



Workpackage 1, Milestone 1: Hazard identification

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Executive Summary

Disease incursion and transmission modelling can play an important role in elucidating important pathways and dynamics of trans-boundary diseases. The development of a spatial risk assessment framework for assessing exotic disease incursion and spread through the European Union (EU) requires knowledge of which diseases are relevant threats to the EU and what the different mechanisms of incursion into/spread within the EU associated with these diseases are, i.e. hazard identification. This task forms the basis of this report, which covers Milestone 1.1 of the SPARE project. The task was completed by APHA with input from disease experts from this institute.

An initial list of animal health pathogens was compiled from the World Organisation for Animal Health (OIE) and European Commission (EC) lists of notifiable diseases. In consultation with disease experts, this list was refined to the final hazard identification list, which included exotic animal health pathogens which were notifiable within the EU and were thought to have sufficient data to be a realistic case study for a quantitative risk assessment model. A shortlist of nine key modes of transmission, for which robust evidence was thought to exist, was also drawn up in consultation with disease experts. A score was assigned to each pathogen/mode combination to describe the likelihood of the pathogen being introduced to the EU via that mode.

It is acknowledged that the scoring system used in assessing the pathogens can be subject to opinion bias, so to help mitigate this, the disease experts were consulted. This input was essential for completion of this milestone and the expert's advice on transmission routes of the various pathogens was central to the conclusions drawn.

The identified hazards were grouped into distinct mode-of-transmission classes illustrating the number of key routes required to model transmission of individual pathogens. From the final list of 33 pathogens, the analysis suggested that 31 could be reasonably modelled using only 4 modes of transmission:

- Arthropod vectors
- Live animal imports
- Wildlife
- Import of animal products.

The key routes for the majority of pathogens and for which proven documented evidence exists were arthropod vectors and live animal imports.

The hazard identification process is pivotal to the SPARE project as it provides essential information on which other project workpackages can build. The information used within the hazard identification pathway will also be useful for the case study modelling, providing information on the main modes of transmission and factors affecting spatial and temporal spread contributing to the exposure and consequence pathways.

1. Hazard Identification

1.1 Introduction

The purpose of the hazard identification task was to compile a list of “relevant exotic animal health pathogens with the identification of the key modes of introduction for each pathogen together with a weighting for the importance of each mode given multiple routes for one pathogen”. The procedure followed, first identified those hazards that were relevant to the European Union (EU) with regards to the status of being notifiable and exotic. The main modes of transmission of each identified hazard were then ascertained and weighted, allowing a final classification of pathogens according to the key modes of transmission. This information is essential for the determination of pathogens for case studies in the full model.

1.2 Approach to Hazard identification

A full list of animal health pathogens was initially compiled from the World Organisation for Animal Health (OIE) and European Commission (EC) lists of notifiable diseases (OIE, 2015a; EC, 2010). The identification of the final list of pathogens relevant to the EU followed the process illustrated in Figure 1.

