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Quantitative risk assessment of entry of contagious bovine pleuropneumonia through live cattle imported from northwestern Ethiopia

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ABSTRACT

Contagious bovine pleuropneumonia (CBPP) is a highly contagious bacterial disease of cattle caused by *Mycoplasma mycoides* subspecies *mycoides* small colony (SC) bovine biotype (MmmSC). It has been eradicated from many countries; however, the disease persists in many parts of Africa and Asia. CBPP is one of the major trade-restricting diseases of cattle in Ethiopia. In this quantitative risk assessment the OIE concept of zoning was adopted to assess the entry of CBPP into an importing country when up to 280,000 live cattle are exported every year from the northwestern proposed disease free zone (DFZ) of Ethiopia. To estimate the level of risk, a six-tiered risk pathway (scenario tree) was developed, evidences collected and equations generated. The probability of occurrence of the hazard at each node was modelled as a probability distribution using Monte Carlo simulation (@RISK software) at 10,000 iterations to account for uncertainty and variability. The uncertainty and variability of data points surrounding the risk estimate were further quantified by sensitivity analysis. In this study a single animal destined for export from the northwestern DFZ of Ethiopia has a CBPP infection probability of 4.76×10^{-6} (95% CI = 7.25×10^{-8} 1.92×10^{-5}). The probability that at least one infected animal enters an importing country in one year is 0.53 (90% CI = 0.042 – 0.97). The expected number of CBPP infected animals exported any given year is 1.28 (95% CI = 0.021 – 5.42). According to the risk estimate, an average of 2.73×10^{6} animals (90% CI = 10,674 – 5.9×10^{6}) must be exported to get the first infected case. By this account it would, on average, take 10.15 years (90% CI = 0.24 – 23.18) for the first infected animal to be included in the consignment. Sensitivity analysis revealed that prevalence and vaccination had the highest impact on the uncertainty and variability of the overall risk.

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1. Introduction

It is stated in the OIE's Terrestrial Animal Health Code, Chapter 4.3. (OIE, 2014b) that "Establishing and maintaining a disease free status throughout the country should be the final goal for OIE members. However, given the difficulty of establishing and maintaining a disease free status for an entire territory, especially for diseases the entry of which is difficult to control through measures at national boundaries, there may be benefits to a member in establishing and maintaining a subpopulation with a distinct health status within its territory. The Code further states that subpopulations may be separated by natural or artificial geographical barriers. . .".

A feasibility study report (FAO, 2005) on the establishment of livestock disease free zone (DFZ) in Ethiopia states that "the development of DFZ may be particularly difficult in pastoral areas but can be considered in the highland areas where diseases challenges are less severe". Based on this recommendation, the Epidemiology and Disease Control Team of the Department of Veterinary Services proposed the establishment of a DFZ in the northwestern region of Ethiopia (MOARD, 2005). The ministry had accepted the initiative to which a financial source was sought for implementation. The objectives of the venture are to eradicate foot and

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mouth disease, improve animal health services, and control CBPP in the zone to promote export trade of livestock and their products. The northwestern region was selected because of absence or low prevalence of transboundary animal diseases (TADs) and their minimal spread, sedentary farming system, better veterinary service delivery, and presence of natural barriers that can limit illegal livestock movement. The DFZ is well separated from neighboring regions by large rivers, which include the Blue Nile, Tekeze, and Siemen Mountain chains. The depth of the Blue Nile canyon measures 1.6 kms (0.994 miles) in the northwestern Ethiopian Plateau (Gani and Abdelsalam, 2006). The Tekeze river canyon is the biggest in Africa and one of the deepest in the world, at some points having a depth of over 2 kms (1.24 miles) (Hoering, 2006).

The international trade of livestock or their products requires informed decisions regarding hazards posed by infectious agents to the importing country. Several trade-restricting diseases are prevalent in Ethiopia. One such disease in the proposed DFZ is contagious bovine pleuropneumonia (CBPP). CBPP is a highly contagious bacterial disease caused by *Mycoplasma mycoides* subspecies *mycoides* small colony (SC) bovine biotype (MmmSC) (Nicolet, 1996; Nicholas and Bashiruddin, 1995), a member of the *M. mycoides* cluster (Manso-Silván et al., 2009) with only one serotype (Geering and Amanfu, 2002). Under natural conditions, *Mmm*SC affects only ruminants of the *Bos* genus, which includes the taurine and zebu cattle; human beings are not susceptible (OIE, 2008; FAO, 2002; Provost et al., 1987; Radostits et al., 2006). CBPP is transmitted through inhalation of infective droplets from acute cases and active chronic carriers. This needs close and repeated contacts between infected and susceptible cattle (Lesnoff et al., 2004a). There is no evidence of indirect transmission through fomites as *Mmm*SC does not persist in the environment (OIE, 2008). Animals affected in the acute stage show obvious respiratory signs of cough, difficulty in breathing, and nasal discharge, accompanied by death in half of the affected cases (FAO, 2002; Radostits et al., 2006).

