevant and available data sources, building the risk assessment model for their country, and presenting it to national policymakers and other stakeholders. During or after the completion of the project, the risk assessment model can be used to inform targeted risk management activities including design of ASFV surveillance and other ASF prevention measures in the country. Each country's risk assessment model developed during the project will need to be updated and adapted in the future, depending on changes in epidemiological situation, and the regulatory or policy environment.

The consultancy team from Hong Kong City University led by Prof. Dirk Pfeiffer will be responsible for training and supporting the FPs in data collection and RA model development. The consultancy team will help with inviting multidisciplinary stakeholders to the training stage. They will produce a final report summarizing the findings, as well as guidelines of RA for participating countries.

The OIE financially supports this study. The OIE team will also keep close communication with the consultancy team to ensure the study objectives are achieved. The OIE will be responsible for publishing the final report and disseminating it to the veterinary services of participating countries.

Data sources

In order to perform the risk assessment, data will need to be collected at various levels. First, a desk review of ASF disease, the virus (including resistance in the environment), and its epidemiological situation in domestic pigs and wild boars in the South-East Asia region, plus China, TL and PNG will be conducted by the consultancy team. This review will gather official data from OIE WAHIS, and via FAO Empres-i. Data will be supplemented by peer-reviewed publications, Food and Agriculture Organisation (FAO) reports, and previous risk assessment reports in the region. It will be forwarded to all stakeholders of the project for review.

Secondly, the consultancy team will ask the FPs to collect, translate, and summarize grey literature as national or local reports, newspaper articles, or NGO reports. The consultancy team will help each FP individually for this task. The consultancy team will train country FPs in using the participatory approach for data collection by interviewing key informants from the countries. This will be done virtually by organizing group interviews of various stakeholders within the countries. The FPs will assist in organizing these interviews, and also provide translation if the interviewee cannot communicate in English. After the training, the FP will conduct the remaining interviews with support from the consultancy team.

Thirdly, the consultancy team will develop a standardized questionnaire. The FPs will use it to collect national data on 1) ASF outbreaks since 2018, 2) pig value chains (with socio-economic and cultural impacts), 3) pig production, 4) wild boar population, 5) laboratory tests and protocols, 6) country of origin and trade data (e.g., live pigs, pig feed, pig semen, pig product), 7) border control (sanitary inspection and legal procedures at the border) , 8) structure of veterinary services (list non-exhaustive).

Value chains and entry risk pathways

As a first step in the RA process, the value chains associated with likely entry risk pathways will be identified. These will be done for all commodities that may be infected or contaminated with ASFV. The output from this process will be value chain maps.

Based on the desk-based literature review, the consultancy team will identify all hypothetical entry risk pathways that could be relevant in any of the study countries. Using value chain maps and other relevant information, FPs will then identify the pathways that are relevant to their country and validate/adjust them to the local context.

The risk pathways will then be used to identify the data that will be needed to estimate the risk associated with each step along the pathway. The data sources mentioned above will be used for this purpose.

Risk estimation

The risk of ASFV introduction will be estimated during expert roundtable gathering the FP, the consultancy team, and a group of country key informants chosen by the FPs. Risk will be expressed as a likelihood, together with its uncertainty using a qualitative scale.

During this process, likelihood and uncertainty estimates will be produced for each step along the relevant risk pathways (see Table 1 and Table 2). Then, the overall risk estimate for each pathway will be obtained using the risk combination matrix, sequentially combining likelihoods along the risk pathway starting with the source.

Table 4: Levels of likelihood for entry risk assessment (Moutou et al., 2001; Dufour et al., 2011)

Likelihood Level	***Descriptive meaning***
Negligible	The event is so rare that it can be ignored, or the event can only occur under exceptional circumstances
Very low	The event is very rare but cannot be excluded
Low	The event is rare but does occur
Moderate	The event occurs regularly
High	The event occurs very often
Very high	The event occurs almost certainly

Table 5: Levels of uncertainty for entry risk assessment (Fournié et al., 2014)

Uncertainty category	***Interpretation***
Low	There are solid and complete data available; strong evidence is provided in multiple references; authors report similar conclusions. Several experts have multiple experiences of the event, and there is a high level of agreement between experts.
Medium	There are some but not complete data available; evidence is provided in a small number of references; authors report conclusions that vary from one another. Experts have limited experience of the event and/or there is a moderate level of agreement between experts.
High	There are scarce or no data available; evidence is not provided in references but rather in unpublished reports or based on observations, or personal communication; authors report conclusions that vary considerably between them. Very few experts have experience of the event and/or there is a very low level of agreement between experts.

Output

As previously mentioned, the main output for each country will be a country-specific entry risk assessment of (re)introduction of ASFV. The FPs are encouraged to produce a report of these risk assessments to present results and recommendations to national stakeholders and policymakers. This report should be written in the official language of the country. The consultancy team will provide assistance in the production of the English versions of these reports. The FPs will also be encouraged to develop protocols to collect data on identified data gaps and to update the model regularly.

The consultancy team will guide the national FPs in their tasks, compare the different models to give regional and international recommendations on risk management strategies. A final report integrating the findings from the country-level risk assessments and resulting recommendations will be produced for OIE.

Capacity building

The project aims to build capacity in risk assessment for FPs. The work will be based on a series of webinars, a documented guideline for conducting entry risk assessment, and group work designed to teach risk assessment skills to the country FPs. Practical implementation of the methodology during this ASF RA project will be an effective "learn-by-doing" experience. Contributors with different expertise will be invited to participate in these webinars. Concepts of risk assessment will be explained using ASFV as the hazard, but through participation in this training FPs will have developed the skills to conduct risk assessment also for other hazards.

