Brucella abortus surveillance of cattle in Fiji, Papua New Guinea, Vanuatu, the Solomon Islands and a case for active disease surveillance as a training tool

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Abstract There have been no surveys of the cattle population for brucellosis in Pacific Island Countries and Territories (PICTs) for more than 15 years. This study used disease surveillance as a capacity building training tool and to examine some of the constraints that impede surveillance in PICTs. The study also developed and implemented a series of surveys for detecting antibodies to *B. abortus* in cattle in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands contributing to OIE requirements. The findings indicated; lack of funds, lack of technical capacity, shortage of veterinarians, high turnover of in-country officials and lack of awareness on the impacts of animal diseases on public health were constraining active disease surveillance. During the development and implementation of the surveys, constraints highlighted were; outdated census data on farm numbers and cattle population, lack of funds for mobilisation of officials to carry out the surveys, lack of equipment for collecting and processing samples, lack of staff knowledge on blood sampling, geographical difficulties and security in accessing farms. Some of the reasons why these were constraints are discussed with likely solutions presented. The detection surveys had the objectives of building capacity for the country officials and to demonstrate freedom from brucellosis in cattle for PNG, Vanuatu and the Solomon Islands. PNG, Vanuatu and the Solomon Islands all demonstrated freedom from bovine brucellosis in the areas surveyed using the indirect ELISA test. Fiji had an outbreak of brucellosis and the objective was to determine its distribution and prevalence on untested farms. The Muaniweni district surveyed during the training had a 95% Confidence Interval for True Prevalence between 1.66 and 5.45%. The study showed that active disease surveillance could be used as a tool for training officials thus improve surveillance capacity in resource poor countries.

Keywords *B. abortus* Prevalence Animal disease surveillance Training

Introduction

Very few Pacific Island Countries and Territories (PICTs) in the South West region of the Pacific are members with World Organisation for Animal Health, i.e. the Office International for Epizooties (OIE), non-members are not are not obliged to submit reports on animal disease occurrence. At the moment, apart from Australia and New Zealand (NZ), only Fiji, Papua New Guinea (PNG), Vanuatu, New Caledonia (NC) and the Federated States of Micronesia (FSM) are OIE members (OIE, 2015a). Remaining a non-member of OIE could be interpreted by other PICTs that they do not have a need to carry out active animal disease surveillance to verify their disease status. However active animal disease surveillance is required irrespective of OIE status by importing countries to verify the disease status of animals or animal products of the exporting country (OIE, 2015b).

Countries such as Fiji, PNG, Vanuatu and the Solomon Islands all have tropical conditions which can have extreme temperatures, humidity and rainfall, giving rise to the habitats for vectors of disease. In addition, drivers for new and re-emerging diseases such as translocation, overcrowding, socio-economic upheaval and contact with naïve populations are common in most Pacific Island countries and Territories and creates an environment that increases the risks for disease transmission and spread (Gummow, 2010). Unfortunately developing countries are often resource limited so are not able to react adequately to disease incursions or to detect them prior to outbreaks occurring (Jakob et al., 2007).

The lack of knowledge and information on diseases in PICTs is also a problem which could lead to the spread of diseases. A recent review of animal disease prevalence in PICTs found that literature was scarce and no longer up to date and there was a need to improve the published knowledge on current animal disease status in PICTs (Brioudes et al., 2014). In addition there is a lack of active surveillance and capacity in PICTs because surveillance is considered a costly operation and difficult to implement when there are no trained officials (FAO, 1999).

The current lack of active animal disease surveillance and capacities therefore are a problem for most PICTs and affects their ability to demonstrate freedom from important diseases required by countries that intend to import animals and animal products. Most training conducted in the region on animal disease surveillance is short course based training usually funded by donor organisations which often lack sustainability once funding ceases and the courses are often theoretical lacking practical aspects. Therefore there is a need to have more innovative ways of training animal health officials on a more sustainable basis (Cokanasiga, 2015).

Cattle farming in PICTs are an important source of meat, milk, weed control and draft power yet little is known about the current status of bovine brucellosis in many of the Pacific Island Countries and Territories (PICTs). Apart from Fiji, no surveys have been carried out for many years and the reasons for this do not appear to have been investigated (Tukana et al., 2015). The re-emergence of brucellosis in cattle in Fiji in 2009, was thought to have partially occurred because there was no active animal disease surveillance to monitor the disease, so when the disease was noticed and reported it had already been well established within the cattle herds in the country (Tukana et al., 2015).

