A SPATIAL ENTRY ASSESSMENT MODEL FOR INCURSION OF EXOTIC SWINE DISEASES INTO THE EUROPEAN UNION

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Introduction

The threat of incursion of exotic animal pathogens into the European Union (EU) Member States (MS) via transmission routes such as human travel and trade of live animals and their products is dynamic and needs to be continually re-assessed. Here, we present a quantitative spatial entry assessment model for assessing the risk of incursion of exotic pig diseases such as Classical Swine Fever (CSF) into the EU.

Methods

Overview: Import risk assessments generally follow the World Organisation for Animal Health OIE risk assessment framework process [1], comprising a release (or entry) assessment, an exposure assessment and a consequence assessment. Here we describe a model, which builds on one developed previously for introduction of bat-borne viruses [2], to estimate the risk of entry to the EU using classical swine fever (CSF) as a case study. Routes considered include live animal trade, legal trade of meat products and illegal trade of meat via air freight, marine cargo containers or aircraft passenger luggage. Figure 1 shows the generic model framework. It is designed to utilise input data such as pathogen incidence and animal demographics to derive an estimate for country level pathogen prevalence by animal species. This is then combined with data on trade products and pathogen survival rates to estimate the risk of introduction to EU Member States. The framework is designed to be generic and applicable for any pathogen.

Figure 1. Model Framework, describing the processes simulated in the release assessment.
OIE input data: Data from the OIE on animal demographics and pathogen prevalence were used to estimate the prevalence of CSF in pigs at the point of export, at the country level; this included estimating pathogen prevalence for countries with no, or limited data. For all 180 countries in the OIE databases over the years 1996-2014, data were obtained for the number of reported outbreaks and cases by country, k, species, s, and year, y, $N_{ob}(k,s,y)$ and $N_{case}(k,s,y)$ respectively. For the period 2004-2014 these data were obtained from the annual reports on the World Animal Health Information System (WAHIS) section of the OIE website [3]. For the period 1996-2004 these data were obtained from Handistatus II [4]. Data on the total number of animals, $N_{animal}(k,s)$, and the number of ‘animal establishments’, $N_{eb}(k,s)$, by country and species, were also obtained, as defined in the country annual reports in the WAHIS section of the OIE website for 2014; this is essentially equivalent to farms.

Country level CSF prevalence: To obtain an estimate of the annual number of cases of CSF in pigs in country k, $N_{country}(k)$, an estimate for the observed number of cases, $N_{caseExp}(k)$ was multiplied by an under-reporting factor, $U_{f}(k)$ and the probability of an outbreak occurring, $P_{ob}(k)$

$$N_{country}(k)=N_{caseExp}(k)*U_{f}(k)*P_{ob}(k).$$

The estimate for number of cases was based on the historical OIE data. For countries where data were missing an estimate was derived based on the number of cases in the same geographical region [5]. The under reporting factor, $U_{f}(k)$, was used to account for potentially unreported cases that could be a risk for disease transmission in an import risk assessment.

Prevalence at export: The number of infected pigs at export, $N_{exp}(k)$, was estimated by multiplying $N_{country}(k)$ by the probability a random infected pig will still be infected when exported, $P_{surv}(k)$, and the proportion of cases expected to occur before detection of the outbreak, $P_{det}(k)$

$$N_{exp}(k)=N_{country}(k)*P_{surv}(k)*P_{det}(k).$$

Countries were defined as either sporadic or continuous, based on the annual frequency of CSF outbreaks; countries with more than one outbreak every 2 years were considered to be continuous, $P_{det}(k)$, while for sporadic countries it was assumed that the outbreak would be detected and a ban on exports implemented, thus $P_{det}(k)=0.1$, based on data from a CSF outbreak in the Netherlands. $P_{surv}(k)$ was estimated by dividing the average duration of clinical signs of CSF, assumed to be 20 days, by the number of days in the year, 365.

Legal trade: Annual EU import data on live animals and meat products were obtained from the comext database in Eurostat [6]. For live animals, the prevalence of the pathogen is assumed to be equivalent to the prevalence at export in the export country, as described previously. For meat products, the prevalence is predicted by estimating the number of animals contributing to the annual quantity of meat and then using the prevalence of the pathogen in the export country. Reduction of the pathogen due to processing effects and natural decay during travel time is also taken into account.

