



Import risk model: A quantitative risk assessment of classical swine fever virus (CSFV) introduction into Arunachal Pradesh via importation of pigs from bordering countries

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Classical swine fever (CSF) is a highly contagious, fatal viral disease that affects pigs, causing huge economic losses to the pig husbandry (Ribbens *et al.* 2004). The causative agent is Classical swine fever virus (CSFV), belonging to the genus *Pestivirus*, family *Falviviridae* (Cole *et al.* 1962). The disease has a diversity of clinical symptoms making it difficult for its diagnosis (Chakraborty and Veeragowda 2013). With the continued implementation of zoo-sanitary controls, various countries like USA, Canada, Australia and New Zealand amongst others have been able to completely eradicate the disease with the help of “test-slaughter policy” (Dongyou 2016).

India is a high risk country for CSF epidemic as depicted by the number of outbreaks that have occurred in many states of the country in the recent past as reflected in the Annual Reports of All India Coordinated Research Project on Animal Disease Monitoring and Surveillance. India imported a quantity of 128 MT of pig and pig products in the period between 2011 and 2012, the same period during which a significant number of CSF outbreaks occurred in the country, particularly in the states of north-eastern region of India (Bett *et al.* 2011). Around 80% of the households in the NE regions rear pigs as it is a key part of their diet (Chander *et al.* 2014). Factors that give rise to the high incidence of CSF in India are due to lack of timely vaccine as well as diagnosis, unrestrained movement of pigs across the boundaries surrounding the NE states and poor public awareness (Bett *et al.* 2011).

The trade of pig and pig products between nations requires information on the risk of introducing infectious agents such as classical swine fever virus (Bronsvooort *et al.* 2008). By means of cross-border trade in livestock which has its economic advantages but also has its correlations in

increased veterinary and economic consequences due to previous outbreaks classical swine fever as experienced in previous outbreaks of classical swine fever (CSF) (Bett *et al.* 2011, Chander *et al.* 2014). Important determinants of the frequency of occurrence and magnitude of contagious livestock diseases is dependent on number of farms, farm size, the concentration of farms in certain areas, specialization of production and constant reliance on cross-border production markets (Bronsvooort *et al.* 2008).

Thus, a structural framework was developed by building pathways based on type of outbreak from scientific material reports (Bronsvooort *et al.* 2008, Kumar 2010) from animal husbandry institutes and in consultation with on-field experts. Subsequently, by identifying pathways for introduction of CSFV into India the risk imposed through live pigs and pig products from the neighboring countries were quantified (Bouma *et al.* 2003). Based on the disease risks associated with importation of animals and animal products, the model was used to assess the annual probability of virus introduction based on the following factors (Morley 1993).

The risk of CSFV introduction depends upon prevalence and vaccination status of CSFV in importing countries, association with livestock demographics and impact of bio security operations in farm operations.

With the above factors as the basic variable, the paper was designed to assess the likelihood of an introduction of CSFV-infected or contaminated material infection through introduction pathways of importance to the swine population by quantifying the volume of trade and scale of movement in Arunachal Pradesh sharing international borders with Bhutan in the west, Burma in the east and China in the north.

Arunachal Pradesh is the largest of the north-eastern states of India and is located in the north-eastern region of India. It shares international borders with Bhutan in the west, Burma in the east and China in the north. Recent molecular characterization of CSFV genotypes showed emergence of sero-group 2.2 CSFV genes which were similar with Chinese counterparts. These were found to be

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mostly associated with the outbreaks of CSF during the 2011–2012 in this region (Roychoudhury *et al.* 2014).

The CSFV genogroup 1.2, 2.1, 2.2, 2.3 had been reported in the recent past (Patil *et al.* 2010, 2012; Barman *et al.* 2010, 2014; Sarma *et al.* 2011, Roychoudhury *et al.* 2014, Shivaraj *et al.* 2015, Khaton *et al.* 2017) beside major circulating 1.1 genogroup in India and south-Asian countries. Previous studies conducted on CSFV isolates in domesticated pigs also confirmed that outbreaks in north east region were not from wild pigs but from domesticated pigs alone (Rajkhowa *et al.* 2014). However, genogroups 2.1 and 2.2 in wild hog and 1.1 genogroup in pigmy hog are circulating in northeastern region of India (Barman *et al.* 2012, Rajkhowa *et al.* 2014,). These studies do have significance with the fact that the north-eastern states does import significant proportions of pigs from the neighbouring countries.

India has a relatively low percent of pork production (7%) and the Indian market for processed pork products is low (Suri 2012). While in the north-east region of India, there is a growing demand of pork as pork consumption is higher than the rest of the country. With repeated outbreaks prevalent in the states (Bett *et al.* 2011), it is difficult to completely get rid of the infection in the states. Therefore, a quantitative risk assessment deemed necessary to assess the risk associated with the import of pigs through these border regions legally.

Risk assessment is defined as the evaluation of the likelihood of entry, establishment and spread of a disease together with the associated potential biological and economic consequences to animal and/or public health (Rausand 2011). Based on the above fact, the quantitative risk assessment was subdivided into three levels, which are as follows:

Selection at the animal level: It is based on the information such as total pig population in the country (www.anivax.com), herd size of pigs in exporting country (Reap 2010), number of pig herds in exporting country and annual undetected herd in exporting country for the 2014–2015 year cycle (Greiner and Paton 2005). The outbreak reports of domestic swine herds in the countries of China, Myanmar and Bhutan were obtained from WAHIS Interface, OIE. PERT (min, mode, max) distribution was used for modeling the expected number of undetected outbreaks of CSFV per year by countries based on number of classical swine fever in the respective countries (Vose 2008). R version 3.2.5 was used to calculate the PERT distribution for this purpose (Martinez- Lopez *et al.* 2008).