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Annex 7

Desk review for the project: “African swine fever cross-border risk assessment – South East Asia”

African Swine Fever Cross Border Risk Assessment – South-East Asia Desk Review

Anne Conan, Younjung Kim, Lisa Kohnle, Veronica Yu, Jeremy Ho, Andrew Bremang, Aaron Yang, Omid Nekouei, Dirk Pfeiffer

Center for One Health Research and Policy Advice, City University of Hong Kong, Hong Kong SAR
Agriculture, Fisheries and Conservation Department, Hong Kong SAR

Contents

Introduction

The first African swine fever (ASF) outbreak in the Chinese domestic pig population was reported in August 2018. Since then, the virus has widely spread within the country as well as into other countries in South-East and East Asia. To date (1st October 2020), a total of 10,154 ASF virus (ASFV) outbreaks have been reported to the World Organisation for Animal Health (OIE) from South-East Asia (including Cambodia, Indonesia, Laos, Myanmar, the Philippines, and Vietnam), plus Papua New Guinea (PNG) and Timor-Leste (TL). The region is at particular risk, as a substantial proportion of its pig population is raised in farms with low-biosecurity systems. Moreover, the limited animal health service capacity and the little knowledge about the epidemiology of ASF in the region complicate the mitigation of the disease, necessitating a coordinated regional multidisciplinary effort across government and private sectors. The present desk review aims to collect and summarise the available data on ASF, including its virology, its clinicopathogenesis, as well as the available epidemiological data in the region, in order to facilitate risk assessment for the (re)introduction of ASFV into South-East Asia, plus China, PNG and TL. This document will ultimately identify knowledge gaps that need to be addressed to conduct the cross-border risk assessment, and help with implementing appropriate risk mitigation measures.

Literature review

1) History and current situation of African Swine Fever

ASF was first described in Kenya in 1921. The virus then spread and was established in most pig populations in Africa, where it is now considered endemic. During the 20th century, the circulation of ASFV was mostly restricted to the African continent, although sporadic introductions of the genotype I into Europe and the Caribbean islands occurred. The epidemiological situation changed after the introduction of genotype II into Georgia in 2007 (Rowlands et al., 2008). Since then, the virus has rapidly spread to eastern Europe, Russia (2007-2018), and eventually China (2018) — the world's largest pork-producing country. Subsequently, several South-East Asian countries have been affected by the virus, resulting in the current panzootic situation.

In 2020, 25 countries/territories notified ASFV outbreaks through immediate notification (FAO, 2020a; OIE, 2020a):

- Europe: Bulgaria, Hungary, Latvia, Moldova, Poland, Romania, Russia, Serbia, Ukraine, Germany
- Asia and Pacific: China, India, Indonesia, Democratic People's Republic of Korea, Republic of Korea, Laos, Myanmar, PNG, the Philippines, Russia, TL, Vietnam
- Africa: Namibia, Nigeria, South Africa, Zambia

The situation in the South-East Asia region plus China, PNG and TL, is summarised in Figure 1 and Table 2 (FAO, 2020a; OIE, 2020a, 2020b). To date, only Malaysia, Singapore, Brunei, and Thailand remain free of the disease, while China, Philippines, Vietnam, and Laos are among the countries that have most severely been impacted by ASF.

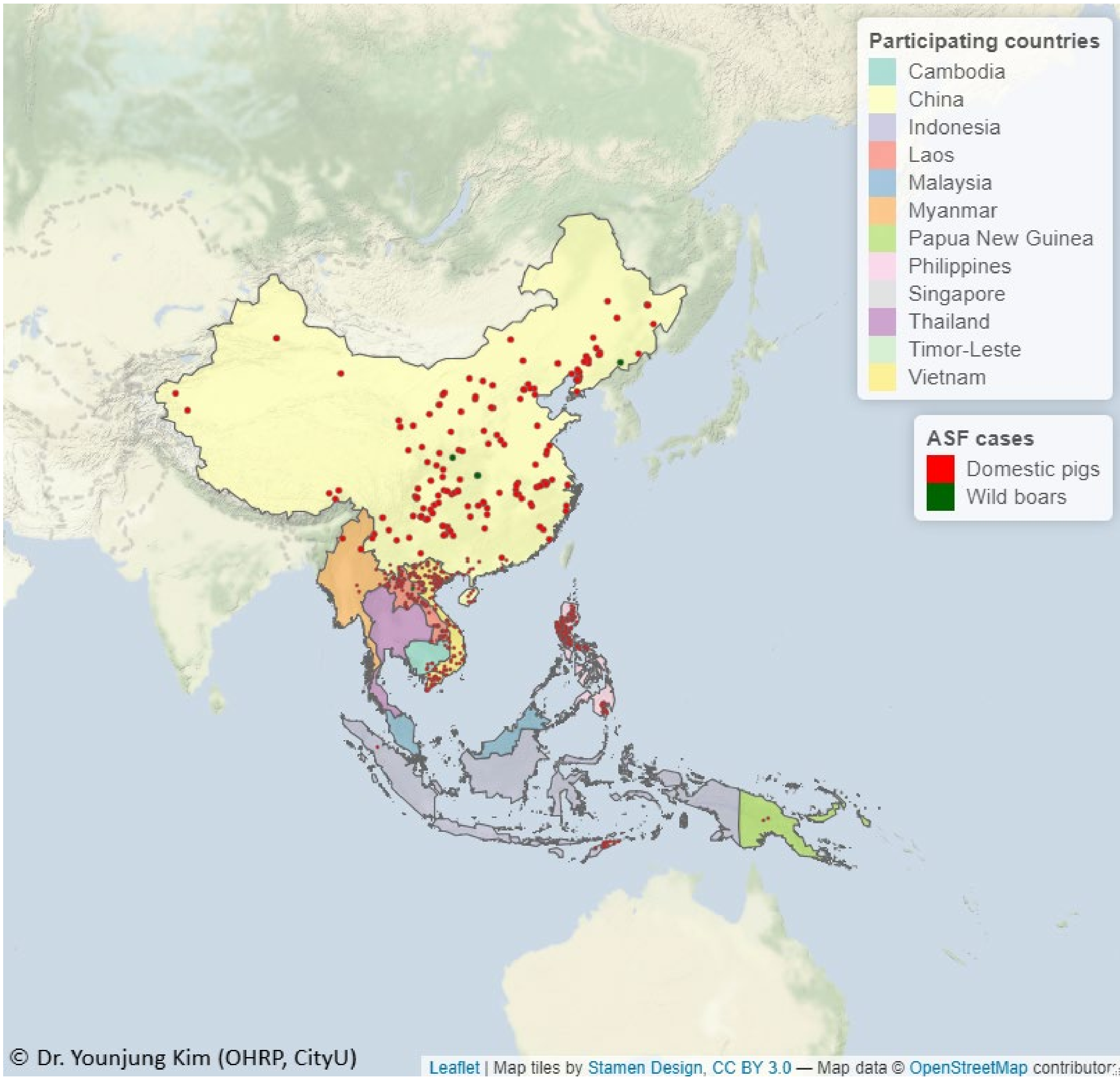

Figure 1: African Swine Fever (ASF) cases (domestic pigs or wild boars) from participating countries by 30th September. 2020 (credit: Younjung Kim, based on (FAO, 2020a)