Illegal trade: The model considers illegal importation of pig products into the EU via legal shipments of maritime containers, air freight and commercial air passenger luggage; illegal smuggling operations were not considered. The number of containers, freight and air passengers were obtained from Eurostat databases [6]. The proportion of containers, freight and passenger luggage that contain illegal meat was estimated based on aggregated data obtained from UK border force (unpublished data). The prevalence of the pathogen was assumed to be equivalent to the prevalence in the exporting
country, but with $P_{det}(k)=1$ for both sporadic and continuous countries, as we don’t expect illegal activities to cease once an outbreak has been detected.

**Outputs:** As well as estimates for CSF prevalence at export, the model consisted of three outputs; 1) annual number of CSF infected live animals entering the EU, 2) annual volume of CSF contaminated pig products entering the EU, 3) annual volume of illegal CSF contaminated pig products entering the MS. Here we rank the results by route and present the relative ranking.

**Results**

From Figure 2 it can be seen that the model predicted the countries at highest risk of CSF in pigs at export are in Central and South America and South East Asia, as would be expected from the raw OIE data. Estimates are also provided for countries where data are missing, e.g. in Africa, and allows for very low probabilities of future occurrence in countries currently officially free of CSF.

![Figure 2. Model predicted country prevalence of CSF in pigs at export.](image)

From Table 1 it can be seen that the relative ranking of EU MSs for entry of CSF differs between routes; e.g. Great Britain has lower risk than other MSs for import from legal trade products, but has the highest risk from illegal trade products. Note a low ranking does not necessarily imply low risk.

**Table 1.** Relative ranking of EU MSs for risk of introduction of CSF via three routes; live animal imports, legal trade and illegal trade of pig products.

<table>
<thead>
<tr>
<th>MS</th>
<th>Live animals</th>
<th>Legal trade</th>
<th>Illegal trade</th>
<th>MS</th>
<th>Live animals</th>
<th>Legal trade</th>
<th>Illegal trade</th>
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<td>9</td>
<td>HUN</td>
<td>1</td>
<td>7</td>
<td>19</td>
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<tr>
<td>BEL</td>
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<td>17</td>
<td>7</td>
<td>IRL</td>
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<tr>
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<td>8</td>
<td>25</td>
<td>ITA</td>
<td>9</td>
<td>1</td>
<td>6</td>
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<tr>
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<td>24</td>
<td>LTA</td>
<td>12</td>
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<td>21</td>
</tr>
<tr>
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<td>LUX</td>
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<tr>
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<td>13</td>
<td>MLT</td>
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</table>
The model described here uses information from global datasets to give a quantitative estimate of the prevalence in pigs at the point of export in all countries of the world and the subsequent risk of introduction of CSF to EU MSs. To make use of these data and cover the broad scope of introduction to the EU, the model cannot be particularly complex, which does lead to quite large uncertainty surrounding the absolute values of the model outputs. However, the strength of the model lies in the relative risks between MSs and routes. The model can be updated with new data as they become available and so can be used as an early warning system, to highlight a change in risk due to factors such as changing trade patterns.

The results of the assessment described here suggest that the EU MSs at highest risk of incursion of CSF differ depending on the route of introduction. The risk is influenced by volume imported and prevalence of CSF in the import country. Live animal imports to EU MSs predominantly occur within the EU only, while imports of pig products are more widespread. The model assumes that illegal meat imports could come from any country of the world, so while the legal trade depends specifically on reported data on pig products, the illegal trade is influenced by total volumes of trade of maritime cargo, air freight and commercial air passengers. It should be noted that, due to lack of data, the model does not include other routes of illegal trade, such as being smuggled across borders, and thus could underestimate the risk from illegal trade in some geographical areas. The model also does not account for differences in border controls upon arrival to EU MSs.

The different scales of the routes should be remembered when considering these results; the live animal route considers the introduction of an infected animal while the other routes consider contaminated pig products. It is likely that the risk of onward spread from an infected live pig will differ from that of a contaminated meat product and the risk from a legally imported meat product may differ from that from an illegally imported product. Thus, the results from this release assessment are not the whole story, but will provide a useful input for an exposure assessment to assess the risk of onward transmission within individual MSs and the EU as a whole.

This spatial assessment model is capable of assessing the risk of disease incursion for other pathogens and thus can provide a framework to compare the relative risk between multiple pathogens and countries for different livestock species. These outputs can help drive surveillance activities, by indicating which pathogens are most likely to enter the EU, by which route and into which MS.
References