Brucellosis is a highly contagious, zoonotic and economically important bacterial disease worldwide that causes significant economic losses from abortion, reduced milk production, low fertility rates and increased cost of replacing cattle (Ducrotoy et al., 2014). It is one of the most important zoonotic diseases in the world as it can impact human health either through direct contact with infected animals or through the consumption of contaminated milk as well as dairy products and it has the potential to also affect animal health (Muhammad et al., 2011).

Taking into account the need for disease surveillance training and the lack of knowledge of cattle diseases in the PICTs, this study therefore sought to find out the status of bovine brucellosis in PNG, Vanuatu and the Solomon Islands and at the same time use surveillance as a training tool to build capacities in PICTs. In addition the study could be used to identify some of the constraints that impede disease surveillance in PICTs.

Materials and methods

The Food Animal Biosecurity Network Project

A Food Animal Biosecurity Network (FABN) was recently set up for Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands (SI) to make better use of the limited resources and capacity in animal disease surveillance and enhance animal health field and laboratory capability to the Pacific Islands (Gummow, 2014). The work in this article formed part of these objectives and utilised the network as a communication tool to coordinate activities in the countries and to obtain information and facilitate the training and surveys required for this project.

Study areas

Pacific island countries

Pacific Island Countries comprise of 25 nations and territories spread over more than 25,000 islands and islets of the western and central Pacific Ocean. This reflects the great cultural diversity in the region, where some 1,200 languages are spoken, with English and French often being official languages. Pacific Island Countries have been traditionally grouped along racial and cultural lines as Melanesia, Micronesia and Polynesia (Monica and Rhonda, 2011). The Melanesian countries include Fiji, Papua New Guinea, Vanuatu, and the Solomon Islands, which was the study area for this project.

Fiji

Fiji is a Melanesian country and has 300 islands, 109 of which are permanently inhabited. There are two main islands supporting the majority of the total population of 860,623 (Fletcher et al., 2013). The climate consists of a cooling trade wind from the east south-east for most of the year. Maximum temperatures rarely move out of the 31^0C to 26^0C range throughout the year. Annual rainfall on the main island is between 2000mm and 3000mm on the coast and low lying areas and up to 6000mm in the mountains (Fiji Report, 2014). Cattle farming in Fiji is important as it provides a source of protein, milk, income, weed control as well as draft power (FAO, 2016b). The industry is quite large compared to other PICTs with a population of 156, 074 cattle, Fiji does not export any cattle or cattle products due to its infected bovine brucellosis and tuberculosis status (OIE, 2013; Secretariat of the Pacific Communitiy, 2009).

Papua New Guinea

Papua New Guinea (PNG) is the largest and most populated of the countries in the Pacific region with a population of 6.5million people. PNG is predominantly a Melanesian country consisting of more than 600 islands with more than 700 language groups, English, Pidgin and Motu are official languages (Monica and Rhonda, 2011). Cattle farming in PNG is mostly for beef with some exports going to Japan and it is important as it provides protein, milk, income, weed control, and draft power (FAO, 2016b). The industry is quite large, i.e. with a population of 92,000 cattle and a lot of farmers depend on the industry as their livelihood (Secretariat of the Pacific Communitiy, 2009).

Vanuatu

Vanuatu is a 900 kilometre-long, volcanic archipelago that consists of more than 80 islands. Most of the islands are inhabited, and around half are mountainous and densely forested with narrow strips of farming land on the coasts. Vanuatu has a tropical climate with regular, sometimes heavy, rainfall and temperatures average between 26°C and 34°C (World Vision Report, 2015). The role of cattle farming in Vanuatu is quite important to its economy as it is a major exporter of beef compared to the other PICTs and the industry is quite large with a population of 211,152 cattle (Secretariat of the Pacific Communitiy, 2009). Smaller cattle farmers meet the demands for the domestic markets and cattle play an important source of milk, beef, income, weed control, transport and draft power in Vanuatu (FAO, 2016b).

Solomon Islands

The Solomon Islands is the third largest archipelago in the South Pacific with a population of 0.5 million and more than 900 islands. Ninety five percent of the population is of Melanesian ancestry and sixty-three language groups have been identified in the country (Monica and Rhonda, 2011). Cattle farming in the Solomon Islands was an important industry prior to the ethnic conflict from the years 2000-2003 and its cattle population has diminished to 3000 cattle (Secretariat of the Pacific Communitiy, 2009). Small holder cattle production is still viewed as important as it has a role to play in the provision of milk, protein, income as well as for weed control under palm plantations (FAO, 2016b).