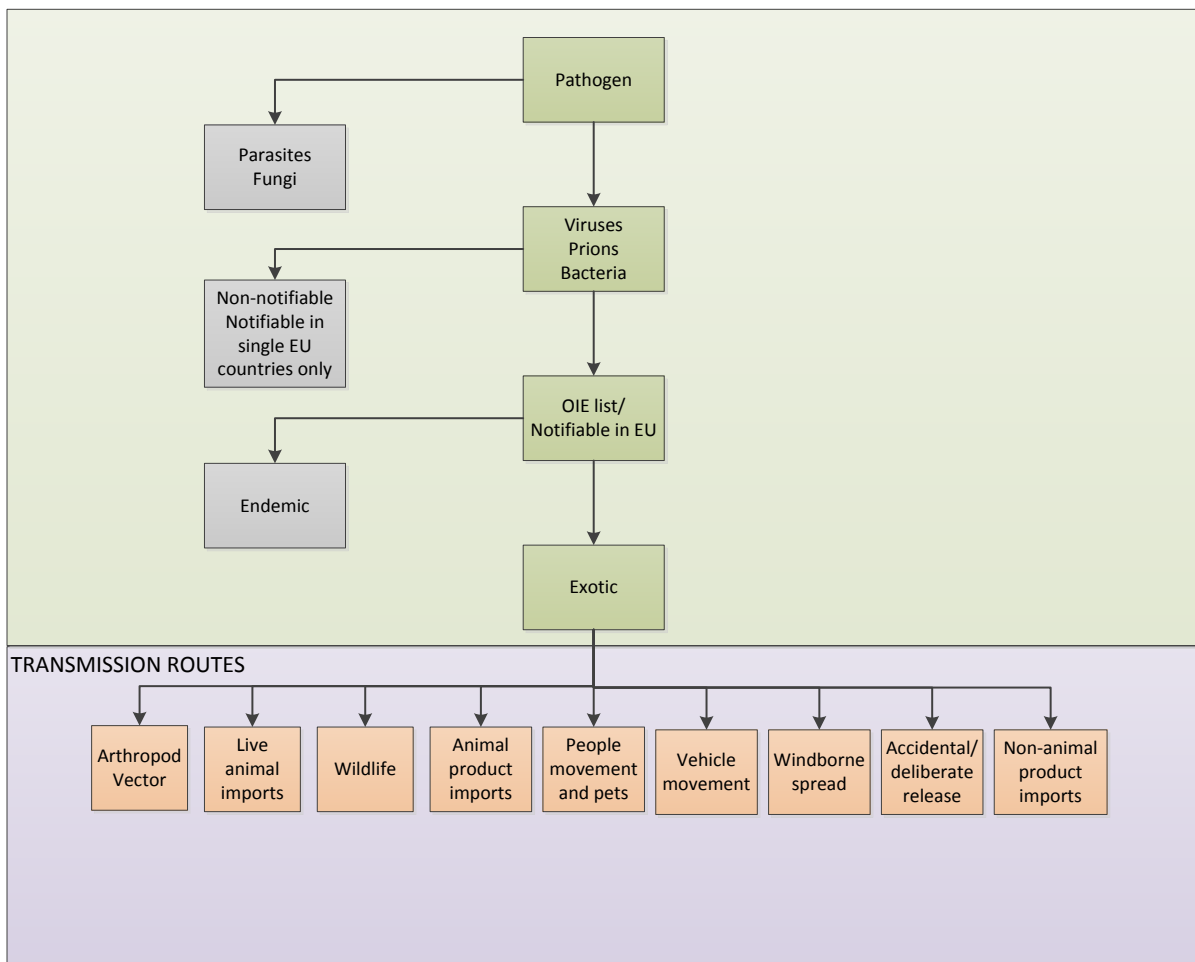


Figure 1: Decision tree for the identification of relevant animal pathogens (pathogens that were assigned to the grey boxes were not taken forward to the full hazard identification assessment)

The pathogens were initially classified into their relevant micro-biotic groups (fungi and parasites were excluded due to predicted lack of strong data for model parameterisation) and defined as endemic or exotic in livestock within EU. Endemic pathogens were excluded from further analysis. The term “exotic” was defined as a pathogen not normally found within the EU, has previously only caused sporadic outbreaks of disease in livestock or only occurred in isolated controlled zones. Conversely, endemic pathogens were identified as those that are maintained within an EU livestock population without the requirement for external inputs. This definition excluded those pathogens which may be considered endemic in wildlife populations such as wild birds, wild boars or ticks. Each pathogen was assessed as endemic or exotic, using information from the OIE WAHID dataset (OIE, 2015b), the EU Animal Disease Notification System (ADNS 2015) and expert opinion (APHA). The numbers of previous outbreaks within each Member State (MS) were taken from the WAHID website to identify whether incidence was sporadic or more continuous within the EU. Table 1 (see appendix) shows a summary of this assessment.