Shipment factors level: It was based on information on the number of pig shipments per herd per year from the country of import and the number of pig herds per shipment. These data was obtained from Agricultural and Processed Food Products Export Development Authority (APEDA) for the 2014–2015 year cycle (Table 1).

Risky period level: It was built on the parameter of the number of days CSFV remains undetected in the country of import. The duration was termed as ‘high risk period’

and was based on expert knowledge (Horst *et al.* 1997) which is basically an estimate of the duration in which the disease may arise in countries with poor to moderate surveillance conditions before the disease is detected accordingly. The quantitative modeling on multi-level binomial models calculate the annual probability of CSFV introduction into India by different pathways and allow comparisons between pathways and particularly between countries (Bronsvort *et al.* 2008). The null hypothesis tested here was that there was a threat involved with the introduction of infected live pigs from the neighbouring countries. The final inversion of these predictions will give the number of years before at least one introduction (Bronsvort *et al.* 2008). The expected number of years in which at least 1 CSFV incursion might occur from pig imports from Bhutan were found to be 1022.23 year for groups with herd sizes depending upon the population of pigs present in the country. Whereas, the predicted risks of pig imports from China were found to be 3373.014, 842.82, 421.124 years for groups of 1,000, 4,000 and 8,000 herds respectively. For Myanmar, it was calculated to be 117132.6934, 58565.8363 and 29282.41 years for the different selection of herds accordingly (Table 1). The present study was intended to assess the likelihood of introduction of CSFV-infected or contaminated material in Arunachal Pradesh from the neighbouring countries, viz. Bhutan, Myanmar and China. The results of risk assessment of introduction of CSF into Arunachal Pradesh from neighbouring countries showed that the prevalence estimate of CSF in Bhutan, China and Myanmar were 0.0585, 0.0053 and 0.0098%, respectively, indicating that there is no threat involved in introduction of infection/virus through infected live pigs from the neighbouring countries to Arunachal Pradesh. Hence the null hypothesis was rejected on the same lines.

To the best of our knowledge, this is the first study of its kind to quantify the risk of CSFV introduction into India by legal import of live pigs in the north eastern state of Arunachal Pradesh where the consumption of pork is seen to be the largest (Bett *et al.* 2011). The movement of live

Table 1. The expected number of years in which at least 1 CSFV incursion might occur (in years) for Bhutan, China and Myanmar

Country and pig population in 2015	Herd size	No. of pig herd in exporting country (H)	Expected no. of years when at least 1 CSFV incursion might occur
Bhutan (15373)	20	768.65	1022.234464
	30	512.4333	681.3084621
	40	384.325	510.8453928
China (482980000)	1000	482980	3373.014059
	4000	120745	842.8230328
	8000	60372.50	421.1242151
Myanmar (10530000)	250	42120	117132.6934
	500	21060	58565.8363
	1000	10530	29282.40771

animals is certainly one of the main routes for disease introduction and in order to minimize risks related with animal trade, OIE and other international organizations are continuously stressing the need to develop risk assessments aimed at preventing and minimizing the potential introduction of diseases into free areas (OIE – World Organization for Animal Health 2018). Many possible routes of transmission which may contribute to the spread of CSF between herds have been suggested, the most common being movement of infected pigs. The structure of livestock population in a country is subjected to driving forces that alter veterinary and economic risks of contagious livestock diseases (De Vos *et al.* 2004). It is important to highlight that other pathways such as illegal import of pigs or pig products, movements of wild boar or introduction of fomites or ticks from infected areas, which may pose greater risks, were not considered in this study, mainly because of the lack of quantitative information. Another limitation could be because the movement of contaminated lorries, contaminated swill feeding and by people which were not included as a variable in the framework of the study. If geographical areas and time periods at highest risk of CSFV introduction are identified it can help update and improve the effectiveness of the surveillance programs for the prevention and control of potential CSFV incursions into India. Insight into changes in this structure is thus important for veterinary contingency planning and future policy implications.

SUMMARY

The aim was to assess the likelihood of an introduction of CSFV-infected or contaminated material through pathways of importance to the swine population by quantifying the volume of trade and scale of movement in Arunachal Pradesh sharing international borders with Bhutan, Burma and China. A binomial-probability model was employed to assess the annual probability of virus introduction based on the factors such as outbreak reports of CSF in these countries of import and their corresponding prevalence of infection along with subsequent import activities. The expected number of years, in which at least 1 CSFV incursion might occur from importation of live pig from Bhutan were 1022.23 years. Whereas, the predicted risks from pig imports from China were 3373.014, 842.82, 421.124 years for groups of 1,000, 4,000 and 8,000 herds respectively. For Myanmar, it was calculated to be 117132.6934, 58565.8363 and 29282.41 years for the different selection of herds accordingly. From the above results, it can be inferred that there is no threat for introduction of CSFV into Arunachal Pradesh via the neighbouring countries of Bhutan, China and Myanmar barring the illegal movement/importation of live pigs.

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