Survey development planning

Available literature on cattle population numbers for Fiji, PNG, Vanuatu and the Solomon islands were collected and reviewed to determine the size of the sampling units in those countries. Since population size data were outdated, field missions were organized to those countries to gather information to assist with the development of surveys to detect *B. abortus*. Local knowledge was used to compile information on the latest data on cattle farm numbers, herd sizes, the number of farms likely to be affected with brucellosis as well as the likely prevalence of brucellosis at animal level. Single and multistage random sampling methods were used to develop the surveys for each country to detect brucellosis.

Training of survey teams

Training of the survey teams was necessary to build country official capacity in order to design sampling frames that represented the population that was surveyed as well to effectively carry out the required detection surveys. Those selected for the survey training were frontline officials that would be involved if there was a disease outbreak or in the monitoring of existing diseases.

The breakdown of the 53 country animal health officials were as follows: Fiji (16), PNG (12), Vanuatu (15) and the Solomon islands (10). The qualifications of the animal health officials were a certificate, diploma or bachelor's degree in tropical agriculture from the University of the South Pacific (USP), Fiji College of Agriculture (FCA), Vanuatu Agricultural College (VAC) and the Solomon Islands National University (SINU). The tropical agriculture qualifications received by the animal health officials from those institutions were based more on animal and crop production with very little on animal health.

Training on survey design and the actual development of random sampling frames for the detection of *B. abortus* in cattle was done with the animal health officials, based on local knowledge of the cattle population in those countries. Prior to survey development a presentation on some of the reasons why disease surveillance was important and some methods to implement disease surveillance was given to the country officials. Interactive exercises were then conducted with the group to develop random sampling frames for the selected districts in their countries. The officials were then divided into smaller groups where they developed random sampling frames for their practical surveys in the field to collect blood samples from cattle.

Training also involved the demonstration and practice of collection of blood samples from cattle. Demonstration and discussion was also conducted on processing the blood samples to collect serum, and on storage of the serum in vials, as well as on packing and shipping of the serum to the reference veterinary pathology laboratories in Fiji and PNG.

Sampling strategy

The number of sampling units (farms) and the number of cattle sampled per farm was calculated using a sample size table as well as a random number table. The sample size table was derived using the formula;

n = [l - (l -a)1/D] [N - (D - 1)/2] (Cannon and Roe, 1982) Equation 1

Where (n) was the required number of samples to be collected, (a) was the probability (confidence level) of observing at least one diseased cow in the sample when the disease affects at least D/N in the population, (D) was the number of diseased cattle in the population and (N) was the population size. D/N was set at 5% of the population and hence the survey would be 95% confident of detecting one *Brucella* sero positive cow at a sero prevalence of ≥ 5% (Thrusfield, 1995), (OIE, 2012b). For a single stage random sampling strategy the sampling comprised a list of farms in the area to be sampled. Those farms were randomly arranged and the number of cattle consecutively numbered with the numbers of cattle on each farm following on from the first and so on until the total number of cattle in the area to be sampled was reached. A random number table was then used to generate n random numbers between 1 and N and those numbers were matched with the sampling frames below to determine the numbers of cattle to be sampled on each farm (Cameron, 1999). The selection of animals sampled on each farm was based on a systematic method, e.g. for a sample size of 10 (n) with a population size of 50 (N) cattle, then 50/10 = 5, so every 5^{th} animal was sampled.

Random sampling frames

Fiji

A single stage random sampling strategy was developed with the country animal health officials of the veterinary and livestock services of Fiji. Twenty four farms were included in the sampling frame, which were all the supervised cattle farms (census) in the Muaniweni district of the Naitasiri Province (Borja, 2014). Naitasiri is one of the 14 provinces in Fiji and can be located on the main island Viti Levu, Fig.1a, (Australian National University, 2015). The district had a total population size of 727(N) cattle and it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 56 (n) blood samples were required for the survey (Thrusfield, 1995), (OIE, 2012b). Fifty six random numbers were then generated between 1 and 727 and used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