Table 1: Date of reports, cumulative number of reported outbreaks and total animal losses in countries of interest adapted from OIE (October 2020)

	Ongoing outbreak (Y/N)	First Report	Start of event	Number of outbreaks	Total animal losses	% of administrative divisions affected (affected/total)
Cambodia	N	April 2019	March 2019	13	3,673	20 (5/25)
China	Y	August 2018	August 2018	184	391,418	100 (31/31)
Indonesia	Y	December 2019	September 2019	521	38,123	3 (1/35)
Laos	N	June 2019	June 2019	141	38,774	94 (17/18)
Malaysia	N	-	-	0	0	0
Myanmar	Y	August 2019	August 2019	8	210	20 (3/15)
Philippines	Y	September 2019	July 2019	365	342,157	33 (27/83)
PNG	Y	March 2020	March 2020	4	397	5 (1/20)
Singapore	N	-	-	0	0	0
Thailand	N	-	-	0	0	0
Timor-Leste	Y	September 2019	September 2019	126	405	100 (1/1)
Vietnam	Y	February 2019	February 2019	8979	5,971,696	100 (63/63)

2) African swine fever virus

ASFV, an enveloped virus with a linear double-stranded DNA, is the single species in the genus *Asfivirus* (family Asfarviridae). The length of the genome varies from 179 to 194 kb. Infective virions consist of a nucleoprotein internal core, 70–100 nm in diameter, surrounded by an internal lipid membrane, an icosahedral capsid, 170–190 nm in diameter, and a dispensable external hexagonal lipid-containing envelope (Alonso et al., 2018; Sánchez-Vizcaíno et al., 2019; Dixon et al., 2020).

Until today, 26 genotypes have been defined around the world. The isolates from China (original China 2018/1 and others from 2018), as well as those from Vietnam (Vietnam/2019) belong to the genotype II (p72 analyses). They are all related to the strain isolated in Georgia (Ge et al., 2018; Dong et al., 2019; Le et al., 2019). Additionally, eight serogroups are also defined based on the CD2v protein of the virus. ASFV immunity is serotype-specific, and therefore, identification of the serotype is essential for diagnosis by serology. Serotypes reported from China are consistent and belong to serotype 8 (Ge et al., 2018; Ye et al., 2020).

3) Epidemiology

ASFV only infects the animals of the Suidae family. In Africa, the transmission cycle involves the warthog (*Phacochoerus africanus*) and possibly the bushpig (*Potamochoerus larvatus*), although the role of the bushpig in ASFV transmission has not been elucidated (Penrith et al., 2019). The current pandemic involves two cycles: a domestic pig cycle and a sylvatic cycle (spread in the wild boar population). In Asia, although the virus has been detected in wild boars, the existence of a sylvatic cycle (see section 10, wild boar population) is still unknown. The transmission route consists of direct contact with infected animals and indirect transmissions through the environment or by biological vectors, e.g. ticks from the *Ornithodoros* family (Coetzer and Tustin, 2005). However, while the role of *Ornithodoros* in the transmission is documented in Africa's and Europe's settings (Arias et al., 2018; Basto et al., 2006; Boinas et al., 2011; Quembo et al., 2018; Ndlovu et al., 2020), the virus has not yet been isolated from ticks in Asia. Some other vectors such as flies, lice, mosquitoes or kissing bugs could also act as potential biological or mechanical vectors (Hess et al., 1987; Bonnet et al., 2020; Saegerman et al., 2020). As the genotype detected in Asia is part of the genotype II, we will focus the rest of this review on the knowledge thereof. Additional data are available for the genotypes circulating in Africa, although they are scarce (Penrith et al., 2019).

Seasonality of ASFV outbreaks has been observed in pigs and wild boars in Europe (Boklund et al., 2018). It is believed that domestic pig farms and wild boars have separate transmission cycles that do not intermingle (Vergne et al., 2017). In the sylvatic transmission cycle, removing wild boar carcasses and increased wild boar hunting was able to decrease the risk of ASFV spread among wild boar populations (Boklund et al., 2018). In domestic pigs in Europe, while transmission between individuals can be direct, the introduction of ASFV into farms has rarely been due to direct contact with infected wild boars or domestic pigs (Boklund et al., 2018). Instead, farming activities, such as transport of live pigs, swill, and other farm input and outputs, have been shown to be the common route of ASFV introduction into domestic pig farms, highlighting the importance of fomites and indirect transmission (Oganesyan et al., 2013; Vergne et al., 2017). In the field, risk factors at the farm level include spatial proximity to infected farms (Vergne et al., 2017).

The risk of ASFV (re)introduction into countries has steadily increased due to globalisation. In the past, most outbreaks outside Africa were attributed to the trade of uncooked waste and swill, feeding of pigs, or even to local airport workers bringing leftover food back home from the airport (Beltran-Alcrudo et al., 2019). The current panzootic is not different. The first ASFV introduction into Georgia is likely to have occurred via the import of contaminated pork products from East Africa or Madagascar (Rowlands et al., 2008). In Russia, it is believed that the spread of the virus to susceptible areas at the beginning of the outbreak was caused by illegal movements of swill containing infected pork products (97% of the route identified) (Gogin et al., 2013; Khomenko et al., 2013). However, it should be noted that countries have different risks of ASFV introduction associated with transport routes. For example, although a study in Europe indicated a low risk of ASFV introduction (e.g., by trucks or waste from planes or ships) into the European Union as a whole, some individual countries, such as Poland or Lithuania, displayed a high risk from those routes (Mur et al., 2012).

The basic reproduction number (R_0) depends on the strain and the epidemiological context of ASF outbreaks. Guinat et al. (2016a) reviewed the studies of R_0 for ASFV. R_0 was usually high in domestic pigs; Under experimental conditions, R_0 varied with transmission mode ranging from 1.4 between pens to 2.8 within a pen (Guinat et al., 2016b). During the Russian outbreak, Gulenkin et al. (2011) reported a R_0 of 9.8. Later, Guinat et al. (2018) obtained a wide range of estimates from 4.4. to 17.3 from the same outbreak. In the sylvatic cycle, R_0 was lower in wild boars, ranging between 1.13 and 3.77 (Iglesias et al., 2016). This high variation between studies could be explained by different epidemiological contexts in which the virus was transmitted. While transmission can be fast and intense, mortality may only be observed weeks after the introduction into the farm, thereby showing the importance of early detection of clinical signs suggestive of ASF during surveillance (Guinat et al., 2018).