1.3 Identifying Modes of Transmission

The modes of transmission associated with each exotic pathogen were identified from peer reviewed literature and government fact sheets. Nine of the most common entry routes/modes of transmission for animal health pathogens were identified as follows:

- Arthropod vector (e.g. mosquito, midge, tick)
- Wildlife (e.g. birds, mammals, bats)
- Human travel (including pets)
- Vehicle movement (e.g. ‘aeroplane with mosquito on board’ (which is considered a separate route to the actual mosquito itself as requires aviation data), livestock trucks)
- Import of live animals
- Import of animal products (e.g. meat, semen)
- Import of non-animal products (e.g. fruit and veg, car tyres)
- Windborne spread
- Accidental/deliberate release.

Modes such as fomites were assumed to be covered by the categories above, for example, via livestock vehicle movement or import of non-animal products. Similarly, mechanical transmission whereby the transmitter is not infected, tissues are not invaded and the agent does not multiply was considered within the arthropod vector category.

Literature searches and APHA expert opinion were used to estimate the likelihood by which each of the exotic pathogens from Table 1 would be transmitted by each route. The scoring system was from 1-4 (see Table 2), with 1 being the most likely route(s) of transmission and 4 being a negligible chance of transmission by this route.

Table 2: Weighting criteria for scoring system of mode-of-transmission routes

Score	Description
1	A major key route for the pathogen with proven documented evidence
2	The route can transmit the pathogen but is less of a key route
3	An indication that the route can transmit the pathogen but evidence is limited
4	Negligible with no existing evidence

These estimates were then used to determine a semi-quantitative score for each pathogen/route combination (Table 3 in appendix). It was assumed that any pathogen/route combination with a score of 4 would not be considered further, while a score of 1 was essential to include. Note that the score refers to how likely the route is as a transmission pathway, *assuming* that the pathogen is present, not to the probability of the pathogen entering the EU via these routes; this will be covered in Workpackage 5.

Using the results from Table 3, the animal pathogens were grouped according to the modes of transmission that would be required to parameterise a model for the individual pathogens. Table 4 shows the results using those modes of transmissions which ranked as either 1 or 2 (see Table 2) in the expert opinion ranking.

Table 4: Grouping of the identified hazards into distinct mode-of-transmission classes illustrating the number of classes required to model transmission and the number of pathogens that could be modelled using transmission rankings 1-2 (pathogens highlighted in grey are those that could not be modelled with only 3 data sets).

Selection	No. of transmission routes required	Transmission routes	Pathogens	Total number of pathogens
A	2	Wildlife People movement and pets	Rabies	1
B	3	Arthropod vectors Live animal Imports Wildlife	Ehrlichia ruminantium Mycoplasma capricolum Mycoplasma mycoides Bluetongue CCHF Enzootic bovine leucosis Epizootic haemorrhagic virus Equine encephalomyelitis (E&W) Equine infectious anaemia Equine Influenza Nairobi sheep disease Transmissible gastroenteritis Venezuelan equine encephalomyelitis Vesicular stomatis West Nile Fever	16

Selection	No. of transmission routes required	Transmission routes	Pathogens	Total number of pathogens
C	3	Live animal Imports Wildlife Import animal products	Brucella ovis Mycoplasma capricolum Mycoplasma mycoides Aujeszky's disease Avian Influenza HP Avian Influenza LP Classical swine fever Enzootic bovine leucosis Equine influenza Foot and mouth disease Newcastle disease Peste des petits ruminants Sheep and Goat Pox Swine vesicular disease Transmissible gastroenteritis	15
D	3	Arthropod vectors Live animal Imports Import animal products	Brucella ovis Mycoplasma capricolum Mycoplasma mycoides African horse sickness Bluetongue Enzootic bovine leucosis Equine infectious anaemia Lumpy skin disease Nairobi sheep disease Rift Valley fever Sheep and Goat Pox Vesicular stomatis	12
E	3	Live animal Imports Import animal products People movement and pets	Brucella ovis Burkholderia mallei Enzootic bovine leucosis Mycoplasma capricolum Mycoplasma mycoides	5
F	3	Arthropod vectors Wildlife Vehicle movement	CCHF Epizootic haemorrhagic virus Equine encephalomyelitis (E&W)	3
G	4	Arthropod vectors Live animal Imports Wildlife Import animal products	African swine fever Japanese encephalitis List from B (16) List from C (+10) List from D (+3)	31
H	4	Live animal Imports Wildlife Import animal products Non-animal products	Nipah virus List from C (+15)	16