PNG

In PNG two regions were focused on, i.e. Region 1; were the small and medium farms in the lower Markham valley and Region 2; were the large farms in the upper Markham valley. The Markham valley consisted of 2 districts within the Morobe province (Fig.1b). The Markham valley runs between the cities of Lae and Madang (Macfarlane, 2009). In Region 1, a single stage random sampling strategy was developed where all fourteen farms (census) were sampled by bleeding in conjunction with the National Authority for Agriculture Quarantine and Inspection Authority (NAQIA) animal health officials. This was an opportunity for animal health cadets to practice blood collection methods on cattle as well as correct storage and transport techniques for sending samples to the animal health laboratory in Kila Kila (Port Moresby). The total cattle population size in Region 1 was 4054 (N) cattle and it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 535 (n) blood samples were required for the survey (Thrusfield, 1995), (OIE, 2012a). Five hundred and thirty five random numbers were then generated between 1 and 4054 and these were used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

Region 2 focused on the larger cattle farms in the upper Markham valley. A total of 5 farms existed in that area and a single stage random sampling strategy was developed where all five farms were included (census) in the study. The farms had a population size of 33,000 (N) cattle and it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 294 (n) blood samples were required for the survey (Thrusfield, 1995), (OIE, 2012b). Two hundred and ninety four random numbers were then generated between 1 and 33,000 and these were used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

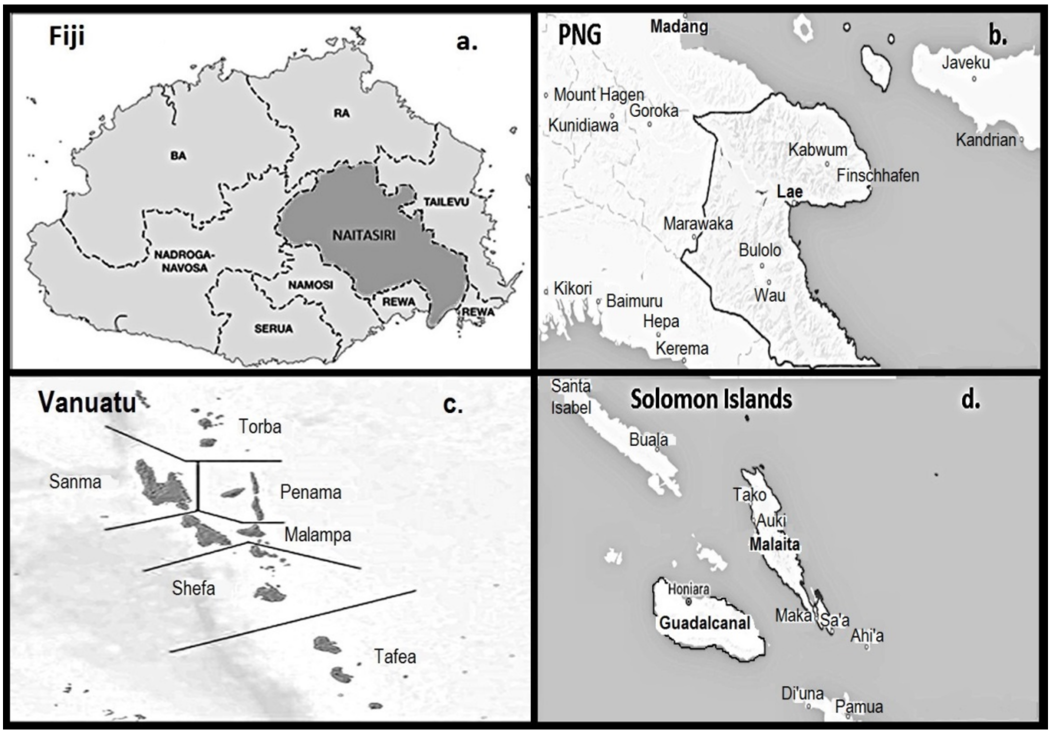

Fig.1 Map of countries surveyed, Fiji (a), PNG (b), Vanuatu (c) and the Solomon Islands (d), (Australian National University, 2015), (Macfarlane, 2009).

Vanuatu

Two islands were focused on in Vanuatu. These were Efate and Santo islands (Fig.1c). On Efate Island, the survey focused on the South East region which is part of the Shefa province. Most of the farms were clustered around the abattoir on Efate and were large, medium and small properties.