In infected pigs, ASFV causes systemic infection and is excreted from the blood system into the environment via different routes. Under experimental conditions where domestic pigs were inoculated with ASFV by intramuscular or intranasal inoculation and housed with other pigs within the same pens, the virus was detected in the blood of inoculated pigs 1 to 4 days post-infection (dpi), considering all inoculation routes (e.g. intramuscular and intranasal) (Guinat et al., 2014; Vlasova et al., 2015; Gallardo et al., 2017; Zhao et al., 2019), while the virus was isolated in the blood at 10.4 days post-exposure (dpe) in the contact pigs (Guinat et al., 2014). The peak of viral titres in the blood observed on 14 dpe for the contact pigs and 6 dpi for the inoculated pigs (Gallardo et al., 2017). ASFV was detected 2-6 dpi in oral-nasal swabs and 3-5 dpi in rectal swabs (Guinat et al., 2014; Vlasova et al., 2015; Zhao et al., 2019). In the contact pigs, the virus was first detected on 5 dpe in oral swabs and 10 dpe in rectal swabs (Zhao et al., 2019). It should be noted that a low-dose inoculation via the oral route didn't reduce the risk of transmission in domestic pigs and wild boars (Pietschmann et al., 2015). Although the virus is excreted mainly via urine, faeces, and mucus (oronasal), it has also been detected in wild boar semen (Guérin and Pozzi, 2005; Maes et al., 2016). Successful transmission to a female domestic pig through artificial insemination has also been reported (Thacker et al., 1984). Finally, while asymptomatic pigs have never been observed with genotype II in field studies, one experimental study observed a single asymptomatic pig that posed a transmission risk through some intermittent and weak viremia (Gallardo et al., 2017). Moreover, some recovered animals were able to become carriers (Guinat et al., 2016a).

4) Virus tenacity

ASFV is known to survive in different live tissues and excretions for a prolonged period of time and under various environmental conditions. It persists longer under low temperatures, high humidity and at the presence of organic matters. Resistance in live tissues and excretions is summarised in Table 2.

Table 2: Survival of ASFV in excretions and live tissues.

Matrix	Environmental conditions	ASFV survival time	Reference
Faeces	4°C	8.48 days	Davies et al., 2017
	37°C	3.71 days	Davies et al., 2017
	Room temperature	11 days	Iowa State University, 2019
		Up to 160 days	European Food Safety Authority, 2014
Urine	4°C	15.33 days	Davies et al., 2017
	37°C	2.88 days	Davies et al., 2017
Oral fluid	-	-	-
Blood	4°C	18 months	Iowa State University, 2019
	Putrefied blood	15 weeks	European Food Safety Authority, 2010
Bone marrow		180-188 days	European Food Safety Authority, 2014
Muscle		90-183 days	Zani et al., 2020
Fat		123 days	McKercher et al., 1987
Skin/fat		300 days	European Food Safety Authority, 2014
Spleen		90-240 days	Zani et al., 2020
	6-8°C	204 days	European Food Safety Authority, 2014
Tissue	-70°C	Years (without loss of titre)	Mazur-Panasiuk et al., 2019
	-2°C	105 weeks (with loss of titre)	Mazur-Panasiuk et al., 2019; Dixon et al., 2020
	4°C	61 weeks	Mazur-Panasiuk et al., 2019; Dixon et al., 2020
Contaminated pig pen		1 month	Iowa State University, 2019

5) Virus resistance

Table 3 shows the survival of ASF under different chemical and temperature conditions, while Table 4 shows the survival of ASFV in different types of meat products. To summarise, the virus remains infectious over a long time of storage below 4°C (at least 75 weeks) and can survive up to 70mins at 56°C, 20mins at 60°C and one week at 37°C (Mazur-Panasiuk et al., 2019). The virus is also stable in a wide range of pH, from 3.9 to 13.4. ASFV in feed and water can be viable for 30 and 60 days at 4°C, respectively (Sindryakova et al., 2016).

Table 3: Survival of ASFV under different temperature and chemical conditions (adapted from European Food Safety Authority (2014))

Temperature/chemical conditions	ASFV survival time	Reference
Temperature of 37°C	11-22 days	Mazur-Panasiuk et al., 2019
Temperature of 50°C	3 hours	European Food Safety Authority, 2014
Temperature of 50°C	1 hours	Mazur-Panasiuk et al., 2019
Temperature of 56°C	70 minutes	OIE, 2019a
Temperature of 60°C	20 minutes	OIE, 2019a
Temperature of 60°C	30 minutes	Mazur-Panasiuk et al., 2019
pH<3.9 or pH>11.5 (serum free media)	Minutes	OIE, 2019a; USDA, 2019
pH 13.4 (serum free media)	21 hours	OIE, 2019a; USDA, 2019
pH 13.4 with 25% serum	7 days	Mazur-Panasiuk et al., 2019; OIE, 2019a; USDA, 2019
Susceptible to ether and choroform		OIE, 2019a; USDA, 2019
Inactivated by 0.8 % Sodium chloride	30 minutes	OIE, 2019a; USDA, 2019
Hypochlorites – 2.3% chlorine	30 minutes	OIE, 2019a; USDA, 2019
0.3 % formaline	30 minutes	OIE, 2019a; USDA, 2019
3 % ortho-phenylphenol	30 min	OIE, 2019a; USDA, 2019
Iodine compounds		OIE, 2019a; USDA, 2019
Slurry addition to concentration of 1 % NaOH or Ca(OH)2 at 4C	1 minutes	OIE, 2019a
1% formaldehyde	6 days	Mazur-Panasiuk et al., 2019
2% NaOH	1 day	Mazur-Panasiuk et al., 2019
Sera or blood kept at room temperature for 18 months	18 months	Mazur-Panasiuk et al., 2019
Tissue deep freezing (-70°C)	Years without (loss of titre)	Mazur-Panasiuk et al., 2019
Tissue freezing (-2°C)	105 weeks (with loss of titre	Mazur-Panasiuk et al., 2019
Tissue (4°C)	61 weeks	Mazur-Panasiuk et al., 2019
Feed frozen (-16 - 20°C)	60 days	Sindryakova et al., 2016
Feed (chilled 4-10°C)	30 days	Sindryakova et al., 2016
Feed room (15-25°C)	5 days	Sindryakova et al., 2016
Water (frozen -16 - 20°C)	60 days	Sindryakova et al., 2016
Water (chilled 4-10°C)	60 days	Sindryakova et al., 2016
Water (room 4-10°C)	60 days	Sindryakova et al., 2016