Selection 'G' in Table 4 illustrates how 31 (out of a possible 33 with the exclusion of Rabies and Nipah virus) of the pathogens selected could be modelled using 4 different modes of transmission: Arthropod vectors, Live animal imports, Wildlife, and Import of animal products. For this exercise, windborne spread of virus of pathogen particles and accidental/deliberate release of pathogen were not included due to the lack of availability of reliable datasets and their relative importance in animal disease entry into the EU.

It should be noted that this task grouped pathogens according to modes of transmission only. It did not further classify the modes according to categories of products/ livestock and, more importantly, did not distinguish between illegal or legal components of the various modes. For example, there are likely to be illegal categories of human travel, vehicle movement, live animals,

and both animal and non-animal products. It is therefore likely that data for both illegal and legal movements would be required to populate each mode of transmission.

1.4 Conclusions

The data presented in the appendix provide information on each animal pathogen's zoonotic ability, host species range and presence within defined entry transmission routes. Table 4 illustrates the importance of the various transmission routes with regard to their ability to transfer individual pathogens. The most important routes for carrying pathogens and for which proven documented evidence exists were arthropod vectors and live animal imports. Whilst the majority of the final list of pathogens, with the exclusion of Rabies and Nipah Virus, could be modelled using 4 different modes-of-transmission it is acknowledged that each mode could require a number of different datasets to be robustly populated. For example, Rift Valley fever affects multiple species so the live animal mode would require data for both illegal and legal import of all species affected. The information provided in Table 1 and 4 forms the basis on which Workpackage 5 can build the case study selection identifying pathogens which have different key modes-of-transmission and considering the ease of transmission, species affected and zoonotic potential amongst other factors.

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- CABI 2015b Equine Influenza <http://www.cabi.org/isc/datasheet/84006>
- CABI 2015c Nairobi sheep disease <http://www.cabi.org/isc/datasheet/73949>
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EAZWVb Chlamydiosis
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Appendix 1

Table 1: List of notifiable diseases according to the OIE or EC lists, host species, zoonotic potential and determination of their endemic/exotic status (Pathogens considered endemic are highlighted in grey and are not considered further in the assessment).

Pathogen	Zoonotic	Host species	Endemic in EU *	Notifiable	Reference
Bacteria:					
<i>Bacillus anthracis</i>	Yes	Multiple	Yes (Croatia, Finland, Germany, Italy, Poland, Romania, Slovakia, Slovenia, Sweden, UK)	OIE	WAHID
<i>Brucella abortus</i>	Yes	Bovine	Yes (Belgium, France, Greece, Ireland, Italy, Portugal, Spain)	OIE	Godfroid 2002
<i>Brucella melitensis</i>	Yes	Ovine/caprine	Yes (France, Greece, Italy, Portugal, Spain)	OIE	Godfroid 2002

