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Breaking the chain of zoonoses through biosecurity in livestock

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ABSTRACT

Increases in global travel, trade and urbanisation are leading to greater incidence of zoonotic disease, and livestock are often a key link in the spread of disease to humans. As such, livestock vaccination strategies, as a part of broader biosecurity solutions, are critical to both animal and human health. Importantly, approaches that restrict infectious agents in livestock, not only protects their economic value but should reduce the potential for spill over infections in humans. Biosecurity solutions to livestock health can take a number of different forms and are generally heavily weighted towards prevention of infection rather than treatment. Therefore, vaccination can provide an effective component of a strategic approach, particularly as production economics dictate the use of cost effective solutions. Furthermore, in an evolving global environment there is a need for vaccines that accommodate for lower socioeconomic and rapidly emerging zoonotics.

1. Introduction

As the world becomes more interconnected, increases in global exchange of goods and the movement of people between countries is reducing the ability for many nations to use their borders to maintain biosecurity [1]. Furthermore, increasingly intensive livestock rearing is enhancing the impact of trans-boundary pests and pathogens (Fig. 1). Added to this, is the suggestion that environmental changes may be supporting the geographic spread of disease vectors into new habitats. For example, it has been suggested that climate variations may potentially expand the breeding areas for the *Culex* mosquito, the vector for West Nile Virus (WNV), which already poses a health risk in tropical areas, to more populated regions [2]. Taken together these changes all increase the risk of zoonoses, which is currently estimated to cause >2 million fatalities each year [3,4]. Of particular concern are geographical areas where population growth is high, ecologically disruptive development is under way and there is significant human and wildlife/livestock overlap leading to a higher risk of zoonotic transmission [5]. Wildlife play a significant role in the transmission of infectious disease to livestock populations, and due to the close interaction of humans and livestock, these pathogens can be transmitted to humans. Additionally, the increased frequency and proximity of these interactions increases the potential for spill over and adaptation to a human host. Avian influenza virus (AIV), WNV and Hendra virus (HeV) infections are among the many examples where wildlife have transmitted disease to people through livestock [6], and some of these have very high mortality rates in humans [7]. As approximately 75% of newly emerging infectious diseases are considered to be zoonotic events, there needs to be a much greater emphasis on controlling infectious diseases in wildlife and livestock in order to prevent an impact on human health [5]. This type of coordinated effort has great potential to reduce both animal as well as human infection [8]. Effectively addressing emerging and endemic zoonotic diseases requires adequate health infrastructure that recognizes the environmental, epidemiological, and social drivers of disease transmission. There is a growing view that a One-Health approach, which includes vaccination strategies, will be crucially important for our preparedness for the next zoonotic pandemic [9,10].

2. The impact of livestock biosecurity breaches

The livestock industry plays a significant role in the economic development of many countries. Consequently, exotic animal diseases not only threaten agricultural productivity but also have far-reaching impacts on the broader economy. Productivity losses through depopulation of infected animals as well as the loss of production capacity are often exacerbated by expenditure on disease control strategies and foregone future revenues due to market trade restrictions [11]. Export-focused agricultural industries thrive on maintaining a disease-free status as it is vital for access to lucrative international export markets. In addition to being economically disruptive, livestock diseases can also pose a serious

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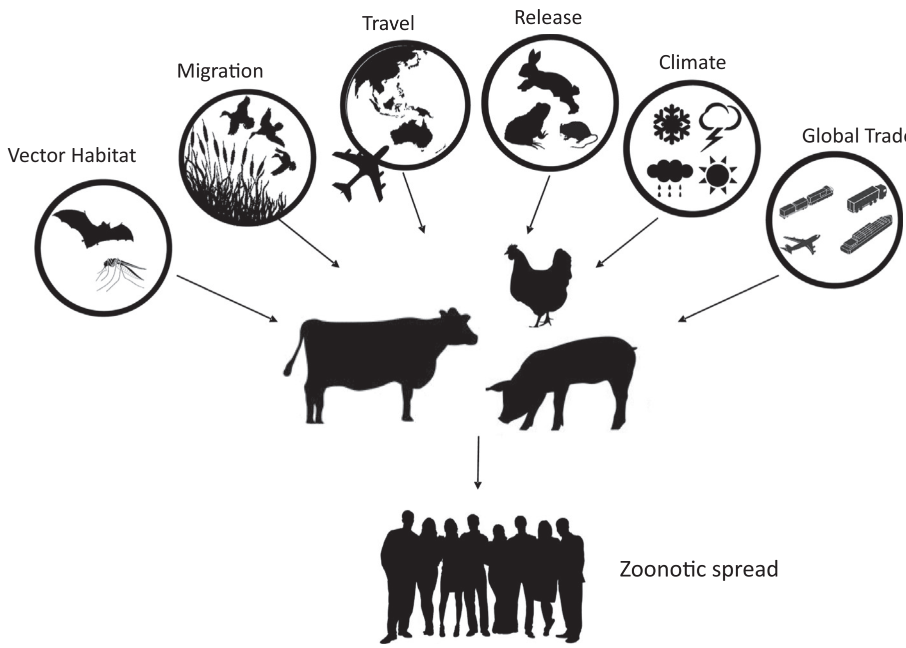