On Efate South East region there were a total of 23 farms with a cattle population size of 28,887 (N). A multistage random sampling strategy was developed for this survey. Using the results of the Fiji survey, where 16% of the farms were found to be infected (see 2.5.1.1), it was decided to use 15% as the minimum prevalence for affected farms in the first stage of sampling. Using Equation 1, 13 farms were selected for the survey at the first stage (Mosese, 2014). Stage 2 was based on the selected 13 cattle farms which had a population size of 22,713 ($N_{1)}$ cattle and it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 622 (n) blood samples were required to detect a positive cow at the assumed disease prevalence of 5% (Thrusfield, 1995), (OIE, 2012b). Six hundred and twenty two random numbers were then generated between 1 and 22,713 and used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

On Santo Island, East region, Sanma province, two regions were focused on; these were the small holder farms in the Natawa district as well as the medium and large cattle farms around the district. In Region 1, all the 27 small holder cattle farms (census) with a population size of 401 (N) cattle in the Natawa district were included. A multistage random sampling strategy was developed for this survey, and again it was decided to use 15% as the minimum prevalence for affected farms based on the Fijian survey results. Using Equation 1, 14 farms were selected at the first stage (Kutoslowo, 2014). Stage 2 was based on the selected 14 farms which had a population size of 272 (N_1) cattle, and it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 184 (n) blood samples were required to detect a positive cow at the assumed disease prevalence of 5% (Thrusfield, 1995), (OIE, 2012b). One hundred and eighty four random numbers were then generated between 1 and 272 and used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

For Region 2, i.e. the medium to large cattle holdings, all of the 9 cattle farms were included (census) in a single stage sampling strategy; these had a population size of 26,036 (N) cattle where it was assumed that ≤ 5% of cattle had antibodies to brucellosis. Using Equation 1, 507 (n) blood samples were required to detect a positive cow at the assumed disease prevalence of 5% (Thrusfield, 1995), (OIE, 2012b). Five hundred and seven random numbers were then generated between 1 and 26,036 and used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

Solomon Islands

Two regions were focused on in the Solomon Islands; these were in relation to where most of the cattle farms were located, i.e. the Guadalcanal and Malaita provinces (Fig.1d.). In Region 1, (Guadalcanal province) a single stage random sampling strategy was developed where all of the 4 existing supervised farms (census) were included in the study, these had a population size 435 (N), cattle where it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 90 (n) blood samples were required to detect a positive cow at the assumed disease prevalence of 5% (Thrusfield, 1995), (OIE, 2012b). Ninety random numbers were then generated between 1 and 435 and used to indicate the number of cattle to be sampled on each farm (Cameron, 1999).

In Region 2, (Malaita province) all of the 53 farms (census) with a population size of 689 (N) cattle were included in the study. A multistage random sampling strategy was developed for this survey and it was again decided to use 15% as the minimum prevalence for affected farms based on the results of the Fiji survey. Using Equation 1, 16 farms were selected at the first stage (Atalupe, 2014). Stage 2 was based on the selected 16 cattle farms which had a population size of 330 ($N_{1)}$ cattle and it was assumed that ≥ 5% of cattle had antibodies to brucellosis. Using Equation 1, 291 (n) blood samples were required to detect a positive cow at the assumed disease prevalence of 5% (Thrusfield, 1995), (OIE, 2012b). Two hundred and ninety one random numbers were then generated between 1 and 330 and used to indicate the number of cattle to be sampled on each farm (Cameron, 1999)

Implementation of the surveys

After the development of the random sampling frames, discussions were held with the country field officials on timelines for implementing the *Brucella* detection surveys. As funds were limited in each of the countries, it was decided that the detection surveys should coincide with other in-country animal health and production work. A primary objective of the survey was to encourage countries to be proactive in animal disease surveillance. The blood samples collected were processed to obtain serum which was then stored in serum vials and transported to the veterinary laboratories in Fiji and PNG for testing.

Diagnostic tests

The indirect ELISA was used for testing the serum samples from the surveys for *B. abortus* antibodies using standard procedures (OIE, 2012b). In PNG serum samples collected from the 2 regions were first tested at the veterinary pathology laboratory in Kila Kila in Port Moresby for antibodies to *B .abortus*. To ensure quality control 10% of the samples received and tested at Kila Kila were randomly selected and sent to the veterinary pathology laboratory in Koronivia, Fiji to also test for *Brucella* and the results were compared, i.e. to confirm that the results obtained in PNG were the same as those obtained in Fiji. All the serum samples collected from Vanuatu and the Solomon Islands were tested in Fiji.

Interpreting the survey results

Since the surveys focussed on selected regions where there were no reports of brucellosis outbreaks, there was a possibility that the disease could have been present, but was not detected in the surveys. Equation 2 below was used to interpret the results in the event of a negative result where; (D) was the number of diseased cattle that could still have been potentially present in the given populations for the countries surveyed, (a) was the probability of observing at least one diseased animal in the sample, (n) was the number of samples collected and (N) was the population size.