CBPP has been known to occur in Europe since the 16th century but it gained a world-wide distribution only during the second half of the 19th century because of the increased international trade in live cattle (Masiga et al., 1996; Provost et al., 1987). It was subsequently eradicated from many countries by the beginning of the 20th century through stamping-out policies (Thiaucourt et al., 2000). However, it is still widely prevalent in many parts of Africa (Masiga et al., 1996; Provost et al., 1987). The disease commonly occurs in southern and western parts of Ethiopia, with prevalence of 32% in Konso and Derashe Districts (Dejene, 1996), 17% in East Wellega and Illubabor, and 48% in West Wellega zones (Desta, 1997). In the northwestern region of Ethiopia its occurrence is rare; at the southern periphery of the DFZ there was one outbreak in 2003, and two more outbreaks in 2004 and 2005 (MOARD, 2010a) (Fig. 1). During an outbreak CBPP control program involves vaccination campaigns using attenuated *Mmm*SC strains T1/44 and sero-surveillance (MOARD, 2010a; Teshale, 2005).

Ethiopia is promoting export trade of livestock and their products and is taking initiatives to control TADs. One of the two proposed DFZ is located in the northwestern highland region of Ethiopia. The other is in the southern pastoral areas of the country. The Ethiopian Ministry of Agriculture is actively pursuing implementation of the DFZ although there is a concern, as for many other TADs, that it might be difficult to establish and maintain CBPP-free status within populations. Failures of maintaining animal movement control, vaccination, quarantine, and surveillance often lead to the risk of introduction of CBPP into importing countries. Quantitative Risk Assessment (QRA) methodology can provide an objective, transparent, and internationally accepted means for evaluating the risks involved (Yu et al., 1997). By using standard epidemiological procedures, QRA methodology helps to identify hazard and risk scenarios at each step in the process. Furthermore, mathematical and computing methods are used to estimate the magnitude of the risks as regard to the likelihood of entry, establishment, or spread of disease (Lammerding and Paoli, 1997; Murray, 2002). The methodology is frequently applied for assessing animal health risks associated with importation of animals (Carpenter et al., 1998; Morley, 1993) and animal products (Asseged et al., 2012a,b; Sutmoller and Wrathall, 1997; Yu et al., 1997), with an objective of providing measurable scientific data to regulatory authorities.

The key steps in QRA methodology have been described (Miller et al., 1993). In this study, quantitative import risk assessment methodology was applied to assess the likelihood of entry of CBPP infected animals into an importing country through live cattle exported from the proposed DFZ of northwestern Ethiopia (OIE, 2014a). To assess this likelihood computer generated simulation models were developed. The risk was assessed in relation to CBPP prevalence in the area, prevailing animal health inspection service, and sanitary management of export cattle. The model examined the probability of introduction of CBPP infected cattle into an importing country.

2. Material and methods

2.1. Study area and population

The study area is located in the northwestern highlands of Ethiopia, covering about 198,000 square kms that stretches across 77 Districts in Benshangul Gumuz, Amhara, and Tigray Regional States. The total cattle population is estimated at 9.6 million out of which 7.3% is slaughtered annually. About 60% of the slaughtered cattle are for domestic consumption. Between 255,000 and 280,000 heads of cattle are available for export every year (MOARD, 2005). By far the majority of cattle are indigenous breeds kept under extensive communal grazing with an average herd size of 3.7 (Asfaw and Jabbar, 2008). Animals are sold on particular days of the week at designated open markets located near towns supplied with major roads. The study area is shown on a map produced using ArcGIS 10.3 for Desktop software (Esri, 2014, Redlands, CA) (Fig. 1).

2.2. The initiating event, the risk question, and assumptions made

The initiating event for this risk assessment was the export of live cattle to the Middle East and parts of Europe from northwestern DFZ of Ethiopia. The risk question was phrased as: What is the likelihood of entry of CBPP into an importing country through the export of cattle from the northwestern DFZ of Ethiopia? The question presumed that the DFZ is physically isolated, there are demonstrable efforts to prevent TADs, and efficient animal health surveillance is in place to detect outbreaks. It was further assumed that animals destined for export would be serologically negative, vaccinated, and quarantined for two months. Thus, any likelihood of release of the CBPP agent would be ascribed to failures of a series of mitigations, including surveillance, animal health inspection, serological test, vaccination, and quarantine, which are designed to detect an infected animal and consequently stop it from being exported.

2.3. Development of the scenario tree

Based on OIE's provision that member states may establish subpopulations with a distinct health status, basic epidemiological principles were applied to develop structured knowledge base with regard to entry of CBPP through live cattle import. Based on the knowledge base, a scenario tree (Fig. 2), represented by risk-associated events (nodes 1–6) and connectors (yes/no), was developed to determine conditions (with associated probabilities) that could lead to the introduction of CBPP. In our case, nodes were

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