Fig. 1. The impact of a changing world on livestock disease and zoonotic spread. A number of factors are contributing to an increased threat of pandemic outbreak. The most likely source of this outbreak will be through a livestock species due to the intensive rearing of livestock and the close interaction between humans and livestock. Changes to the way we trade, travel and develop the world around us are leading to changes in bird and pest migration as well as changing the location of disease vectors.

threat to human health. Furthermore, AIV outbreaks represent a prime example of how close proximity to infected livestock can cause increased incidence of zoonosis. Recently, a number of Asian countries have unfortunately been a centre for the re-assortment of AIV, partly due to the abundance of live bird markets and environmental conditions [12]. The transmission and reassortment of highly pathogenic avian influenza (HPAI) has led to the culling of millions of animals [13] and sparked significant public health concerns owing to the high mortality associated with outbreaks. The H5N1 HPAI virus has spread through East Asia and as far as Europe and Africa through wild bird migration [14], causing a sustained infection in wild birds, domestic poultry and a high mortality infection in humans [15]. Culling of infected animals is one of the most effective control measures following an outbreak, however, this practice is associated with several ethical and economic complications [16]. In 2002 a combination of culling and vaccination was successfully used to contain an outbreak of H5N1 influenza in Hong Kong [17]. During this outbreak significant depopulation was undertaken, however, it was followed by a second outbreak where additional measures were required to reduce the impact including isolation, vaccination and sanitation, ultimately bringing an end to the spread of disease. Nevertheless, further outbreaks of H5N1 avian influenza continued through Asia and the world resulting in the culling of hundreds of millions of birds and devastating economic impacts for farmers [18]. For example, the cost of culling of birds in Hong Kong in 2002 and 2004 was predicted to be >US$22 billion. Although seen to be an effective measure of biosecurity, many questions have been raised about the efficacy of these 'stamping out' practices. Shim and Galvani (2009) undertook a mathematical assessment of mass culling with respect to avian influenza and showed although providing a short term benefit there are long term repercussions on the immunological fitness of the animals as natural selection is obstructed as well as a bias towards increased virulence of the virus [19]. In many circumstance, mass culling is an expensive exercise due to the loss of livestock and the cost of waste management. Despite increased biosecurity measures the number of human HPAI cases has risen dramatically over the last 15 years (Fig. 2), an observation which may in part be attributed to increased surveillance and/or changing environmental conditions. As such, it would appear that approaches that focus on preventative biosecurity, such as vaccination, have far more positive outlook.

WNV is a mosquito-borne flavivirus which causes encephalitis in its dead-end hosts: humans and horses [20]. Although the infectious agent was isolated in 1937 [21], WNV was in many ways not considered a critical animal or public health concern until the 1999 outbreak in the Unites States [22]. Since then, WNV has been the cause of outbreaks and sporadic cases in Europe [23] including 17 human cases of the disease in Italy [24] and the 2010 outbreak in Greece with 17% mortality rate [25]. Furthermore, approximately 900 cases of equine encephalitis were reported in Australia in 2011 [26] and recently, 139 cases of human WNV infection were confirmed in Texas in 2014 [27]. These observations underscore the importance of implementing WNV control programs and the inclusion of vaccination strategies. Another zoonotic agent that has had a significant impact associated with horses is HeV, a paramyxovirus that has spilled over from horses into humans with very high mortality [28]. HeV is thought to infect horses through the urinary secretions of its reservoir host the *Pteropus* bat and currently no evidence exists of direct infection from bats to humans [29]. Although the number of human cases is low (7 with 4 fatalities) for this emerging infectious disease, there have been 94 confirmed cases (until June 2015) of equine HeV infection in Australia with an 89% mortality rate [30]. This disease has had far reaching impacts on the Australian horse industry primarily due to movement restrictions imposed by quarantine to maintain appropriate biosecurity.

In addition to viruses, zoonotic bacterial diseases also exert a significant burden on the livestock industry and public health. *Mycobacterium bovis* (*M. bovis*) is a member of the *Mycobacterium tuberculosis* complex that has adapted to infect different animal hosts, including humans, and is the most common cause of tuberculosis (TB) in livestock. Bovine TB is estimated to infect >50 million cattle worldwide with annual economic costs of ~$3 billion [31]. Zoonotic TB in humans due to *M. bovis* infection generally

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