$D = [1 - (1 - a)^{1/n}) (N - [(n - 1)/2])$ (Cannon and Roe, 1982) Equation 2

Since Fiji had a current outbreak of brucellosis during the period of the study, the true prevalence (TP) was calculated for the selected province surveyed using Equations 3-6.

Apparent Prevalence (AP): Equation 3

AP = Total no.seropositive Brucella cases at a given time/Total population at risk (Thrusfield, 1995)

True Prevalence (TP): Equation 4

$$TP = \frac{AP + Sp - 1}{Se + Sp - 1}$$ (Thrusfield, 1995)

In Eq. (4) above, TP was the true prevalence at farm level, AP the apparent prevalence, Se the test sensitivity, and Sp the test specificity. The Se and Sp values used for the indirect ELISA tests were: Se = 96.0% and Sp = 93.8% (Gall and Nielsen, 2004).

$$\mathrm{Pe} - 1.96\left\{\frac{c}{T}\sqrt{\frac{V}{c(c-1)}}\right\};\mathrm{Pe} + 1.96\left\{\frac{c}{T}\sqrt{\frac{V}{c(c-1)}}\right\}$$

Equation 5

In Eq. (5) above, Pe was the apparent prevalence for the farms in the district surveyed, c the total farms (clusters) in the district. T is the total number of cattle in the district. V was calculated using Eq. (3) (Thrusfield, 1995). Eq. (5) was used to calculate the 95% Confidence Interval (CI) for TP at a district level taking into account the effect of clustering.

$$\mathrm{V} = \mathrm{Pe}^2\left(\sum \mathrm{n}^2\right) - 2\mathrm{Pe}\left(\sum \mathrm{nm}\right) + \left(\sum \mathrm{m}^2\right)$$

Equation 6

In Eq. (6) above, V was the variation that was likely to be taking place between the clusters (farms) in the district, n was the number of Brucella positive cattle on each farm. The V value calculated was then inserted into Eq. (5) to calculate the 95% confidence interval (CI) for TP adjusting for clustering (Thrusfield, 1995).

Eliciting opinion on disease surveillance constraints

A Rapid Rural Appraisal (RRA) method of ranking developed by FAO was used to elicit opinion on the disease surveillance constraints for Fiji, PNG, Vanuatu and the Solomon Islands. RRA is a social science approach that emerged in the late 1970's and had the intention of quickly collecting, analysing and evaluating information on rural conditions and local knowledge (FAO, 2016a).

During the training, the same animal health officials detailed above (see 2.4) were asked to independently list on pieces of paper some of the constraints they faced in relation to animal disease surveillance programs in their countries as well as constraints they thought would impede the development and implementation of disease surveys in their countries. These were then grouped together under the 5 common constraints that had emerged during the discussion with the country officials. Using the RRA method, the animal health officials were then asked to rank the constraints according to the least and most important. Each official's opinion was equally weighted. E.g. in Fiji, since there were 16 officials the total points a constraint could receive was 16 if all officials listed it. Those constraints that had the highest points allocated to them were considered more important than the rest (FAO, 2016a).

Results

Prioritised constraints from group discussions

General constraints affecting active animal disease surveillance programs

In Fiji, 88% of the participants at the training indicated that "Lack of funds" was the most important general constraint that impeded active animal disease surveillance, this was followed by; Lack of technical capacities (69%), Shortage of veterinarians (56%), High turnover of in-country officials (44%) and Lack of awareness on the impact of animal diseases on public health (38%) respectively.

In PNG, 83% of the participants at the training indicated that "Lack of funds" was the most important general constraint that impeded active animal disease surveillance, this was followed by; Lack of technical capacities (75%), Shortage of veterinarians (67%), High turnover of in-country officials (33%) and Lack of awareness on the impact of animal diseases on public health (25%) respectively.

In Vanuatu, 87% of the participants at the training indicated that "Lack of funds" was the most important general constraint that impeded active animal disease surveillance, this was followed by; Lack of technical capacities (67%), Shortage of veterinarians (60%), High turnover of in-country officials (47%) and Lack of awareness on the impact of animal diseases on public health (33%) respectively. In the Solomon Islands 90% of the participants at the training indicated that "Lack of funds" was the most important general constraint that impeded active animal disease surveillance, this was followed by; Lack of technical capacities (60%), Shortage of veterinarians (50%), High turnover of in-country officials (30%) and Lack of awareness on the impact of animal diseases on public health (20%) respectively.