Pathogen	Zoonotic	Host species	Endemic in EU *	Notifiable	Reference
<i>Brucella ovis</i>	No	Ovine	No (Romania)	OIE	WAHID
<i>Brucella suis</i>	Yes	Swine	Yes	OIE	Godfroid 2002
<i>Burkholderia mallei</i> (Glanders)	Yes	Equine	No (Germany)	OIE/EU	WAHID
<i>Campylobacter fetus</i> (Bovine genital campylobacteriosis)	Yes	Bovine	yes	OIE	CFSPH
<i>Chlamydia abortus</i>	Yes	Ovine/caprine	Yes	OIE	EAZWVa
<i>Chlamydia psittaci</i>	Yes	Avian	Yes	OIE	EAZWVb
<i>Coxiella burnetii</i>	Yes	Multiple	Yes	OIE	EFSa 2010
<i>Ehrlichia ruminantium</i> (Heartwater)	No	Multiple	No	OIE	WAHID
<i>Mycobacterium avium</i> Subsp. paratuberculosis	Debatable	Multiple	Yes (except Sweden)	OIE	Stevenson 2009
<i>Mycobacterium bovis</i>	Yes	Bovine	Yes	OIE	EFSa 2014
<i>Mycoplasma agalactiae</i> causing contagious agalactia (CA)	No	Ovine/caprine	Yes (Mediterranean Region and Balkan Peninsula)	OIE	Zendulkova 2004; Expert opinion APHA
Contagious agalactia related organisms-OIE listed: <i>Mycoplasma capricolum</i> subsp. <i>Capricolum</i> ; <i>Mycoplasma mycoides</i> subsp. <i>Capri</i> (Mmc); <i>Mycoplasma putrefaciens</i>	No	Mainly caprine, some sheep even rarer in bovine (Mmc)	Yes	OIE	Expert opinion APHA
<i>Mycoplasma capricolum</i> subsp. <i>Capripneumoniae</i> (contagious caprine pleuropneumonia)	No	Caprine	No (Turkey)	OIE	OIE
<i>Mycoplasma gallisepticum</i>	No	Avian	Yes	OIE	Expert opinion APHA
<i>Mycoplasma mycoides</i> subsp. <i>mycoides</i> (small colony)	No	Bovine/Bison	No	OIE/EU	Lorenzon 2003; Expert opinion APHA
<i>Mycoplasma synoviae</i>	No	Avian	Yes	OIE	Expert Opinion APHA
<i>Salmonella Abortusovis</i>	No	Ovine/caprine	Yes	OIE	Valdezate 2007
<i>Salmonella Gallinarum</i>	No	Avian	Yes	OIE	Expert opinion APHA
<i>Salmonella Gallinarum</i> -biovar <i>Pullorum</i>	No	Avian	Yes	OIE	Expert Opinion APHA
<i>Taylorella equigenitalis</i> (Contagious equine metritis)	No	Equine	Yes	OIE	EU RL for equine diseases
Tularemia	Yes	Multiple	Yes	OIE	Tarnvik 2004
Viruses:					
African Horse Sickness	No	Equine	No	OIE/EU	EFSa 2009a
African Swine fever	No	Swine	No (Estonia, Latvia, Lithuania, Poland)	OIE/EU	WAHID
Aujeszky's disease	No	Swine	No (Belgium, France, Germany, Luxembourg, Slovakia)	OIE	WAHID; Defra factsheet
Avian infectious bronchitis	No	Avian	Yes	OIE	APHA expert opinion