Table 4: Survival of ASFV in meat and meat products (adapted from (European Food Safety Authority, 2014)

Matrix	ASFV survival time	Source
Sera or blood kept at room temperature for 18 months	18 months	Mazur-Panasiuk et al., 2019
Meat and pork fat stored at 22–27°C (salted)	105 days	Hartnett et al., 2004; European Food Safety Authority, 2010
Chilled meat	84-155 days	European Food Safety Authority, 2014
Salted meat	84-182	Mebus et al., 1993, 1997; Hartnett et al., 2004; European Food Safety Authority, 2010, 2014
Ground meat	105 days	Hartnett et al., 2004; European Food Safety Authority, 2010
Natural smoked meat	30-300 days	European Food Safety Authority, 2014
Frozen meat	104 days-years	European Food Safety Authority, 2014
Cooked/canned meat	None	Hartnett et al., 2004; European Food Safety Authority, 2010
Regionally produced salted ham-shoulder	112-183 days	McKercher et al., 1987; Mebus et al., 1993
Raw dry fermented sausages (4–10°C)	30 days	McKercher et al., 1987
Salted (cured) and dried meat (e.g., ham, shoulder, loin)	112-399 days	Hartnett et al., 2004
Salted (cured) fermented and dried (e.g., salami/pepperoni)	30 - 120 days	Hartnett et al., 2004
Salted (cured), fermented dried and spiced (e.g., pepperoni)	30-120 days	Hartnett et al., 2004
Ham in brine	180 days	Hartnett et al., 2004

6) Clinicopathology (in pigs and wild boars)

Domestic pigs (*Sus domesticus*) and wild boars (*Sus scrofa*) have been the only species identified as susceptible to ASFV. However, no information has been collected regarding the potential susceptibility of other wild pigs, particularly in Asian wild pigs.

In domestic pigs and wild boars, all breeds and ages can be affected. Under experimental conditions, the incubation period in domestic pigs after intravenous injection was 3-5 days, while the incubation period in contact pigs was about 9-10 days. The incubation period after an intramuscular injection was around 4 days post-infection (Guinat et al., 2014; Zhao et al., 2019). Another study reported the development of fever (> 40.5°C) in contact pigs 1 to 13 days post-exposure (Pershin et al., 2019), while Olesen et al. (2018) reported an incubation period of 7 days in contact animals. OIE defined the incubation period in *Sus scrofa* to be 15 days (OIE, 2019b).

The clinical presentation of ASF would depend on the strain of the virus, the species and breed of infected animals, and the route of infection (Pan and Hess, 1984). In Russia, the average time between the appearance of hyperthermia and death or recovery was reported to be 6.3 days, ranging between 0 and 18 days (Pershin et al., 2019). Clinical signs are summarised in Table 5. Several forms of the disease, ranging from chronic to acute, have been observed in domestic pigs. Field observations in Sardinia and Russia suggest that animals may develop subacute or unspecific mild clinical signs. A chronic form has also been described after infection with genotype I in Spain, Portugal and the Dominican Republic (Sánchez-Vizcaíno et al., 2012). However, the peracute form is most commonly reported in ASF-affected areas. For example, in the first outbreak in Vietnam, marked redness on the body, conjunctivitis and haemorrhages were observed in a piglet and a sow infected with ASFV, with a mortality rate exceeding 50 % (Le et al., 2019).

Wild boars showed a higher susceptibility to ASFV than domestic pigs under experimental conditions. After experimental inoculation with the genotype II virus, fever was observed 3-4 dpi, followed by death within 7 dpi. The infected wild boars showed clinical signs characteristic of an acute form of ASF (haemorrhages in multiple oedematous and enlarged lymph nodes, hyperplasia of mesenteric lymph nodes, pulmonary hyperaemia and alveolar oedema, and haemorrhagic gastritis; no skin lesions described) (Gabriel et al., 2011; Sánchez-Cordón et al., 2019). Low-dose infection also led to an acute disease. However, under field conditions, wild boars may look apparently healthy or show non-pathognomonic clinical signs, such as prostration or abnormal behaviour (Guberti et al., 2019).

Table 5: Summary of clinical signs observed for different forms of the disease

Form of disease	Clinical Signs	Reference
Peracute	Sudden death, or 1-4 days after the onset of clinical signs. No gross lesions on post-mortem Pyrexia (>41°C), inappetence, depression, hyperpnoea, and cutaneous hyperaemia.	Gallardo et al., 2017; Sánchez-Vizcaíno et al., 2019
Acute	Inappetence, pyrexia (>40°C), inactivity, early leukopenia, pulmonary oedema, extensive necrosis and hemorrhage of lymphoid tissue, hemorrhages in skin, splenomegaly Other clinical signs: nasal hemorrhaging, constipation, vomiting, diarrhea, melaena, skin hyperemia, hematomas, necrosis Abortion in gestating females Mortality >90% at day 7 after onset of clinical signs	Schlafer and Mebus, 1987; Opriessnig et al., 2012; Pershin et al., 2019; Sánchez-Vizcaíno et al., 2019
Subacute	Transitory thrombocytopenia, leukopenia, numerous hemorrhagic lesions Other clinical signs: moderate to high fever, ascites, hydropericardium, oedema in multiple organs (gallbladder, kidneys), abortion, splenomegaly. Mortality rates range from 30 to 70%. Animals may recover after 3-4 weeks. ASFV antibodies or intermittent viremia may be present	Sánchez-Vizcaíno et al., 2019
Chronic	Necrotic skin lesions and arthritis No specific clinical signs (only detected during serological screening to eradicate the disease in Spain). Other clinical signs: delayed growth, emaciation, lameness, respiratory signs, abortion and low mortality	Botija, 1982; Arias and Sánchez-Vizcaíno, 2008; Sánchez-Vizcaíno et al., 2012; Sánchez-Vizcaíno et al., 2019