Constraints affecting the development and implementation of the detection survey

In Fiji, 81% of the participants at the training indicated that "Outdated census data on farm numbers and cattle population" was the most important constraint that impeded the development and implementation of surveys, this was followed by; Lack of funds for equipment and mobilisation of officials to carry out the surveys (63%), Lack of experienced staff with the knowledge of blood sampling (50%), Geographical difficulties in accessing farms (25%) and Security difficulties in accessing farms (6%) respectively.

In PNG, 92% of the participants at the training indicated that "Outdated census data on farm numbers and cattle population" was the most important constraint that impeded the development and implementation of surveys, this was followed by; Lack of funds for equipment and mobilisation of officials to carry out the surveys (83%), Lack of experienced staff with the knowledge of blood sampling (50%), Geographical difficulties in accessing farms (66.67%) and Security difficulties in accessing farms (75%) respectively.

In Vanuatu, 80% of the participants at the training indicated that “Outdated census data on farm numbers and cattle population” was the most important constraint that impeded the development and implementation of surveys, this was followed by; Lack of funds for equipment and mobilisation of officials to carry out the surveys (73%), Lack of experienced staff with the knowledge of blood sampling (67%), Geographical difficulties in accessing farms (53%) and Security difficulties in accessing farms (7%) respectively.

In the Solomon Islands, 80% of the participants at the training indicated that “Outdated census data on farm numbers and cattle population” was the most important constraint that impeded the development and implementation of surveys, this was followed by; Lack of funds for equipment and mobilisation of officials to carry out the surveys (70%), Lack of experienced staff with the knowledge of blood sampling (60%), Geographical difficulties in accessing farms (30%) and Security difficulties in accessing farms (10%) respectively.

Brucella detection survey results for Fiji, PNG, Vanuatu and the Solomon Islands

PNG, Vanuatu and the Solomon Islands all returned a negative result from the indirect ELISA test in 2014 (Table 1). However due to the sample sizes, some farms could still have had brucellosis positive cattle but these were not detected during the survey. The proportion of cattle that could potentially have had brucellosis in the areas surveyed using Equation 2 is shown in Table 1.

Fiji had 27 sero positive cattle for *B. abortus* from the indirect ELISA test in the Muaniweni district in the Naitasiri province in 2012 (Table 2). The apparent prevalence (AP) was therefore 3.20% and the 95% confidence interval (CI) for the TP was calculated as 1.66% to 5.45% accounting for the clustering effect between the farms in the district of Muaniweni in Fiji.

Discussion

No surveys for animal disease have been done for more than 15 years in these countries, i.e. the last published survey was in 1999, making the results of this study significant (Martin and Epstein, 1999) (Tukana et al., 2015). This also poses the question why no studies have been done in these countries recently. The major constraint which impeded active animal disease surveillance in these countries are the lack of funds, this was

Table 1 Brucella survey results for PNG, Vanuatu and the Solomon islands (2014).

Country	Pop. Size (N)	No. of samples calculated (n)	No. of samples collected (n)	Indirect ELISA results	Max no. Possible Diseased	Max % cattle that could have Brucella
PNG Region 1	4054	535	535	Negative	21	0.52
PNG Region 2	33000	294	294	Negative	333	1.00
Vanuatu Region 1, Efate Island	22713	622	622	Negative	107	0.47
Vanuatu Region 2, Santo Island (Large farms)	26036	507	507	Negative	151	0.58
Vanuatu Region 3, Santo Island (Small farms)	272	185	185	Negative	3	1.10
Solomon Islands Region1, Guadalcanal	435	90	36	Negative	33	7.59
Solomon Islands Region 2, Malaita	330	291	0	Na	Na	Na

Na- Not available; ELISA- Enzyme-Linked Immunosorbent Assay

Table 2 Brucellosis indirect ELISA prevalence results for the Muaniweni district in Fiji (Viti Levu) in 2012.

