Preventive Veterinary Medicine 145 (2017) 49–66

Contents lists available at ScienceDirect

Preventive Veterinary Medicine

journal homepage: www.elsevier.com/locate/prevetmed

Risk assessment of the entry of canine-rabies into Papua New Guinea via sea and land routes

Victoria J. Brookes[a,*], Andy Keponge-Yombo[b], David Thomson[b], Michael P. Ward[a]

[a] Sydney School of Veterinary Science, Faculty of Science, The University of Sydney, 425 Werombi Road, Camden, NSW 2570, Australia
[b] National Agriculture Quarantine and Inspection Authority, PO Box 741, Port Moresby, National Capital District, Papua New Guinea

ARTICLE INFO

Article history:
Received 12 August 2016
Received in revised form 20 May 2017
Accepted 13 June 2017

Keywords:
Rabies
Risk assessment
Papua New Guinea
Sobol
Global sensitivity analysis

ABSTRACT

Canine-rabies is endemic in parts of Indonesia and continues to spread eastwards through the Indonesian archipelago. Papua New Guinea (PNG) has a land border with Papua Province, Indonesia, as well as logging and fishing industry connections throughout Asia. PNG has a Human Development Index of 0.505; therefore, an incursion of canine-rabies could have devastating impacts on human (7.5 million) and animal populations. Given the known difficulties of rabies elimination in resource-scarce environments, an incursion of rabies into PNG would also likely compromise the campaign for global elimination of rabies. A previous qualitative study to determine routes for detailed risk assessment identified logging, fishing and three land-routes (unregulated crossers ["shopper-crossers"], traditional border crossers and illegal hunters) as potential high risk routes for entry of rabies-infected dogs into PNG. The objective of the current study was to quantify and compare the probability of entry of a rabies-infected dog via these routes into PNG and to identify the highest risk provinces and border districts to target rabies prevention and control activities.

Online questionnaires were used to elicit expert-opinion about quantitative model parameter values. A quantitative, stochastic model was then used to assess risk, and parameters with the greatest influence on the estimated mean number of rabies-infected dogs introduced/year were identified via global sensitivity analysis (Sobol method). Eight questionnaires – including 7 online – were implemented and >220 empirical distributions were parameterised using >2900 expert-opinions. The highest risk provinces for combined sea routes were West Sepik, Madang and Western Province, driven by the number of vessels and the probability of bringing dogs. The highest risk border districts for combined land routes were Vanimo-Green River and South Fly, driven by the number of people crossing the border and the number of dogs (with hunters). Overall, the risk posed by land routes was much higher than the risk of rabies introduction by sea routes.

This study provides a foundation to develop targeted border control measures, surveillance and response strategies for canine-rabies for the highest risk routes and regions in PNG. Sensitivity analysis using the Sobol method played a key role in this study and directed further data collection to refine risk estimates. The ease of expert-elicitation using online methods demonstrates the feasibility of using such methods for animal and human disease surveillance in PNG.

1. Introduction

Canine-rabies continues to spread through the eastern Indonesian archipelago, most recently to the Tanimbar and Babar Islands (2010 and 2011 respectively) and Kisar Island (2013) in southern Maluku Province, Indonesia (Amaral et al., 2014; Ward and Hernandez-Jover, 2015). Although sources have not been conclusively identified, introduction of rabies onto previously free islands is attributed to the local movement of dogs facilitated by human activities such as fishing and migration (Windiyaningsih et al., 2004; Putra et al., 2013). This hypothesis is supported by phylogenetic analysis demonstrating a cluster of related Lyssavirus genotype 1 dog isolates from the eastern Indonesian islands of Kalimantan, Sulawesi and Flores, suggesting that these incursions have a common origin (Susetya et al., 2008). For the regional control

Abbreviations: PNG, Papua New Guinea; NAQIA, National Agriculture Quarantine and Inspection Authority; TBC, traditional border crosser; PI, prediction interval; GSA, global sensitivity analysis; SI, sensitivity index; HDI, Human Development Index.

* Corresponding author.
E-mail address: victoria.brookes@sydney.edu.au (V.J. Brookes).

http://dx.doi.org/10.1016/j.prevetmed.2017.06.011
0167-5877/

of rabies, in addition to efforts to eliminate rabies from infected Indonesian islands, efforts are also needed to maintain rabies freedom in neighbouring Oceanic countries – including Timor Leste, Papua New Guinea (PNG) and Australia – by targeting border control measures, surveillance and response strategies for routes and regions that have the highest probability of entry of a rabies-infected dog (Amaral et al., 2014; Sparkes et al., 2015; Brookes and Ward, 2016).

Prevention, early detection and elimination of a canine-rabies incursion – through effective border control measures, surveillance and response strategies – are of critical importance to PNG. Although the gross domestic product of PNG has grown exponentially in the last decade, the human development index (HDI) is low (0.505, ranked 158th in the world). Less than 13% of the 7.5 million human population is urban and in 2009, 40% of the population lived below the national poverty line (http://data.worldbank.org/country/papua-new-guinea, http://hdr.undp.org/en/countries/profiles/PNG, accessed 24/05/16). Resources to respond to a canine-rabies incursion are therefore limited, and access to healthcare for the majority of the population is logistically difficult and expensive, or even impossible, in many rural communities. Consequently, a rabies incursion in PNG could have a low chance of elimination if not detected quickly; this would have a major impact on human and animal health.