7) Laboratory detection and diagnostic tests

Laboratory diagnostics must be run to confirm ASF cases. Clinical presentation of ASF is usually indistinguishable from classical swine fever (CSF), erysipelas and septicaemic salmonellosis (Quinn et al., 2011). In domestic pigs, CSF and ASF cases show high fever, appetite loss, lethargy, and gastro-intestinal signs leading to high mortality. Erythema and petechial haemorrhage are seen for ASF, while severe haemorrhagic and neurological signs may be observed with CSF (Schulz et al., 2019). *Erysipelothrix rhusopathia* causes the 'diamond skin disease.' As its name suggests, infected pigs may develop skin lesions which progress from small, light or purple, raised area to diamond-shaped erythematous plaques. Other signs of erysipelas, such as septicaemia or arthritis, are also described (Quinn et al., 2011). Its mortality is usually lower than for ASF, but some outbreaks were accompanied by high rates with abortions and sow mortality (Opriessnig et al., 2020). Septicaemic salmonellosis similarly leads to high fever, depression and recumbency. Blueish discoloration is observed around ears and snout of animals infected with septicaemic salmonellosis. However, septicaemic salmonellosis is more frequently observed in piglets with a higher mortality (Quinn et al., 2011). To differentiate ASF from these other differential diagnoses, laboratory testing is mandatory. Additionally, as was stressed previously in this review, clinical diagnosis should not be based only on the abnormal mortality in the herd/region, as mortality may only appear weeks after the cases (Guinat et al., 2018). Therefore, veterinarians and farmers should be trained to recognize the disease as early as possible.

OIE recommends the following definition for a confirmed case of ASFV: "1) ASFV has been isolated from samples from a suid; OR 2) antigen or nucleic acid specific to ASFV has been identified in samples from a suid showing clinical signs or pathological lesions suggestive of ASF or epidemiologically linked to a suspected or confirmed case of ASF, or from a suid giving cause for suspicion of previous association or contact with ASFV; OR 3) antibodies specific to ASFV have been detected in samples from a suid showing clinical signs or pathological lesions consistent with ASF, or epidemiologically linked to a suspected or confirmed case of ASF, or giving cause for suspicion of previous association or contact with ASFV" (OIE, 2019b).

While these principles are applied internationally, individual countries may use a different case definition and test based on the availability of diagnostic and laboratory resources. Laboratory capability and quality assurance of the performance of a diagnostic laboratory (e.g. accreditation and participation in proficiency testing) for ASF are key considerations of quality management in a veterinary diagnostic laboratory (OIE, 2018). With respect to this, the OIE has developed the OIE Tool for the Evaluation of Performance of Veterinary Services (PVS) to evaluate relevant competencies of different countries. The critical competencies of concern in the OIE PVS Tool are under the category of technical authority and capability and related to laboratory diagnosis and surveillance, as listed below (OIE, 2019c)

- II-1: Veterinary laboratory diagnosis
- II-2: Risk analysis and epidemiology
- II-3: Quarantine and border security
- II-4: Surveillance and early detection
- II-5: Emergency preparedness and response
- II-6: Disease prevention, control and eradication

For ASF diagnosis, samples appropriate for laboratory testing include blood on EDTA, serum and tissues (mainly spleen, lymph nodes, bone marrow, lung, tonsil, and kidney). Various factors may influence the sensitivity and specificity of the test, including but not limited to the quality of the samples or the maintenance of the cold chain (Oura, 2013).

Multiple diagnostic tests (virologic and serologic) have been developed to detect ASFV and diagnose ASF. In May 2020, OIE officially recognised a real-time PCR based-test for ASF for the first time: VetMAX™ African Swine Fever Virus Kit from Thermo Fisher Scientific LSI S.A.S.(OIE, 2020c). The kit has been evaluated with 100% analytical and diagnostic sensitivity, as well as 100% analytical and diagnostic specificity, with good comparative performance and reproducibility (OIE, 2019d). So far, this is the only OIE-recognized diagnostic kit for ASF. Table 6 summarises the laboratory tests and their corresponding ranking on different purposes as recommended by the OIE for ASF diagnosis. The procedures of those diagnostic tests are detailed in the OIE Terrestrial manual (OIE, 2019e). The rapid, reliable, sensitive and specific detection of ASFV is essential for the effective control of AFSV.

Data on used ASF tests in our region of interest are only sparse in the published literature. Some countries reported the use of PCR (e.g. conventional and real-time) for detection of ASF cases, yet the sensitivity of individual tests and other potential technical limitations are to be considered. In Vietnam, where conventional PCR was used to detect the first case in 2019 (Nga et al., 2020), a field study highlighted the possible limitation of the real-time PCR. Truong et al. (2020) indeed found a false-negative result by real-time PCR testing due to a single mismatch in the probe binding site. Therefore, the use of two tests to increase sensitivity was recommended. Virus isolation followed by a hemadsorption (HAD) test can be used as a second test to confirm an outbreak, but the time to obtain a result (up to a week) is not compatible with an early diagnosis (Tran et al., 2020; Truong et al., 2020). Thailand was another country publishing about testing. At the Thai border, meat products were tested with real-time PCR (Wang et al., 2019). Serology using indirect enzyme-linked immunosorbent assays (ELISA) to detect antibodies to ASFV has also been used from 2010 to 2015 during a seroprevalence survey (Ketusing et al., 2017).