Pathogen	Zoonotic	Host species	Endemic in EU *	Notifiable	Reference
Avian infectious laryngotracheitis	No	Avian	Yes	OIE	APHA expert opinion
Avian influenza HP	Yes	Avian	No (all except: Belgium, Cyprus, Estonia, Finland, Ireland, Latvia, Lithuania, Luxembourg, Malta, Portugal)	OIE/EU	WAHID
Avian Influenza LP	Yes	Avian	No (Belgium, Czech Republic, Denmark, France, Germany, Ireland, Netherlands, Portugal, Romania, Spain, UK)	OIE/EU	WAHID
Bluetongue	No	Primarily sheep/deer/cattle	No (all except: Estonia, Finland, Ireland, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia)	OIE/EU	WAHID
Bovine viral diarrhoea	No	Bovine	Yes	OIE	Lindberg 2006
CAE/MV	No	Caprine/ovine	Yes	OIE	AHVLA 2010
Classical Rabies	Yes	Multiple	No (Belgium, Finland, France, Greece, Italy, Netherlands, Slovakia, Spain, Sweden)	OIE	Freuling 2012
Classical swine fever	No	Swine	No (Bulgaria, Croatia, Germany, Hungary, Latvia, Lithuania, Slovakia)	OIE/EU	Postel 2013
Crimean Congo haemorrhagic fever	Yes	Multiple	No (Greece and eastern European MSs)	OIE/EU	Maltezos 2010; Fernandez-Garcia 2014
Duck virus hepatitis	No	Avian	Yes	OIE	APHA expert opinion
Enzootic bovine leucosis	No	Bovine	No (Finland, Germany)	OIE	CABI 2015a
Epizootic haemorrhagic virus	No	Cervid/bovine	No	OIE	EFSA 2009b
Equine encephalomyelitis – Eastern and Western	Yes	Equine	No	OIE/EU	Durand 2013
Equine herpesvirus 1	No	Equine	Yes	OIE	CABI 2012
Equine infectious anaemia	No	Equine	No (Belgium, France, Germany, Greece, Hungary, Ireland)	OIE/EU	WAHID
Equine influenza	No	Equine	No	OIE	CABI 2015b
Equine viral arteritis	No	Equine	Yes	OIE	BEVA
Foot and Mouth Disease	No	Multiple	No (Belgium, Cyprus, UK)	OIE/EU	WAHID
Infectious bovine rhinotracheitis	No	Bovine	Yes	OIE	Expert opinion APHA
Infectious bursal disease	No	Avian	Yes	OIE	Expert opinion APHA
Japanese encephalitis	Yes	Multiple	No	OIE	Durand 2013
Lumpy Skin Disease	No	Bovine	No (Cyprus, Greece)	OIE/EU	EFSA 2015a; Anon 2015; Gale 2015; Defra 2015
Nairobi sheep disease	No	Ovine/caprine	No	OIE	CABI 2015c

Pathogen	Zoonotic	Host species	Endemic in EU *	Notifiable	Reference
Newcastle Disease	Yes	Avian	No (all except: Austria, Hungary, Ireland, Lithuania, Luxembourg, Malta, Poland, Portugal, Slovenia)	OIE/EU	WAHID
Nipah Virus	Yes	Pigs	No	OIE	Simons 2014
Peste des petits ruminants	No	Ovine/caprine	No	OIE/EU	Banyard 2010; EFSA 2015b; Anon 2015
Porcine reproductive and respiratory syndrome	No	Swine	Yes	OIE	De Paz 2015
Rift Valley fever	Yes	Multiple	No	OIE/EU	EFSA 2013
Rinderpest	No	Multiple	No	OIE/EU	OIE 2011
Sheep pox and goat pox	No	Ovine/caprine	No (Bulgaria, Greece)	OIE/EU	EFSA 2014a; Gale 2015
Swine vesicular disease	No	Swine	No	EU	EFSA 2012
Transmissible gastroenteritis	No	Swine	No	OIE	CABI 2015d
Turkey Rhinotracheitis	No	Avian	No	OIE	APHA expert opinion
Venezuelan equine encephalomyelitis	Yes	Equine	No	OIE/EU	Durand 2013
Vesicular stomatis	Yes	Multiple	No	EU	EFSA 2012
West Nile fever	Yes	Equine	No (Austria, Bulgaria, Croatia, France, Greece, Italy, Portugal, Romania, Spain)	OIE	Di Sabatino 2014
Bovine Spongiform Encephalopathy	Yes	Bovine	Yes (France, Germany, Ireland, Italy, Poland, Portugal, Spain, UK)	OIE/EU	WAHID
Scrapie	Unknown	Ovine/caprine	Yes	OIE	Cassard 2014; EFSA 2014b