Risk assessment can be used to identify the highest risk routes and regions to which border control measures, surveillance and response strategies should be targeted. Although previous studies have quantitatively assessed the risk of introduction of rabies (Jones et al., 2005; Napp et al., 2010; Ramnial et al., 2010; Weng et al., 2010; Goddard et al., 2012), quantitative data is difficult to access in PNG; qualitative risk assessment might seem a more feasible option. However, the information gained from sensitivity analysis of model output to quantitative model inputs can be as important as the overall outputs of the model itself (Saltelli and Annoni, 2010), making the use of quantitative risk assessment advantageous and worth pursuing. A benefit of sensitivity analysis when assessing the risk of entry of a rabies-infected dog is identification of factors that should be targeted by border control measures. For example, Weng et al. (2010) found that the country of origin – in this case the Philippines – most influenced risk of entry of rabies into Taiwan, and Jones et al. (2005) found that levels of compliance with import regulations (for example, vaccination and serological testing) and the number of imported animals most influenced the probability of rabies introduction into the UK from Morocco. Another benefit of sensitivity analysis is identification of parameters that most influence precision of risk estimates. For example, in data and resource scarce environments such as PNG, expert-opinion or assumptions based on the plausibility of findings from other studies can be used to parameterise risk assessments. Assessment of the effect of uncertainty regarding these parameters using sensitivity analysis can help to direct scarce resources for data collection to reduce uncertainty and refine risk estimates so that efforts to prevent and detect incursions can be better targeted.

PNG has an 820 km land border with Papua, Indonesia, and sea borders with Australia, the Federated States of Micronesia and the Solomon Islands. Papua Province, Indonesia and these Oceanic countries are reported canine-rabies free. However, given the length of the PNG–Papuan border, as well as the cultural links and proximity of rabies-endemic regions in Indonesia to Papua Province, it could be assumed that the land border might pose the highest risk of entry of a rabies-infected dog. However, PNG has well-developed logging and fishing industries that attract vessels from all regions of Asia as well as neighbouring Oceanic countries. A previous expert-opinion exercise using a rapid-screening method identified these sea routes as well as three land routes – unregulated "shopper-crossers", traditional border crossers (TBCs) and illegal hunters – as potential high-risk pathways for entry of canine-rabies into PNG (Brookes and Ward, 2017). Therefore, the objective of this risk assessment was to quantify and compare the probability of entry of a rabies-infected dog via sea and land routes into PNG to identify the coastal provinces and border districts at highest risk of entry of a rabies-infected dog. Online questionnaires were used to elicit expert-opinion about model parameters. Global sensitivity analysis (GSA) using the Sobol method was used to identify parameters with the greatest influence on the estimated mean number of rabies-infected dogs introduced/year. In addition to expert-opinion elicitation of quantitative distributions for use in the risk assessment, qualitative data was collected both within questionnaires and using an online discussion site and used to provide background information relevant to the risk assessment. We present the results of the risk assessment, and also discuss the novel use of online expert-opinion elicitation in a low HDI country and Sobol GSA in the context of biosecurity risk assessment. The findings of this risk assessment and sensitivity analysis will be used to develop targeted border control measures, surveillance and response strategies for canine-rabies to the highest risk routes and regions in PNG.

2. Materials and methods

2.1. Risk assessment scenarios and simulation

Risk assessment pathways were identified based on findings in a previous study (Brookes and Ward, 2017). Sea-routes included in this risk assessment were associated with logging and commercial fishing – both legal and illegal pathways – and illegal coastal fishing. The risk assessment for each route considered a scenario in which a vessel leaves its port of origin carrying one or more dogs and either docks in PNG or transfers dogs to a PNG-origin vessel which returns to port in PNG. The vessel might not be inspected sufficiently thoroughly to detect dogs. If a dog is rabies-infected (dependent on the region of origin and prevalence of rabies) and has survived the journey, there is a probability that it disembarks the vessel and enters PNG. This probability might depend on whether the dog is in the clinical phase of rabies infection (appears healthy or sick). Each entry was considered a unique event to account for vessels and dogs that enter PNG more than once each year. Fig. 1 illustrates a generic scenario-tree describing the entry of rabies-infected dogs via these routes.

Land-routes included in this risk assessment were associated with unregulated shopper-crossers, illegal hunters and traditional border-crossers (TBCs). Unregulated shopper-crossers are people who cross the border for trade purposes without quarantine checks at the border post (Wutung in West Sepik Province). Traditional border crossers are people who have cultural and family links across the PNG-Papua border and cross for traditional reasons such as family events, hunting or maintaining small plots of agricultural land for personal use. Illegal hunters include anybody who is hunting for commercial purposes, as well as those who are hunting for their own food and cannot be classified as TBCs. The risk assessment for land-routes was similar to sea-routes and considered the following scenario (Fig. 2). A person undertaking activities associated with one of the three land routes is travelling from Papua to PNG with one or more dogs. The person might have travelled directly with dogs from a rabies-endemic region (for example, a rabies-endemic Indonesian island), or might have received the dogs from a rabies-endemic region. Consistent with sea-routes pathways, each entry was considered a unique event to account for people and dogs that enter PNG more than once each year. If a dog is rabies-infected, survives the journey, and appears healthy, the dog enters PNG. We assumed that if a dog appeared sick prior to entry into PNG, the dog would be discarded in Papua. Due to the nature of these activities,