Table 6: Laboratory test recommended by the OIE for ASF diagnosis (adapted from: (Gallardo et al., 2015; OIE, 2019e)

	Sensitivity	Specificity	Population freedom from infection	Individual animals' freedom from infection prior to movement	Contribute to eradication process	Confirmation of clinical cases	Prevalence of infection-surveillance
			Detection of immune response				
ELISA (experimental condition)	OIE: 22.2 %	84.3-97.6 %	+++	+++	+++	+	+++
Indirect immunoperoxidase test (IPT)			+++	+++	+++	+	+++
Indirect fluorescent antibody test (IFAT)			+++	+++	+++	+	+++
Immunoblotting test (IBT)			++	++	++	+	++
			Agent identification				
Virus isolation/HAD test			n/a	n/a	++	+++	++
FAT			n/a	n/a	++	++	+
ELISA for antigen detection	OIE: 77.2 %		+	++	+	+	+
Real-time PCR	OIE: 98.5 %		+++	+++	+++	+++	+++
Conventional PCR	OIE: 96.7 %		++	++	++	++	++

+++ recommended method, validated for the purpose shown; ++ = suitable but need further validation; +=may be used in some situations, but cost, reliability, or other factors severely limits its application

8) Pig production systems

In South-East Asia, plus China, PNG and TL, pig industry significantly contributes to the livelihood of rural and peri-urban populations, and pork is one of the most consumed animal proteins in many of these countries (Qiu et al., 2020). As an example, pork represents more than 70% of the meat consumption in Vietnam (Nga et al., 2015; Qiu, 2019). In 2018, it was estimated that nearly 77,775,552 domestic pigs were stocked in the South-East Asia region. The same year, China was the largest producer of pork processed products in the world, with an estimated pork production of 54,983,905 tonnes. Vietnam and the Philippines are the other two major pig producers with 3,816,414 and 1,873,063 tonnes of pork produced in 2018 (FAO, 2018). While the pig industry has played a substantial role in meeting the current demands for animal protein in the region, recent introduction and spread of ASF have threatened food security in the region by affecting pork production and price.

South-East Asia is characterised by a variety of pig production systems ranging from very small family holders to large-scale enterprises. Because of large variability in pig farming and management, there is no consistent definition for the different production systems. However, three main groups of production systems are usually described based on herd size, production goals and husbandry management (Gilbert et al., 2015; Qiu, 2019; FAO, 2020b):

- Subsistence farming scavenging pigs (extensive/backyard): Pigs are raised in a traditional system. They usually roam and are kept for family consumption. They may be sold for a particular event, such as the need for emergency cash or family festivity. Herd size is often fewer than 10 animals, and there are no biosecurity measures in place. This production system is frequent in South-East Asia; e.g. the average number of pigs per pig-owning household in Laos is estimated between 1 and 4 animals (Qiu, 2019) and 86% of the pig production in Cambodia comes from the backyard system (Sothyra, 2019).
- Small-scale confined pig production (semi-intensive): Pigs are confined, but investment in biosecurity practices or hygiene is limited. The production is low-cost and pork is usually sold locally. The herd size ranges between 10 and 100 pigs.

- Large-scale confined pig production (intensive/commercial): This category includes commercial production systems with larger herd sizes (>100) and high biosecurity standards. The health of pigs is monitored by veterinarians. This system of production is frequent in China and Thailand (more than half of the farms). In the Philippines and Vietnam, the intensive system represents about half of the farming while Cambodia, Laos, and Myanmar report only few commercial farms (Dong et al., 2019; Qiu, 2019).

9) Value chain and trade of live pigs and pork products

The value chains of live pigs and pork products in the region are dominated by direct transactions between the producers and traders of those commodities. Their trade is driven by market demand and price differentials. Traditionally, town traders, including slaughterhouse operators and market sellers, come to villages to purchase pigs to meet local demand. These traders re-sell live pigs to butchers, pork processors, who then supply pork products to markets, restaurants street sellers. This leads to the movements of different types of pigs (e.g. piglets, finishers, and sows) between farms, thereby facilitating the spread of infectious agents through infected pigs or contaminated vehicles and equipment. Improved road infrastructure has also facilitated long-distance trade of live pigs between farms and of pork products from rural producers to big cities and even overseas markets. In most areas, such movements are difficult to monitor, due to the lack of effective tracing systems, and there are many illegal movements. Further, it is believed that the current spread of ASF dramatically affects the price of live pigs and pork products, leading to changes in trade and movement patterns, both locally and internationally (Qiu, 2019; Qiu et al., 2020).

There has been an active exchange of live pigs and different kinds of pork products (e.g. sausages, cured pork) within the South-East Asia region (Magno, 2019; Qiu, 2019). As an example, Vietnam exports pork to its neighbouring countries, including Laos and China, and especially Hong Kong; receiver of 74% of Vietnam's pork exports. Laos and Cambodia are usually net importers of pigs and pork products, while Myanmar can act as a cross-road for import, export, and transit among its neighbouring countries. The Philippines is also highly reliant on small-scale pig farmers to meet its domestic demands. Unlike the aforementioned countries, Thailand relies mostly on commercial farming and has had a constantly high level of pork exportation. Thailand is a net exporter of pigs, especially to its neighbours (e.g., Cambodia, Laos, and Myanmar).

Recent ASF outbreaks in South-East Asia have caused a clear difference in price of live pigs and pork products among these countries. Affected areas in Vietnam have experienced the lowest prices over the past couple of years. These price differentials may incentivise the unregulated movements of pigs across borders and especially to China, due to its rising demand for pork. In general, cross-border control of ASF in this region was deemed difficult because of long and permeable borders between these countries. The ASF outbreaks are expected to cause substantial changes in the current pig production and value chain systems so that moving toward more sustainable methods of production will be inevitable. Therefore, more meticulous research on the structure of local pig industries in the region is warranted to bridge the current data and knowledge gaps in the traceability of live pigs and pork products, as well as the attitude and behaviour of all stakeholders involved (Qiu, 2019).

10) Ecology of wild boar

As mentioned previously, wild boars play an important role in the transmission cycle of ASFV in Europe. A study showed that the spatial patterns of domestic pig farm outbreaks and wild boar cases were not associated with one another in the Krasnodar and the Tver regions of Russia (Vergne et al., 2017). Another publication in Latvia linked outbreaks in domestic pigs to ongoing infection in the wild boar population. The transmission was suspected of having been through contaminated fresh grasses or crops (Oļševskis et al., 2016). However, it should be noted that there are insufficient studies that assessed the role of wild boars in spreading the virus to domestic pig farms in different epidemiological contexts. Pig production in South-East Asia is dominated by extensive and backyard farms with relatively low biosecurity. This farming system makes the interaction between domestic and wild boars easier. Moreover, wild boars are an important vector that could introduce the virus into new territories, as they can travel long distances. In Europe, the main risk factor of ASFV in wild boar is the density of wild boar. Among the countries participating in the present study, five wild boar cases have been reported in China (n=4), Laos (n=2) and Vietnam (n=1) since the virus was introduced into the region (FAO, 2020a).