*= MSs in brackets for endemic diseases are those in which the pathogen is regularly found; MSs in brackets for exotic diseases are those in which outbreaks have occurred over the past 10 years (WAHID)

Table 3: Weighting of transmission routes with regards to their potential to contain pathogen

Pathogen	Transmission route/mode								
	Vector	Live animal Imports	Wildlife	Import animal products	People movement and pets	Vehicle movement	Non-animal products	Windborne spread of viral particles	Accidental /deliberate release
<i>Brucella ovis</i>	4	1	4	1	4	4	4	4	4
<i>Burkholderia mallei</i> (Glanders)	4	1	3	2	2	3	4	4	3

Pathogen	Transmission route/mode								
	Vector	Live animal Imports	Wildlife	Import animal products	People movement and pets	Vehicle movement	Non-animal products	Windborne spread of viral particles	Accidental /deliberate release
Ehrlichia ruminantium (Heartwater)	1	2	2	4	4	4	4	4	4
Mycoplasma capricolum subsp. Capripneumoniae (contagious caprine pleuropneumonia)	4	1	3	4	4	4	4	4	4
Mycoplasma mycoides subsp mycoides (small colony)	4	1	4	4	4	4	4	4	4
African Horse Sickness	1	2	3	2	4	3	4	4	4
African Swine fever	1	1	2	1	4	3	4	4	4
Aujeszky's disease	3	1	2	2	4	3	4	3	4
Avian influenza HP	3	2	1	2	4	3	4	3	4
Avian Influenza LP	4	2	1	2	4	3	4	3	4
Bluetongue	1	2	3	3	4	3	4	4	4
Classical Rabies	4	4	1	4	1	4	4	4	4
Classical Swine Fever	4	1	2	1	4	3	4	3	4
Crimean Congo Haemorrhagic Fever	1	3	2	4	3	4	4	4	4
Enzootic bovine leucosis	4	1	4	3	4	4	4	4	4
Epizootic haemorrhagic virus	1	4	2	4	4	3	4	4	4
Equine encephalomyelitis – Eastern and Western	1	3	1	4	3	3	3	4	4
Equine infectious anaemia	1	1	3	3	4	4	4	4	4
Equine influenza	4	1	2	4	4	4	4	4	4
Foot and Mouth Disease	4	1	2	2	3	3	4	3	4
Japanese encephalitis	1	2	2	2	3	3	3	4	4
Lumpy Skin Disease	1	2	4	2	4	3	3	4	4
Nairobi sheep disease	1	2	4	4	4	4	4	4	4
Newcastle Disease	3	2	1	2	4	4	4	3	4
Nipah Virus	4	2	1	2	3	4	2	4	4
Peste des petits ruminants	4	1	2	2	4	4	4	4	4
Rift Valley fever	1	1	3	2	3	3	3	4	4

Pathogen	Transmission route/mode								
	Vector	Live animal Imports	Wildlife	Import animal products	People movement and pets	Vehicle movement	Non-animal products	Windborne spread of viral particles	Accidental /deliberate release
Sheep pox and goat pox	3	1	4	2	4	4	4	4	4
Swine vesicular disease	4	1	2	2	4	3	4	4	4
Transmissible gastroenteritis	3	1	2	4	3	4	4	4	4
Venezuelan equine encephalomyelitis	1	2	1	4	3	3	3	4	3
Vesicular stomatis	1	1	3	4	4	4	4	4	4
West Nile Fever	1	2	1	3	3	3	3	4	4
Total No. of key routes ('1')	15	17	8	3	1	0	0	0	0

Key:	
1	A major key route for the pathogen with proven documented evidence
2	The route can transmit the pathogen but is less of a key route
3	An indication that the route can transmit the pathogen but evidence is limited
4	Negligible with no existing evidence