Wild boars are present in South-East Asia. While their density is unknown, two modelling studies highlighted the possibility of high density in some area of the region, based on the suitability of the environments for wild boar habitation (Bosch et al., 2017; Lewis et al., 2017). The two maps are reproduced in Figure 2 and Figure 3.

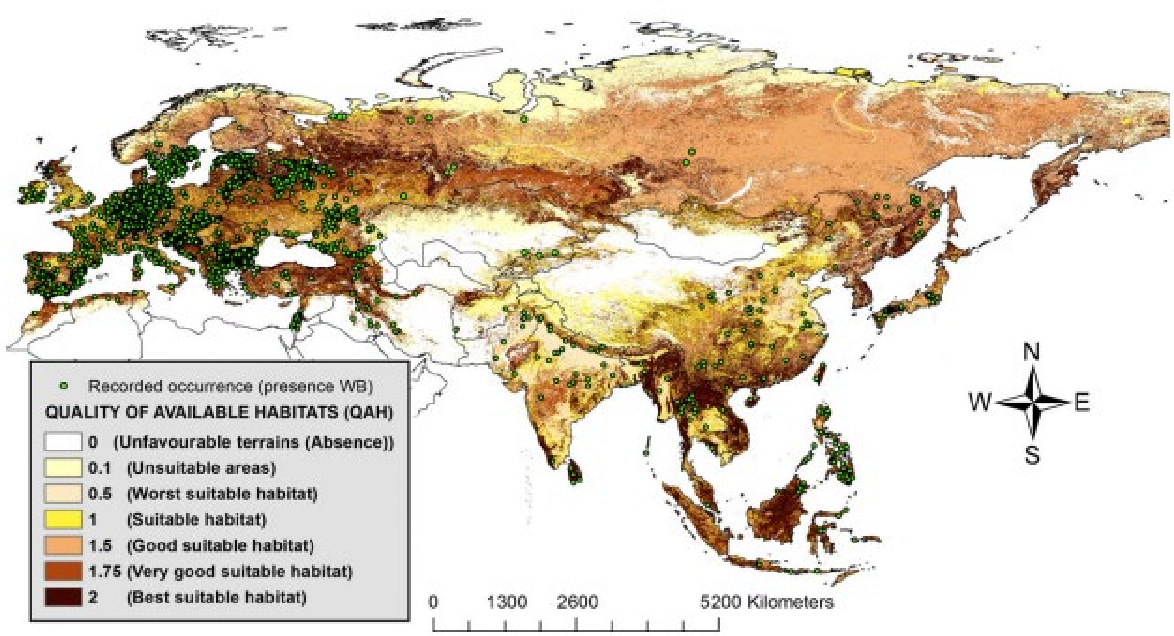

Figure 2: Reproduction "Map of the quality of available habitats (QAH) levels for wild boar in Eurasia. Darker colours indicate areas with greater quality of habitat availability; light yellow, areas with lower quality of habitat availability; white, areas with unfavourable terrains of wild boar. The complete data set of wild boar occurrences (n=22 362) is shown as green dots" (Bosch et al., 2017).

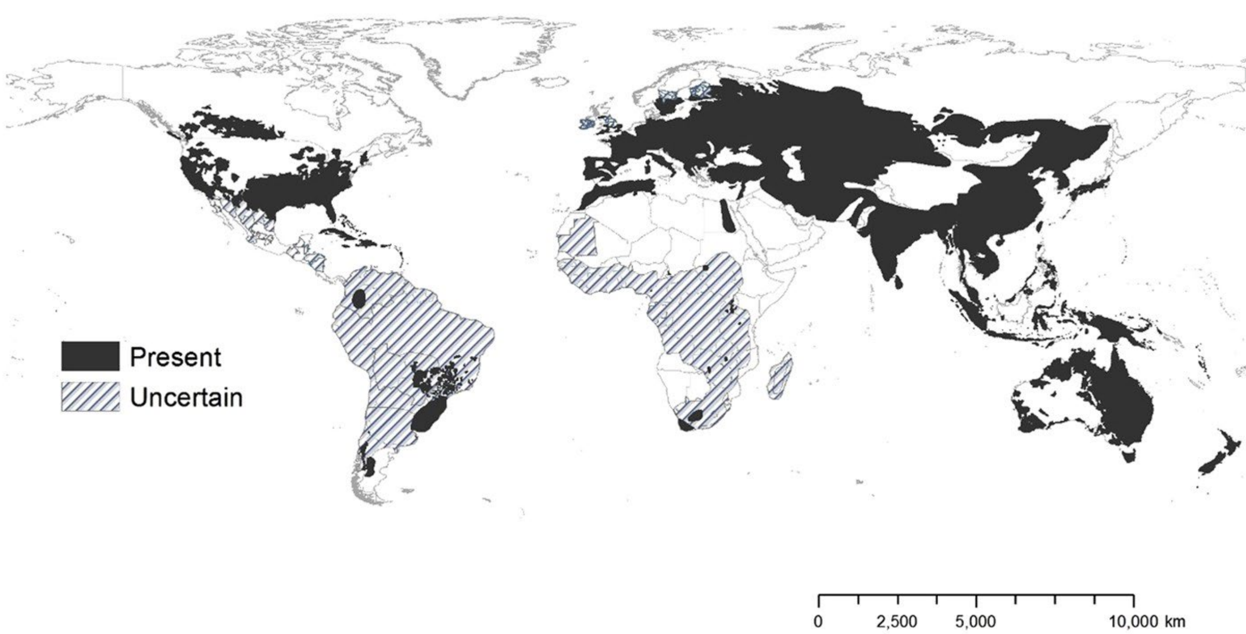

Figure 3: Reproduction: "Geographic range of wild pigs across their native and non-native global distribution."(Lewis et al., 2017)

Moreover, other species of *Suidae*, warty pigs (*Sus phillippensis*) and bearded pigs (*Sus barbatus)*, live in the countries of interest, including Indonesia and the Philippines. Although the susceptibility of these species to ASFV is unknown, considering that they also are species from the *Sus* family, it is expected that they would develop the same clinical signs as domestic pigs and wild boars. Other species from distinct genera (as *Babirousa babyrussa*) may have a different susceptibility and are believed to be resistant (Funk et al., 2007; Netherton et al., 2019). However, surveillance should encompass these species as well, as they could pose a risk of spreading ASFV to domestic pig production. ASF presents also a risk for the conservation of these wild species (Carr and Howells, 2019).

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