			Indirect ELISA results (%) 2012	
Farm codes	**No. cattle tested**	**ELISA +ve Cattle**	**AP**	**TP**
A	76	23	30.26	30.10
B	87	2	2.30	2.14
C	6	1	16.67	16.51
D	32	1	3.13	2.96
E	45	0	0.00	0.00
F	32	0	0.00	0.00
G	10	0	0.00	0.00
H	13	0	0.00	0.00
I	2	0	0.00	0.00
J	13	0	0.00	0.00
K	20	0	0.00	0.00
L	19	0	0.00	0.00
M	30	0	0.00	0.00
N	27	0	0.00	0.00
O	25	0	0.00	0.00
P	11	0	0.00	0.00
Q	27	0	0.00	0.00
R	20	0	0.00	0.00
S	10	0	0.00	0.00
T	121	0	0.00	0.00
U	7	0	0.00	0.00
V	32	0	0.00	0.00
W	25	0	0.00	0.00
X	37	0	0.00	0.00
95% CI for TP for the Muaniweni district on the main island of Fiji = 1.66-5.45				

ELISA – Enzyme-Linked Immunosorbent Assay; AP – Apparent Prevalence; TP – True Prevalence; CI Confidence Interval common across the countries studied. In comparison to developed countries, developing countries are at a disadvantage because of limited skilled human and financial resources and cannot adequately respond to zoonosis outbreaks (Jakob et al., 2007). The next constraint was the lack of technical capacity, this basically means that the frontline animal health officials are not able to develop and implement surveys for the detection or monitoring of animal diseases. Lack of technical capacities are also closely linked to the shortage of veterinarians as well as the high turnover of animal health officials in the Pacific Island Countries and Territories (Jakob et al., 2007).

Many Pacific island countries do not have veterinarians, so frontline animal health officials who have limited livestock knowledge and experience have no one to guide them through animal health issues and in particular identification and containment of zoonotic diseases. The shortage of veterinarians means that there is limited capacity to respond to infectious diseases spreading from animals to humans and because this is quite common in PICTs, efforts are underway to address this problem via training of veterinarians and livestock officials in the Asia and the Pacific region (FAO, 2009).

The shortage of veterinarians is exacerbated by the fact that in-country worker turnover can be quite high in PICTs, i.e. officials tend to move on to jobs that pay better, so the veterinary and livestock divisions are left with either no officials or officials with little knowledge and experience leading to reduced capacities for animal disease surveillance and disease containment.

Lack of awareness on the impacts of animal diseases on public health means that animal disease surveillance are not normally prioritised as important by decision makers, so there is reduced or no technical and financial support at all for such activities. This leaves PICTs vulnerable due to reduced disease surveillance capacities which has resulted due to the lack of public awareness and which increases the risk of re-emerging diseases (WHO, 2007).

During the training and survey development a major constraint encountered was the fact that the agricultural census and survey data for the countries were outdated, this caused difficulties when attempting to develop random sampling frames for the cattle farms that needed to be sampled, this was common across the countries studied. We had to get around this constraint by seeking information from in-country officials who had accurate information on the cattle farms and cattle population as they had been providing those farms with technical assistance (Mosese, 2014). However, the potential for using this information and capturing it for disease surveillance had not been realised.

In regards to training to build capacity, most of the country officials trained had qualifications which were general, i.e. included basics of animal and crop production and those that had basic training in animal health were more theory based and lacked practical aspects, this contributed to the reduced capacities in investigating and containing the spread of animal diseases. The collection of blood samples was also a vital part for the *Brucella* detection survey, even though this was practiced by the officials during the survey, they still needed more practice before going out to the field, this was particularly evident for the Solomon Islands. Practical animal disease surveillance therefore is very important to build capacities in these countries where they are able to carry out surveys on their own to detect and monitor important livestock diseases. This study has improved on that capacity, and an example is Vanuatu who have now conducted a survey for selected livestock diseases in several provinces in 2015 (Puana 2015).

The lack of project and in-country funds was also a constraint during the implementation of the survey, i.e. since funds were limited, the survey for the detection of brucellosis had to be planned to coincide with other field work causing delays in the timeframe for implementation.

The lack of equipment for collecting and processing blood samples was also a major constraint for the countries being surveyed, e.g. the centrifuge had broken down so blood serum could not be separated and blood vacutainers were old and no longer had vacuum in them. This related to the lack of funding as well as technical capacities to plan and procure new items for disease surveillance activities.

The lack of experienced staff with knowledge of blood sampling was also identified as a constraint during the survey, i.e. all the countries surveyed had young officials who took the opportunity to practise collecting blood from cattle, since all the older experienced officials had retired. This created a situation where the amount of blood collected in the vacutainers was low, so it became difficult to obtain sufficient serum for testing. In addition the survey took a longer timeframe to complete as the officials were inexperienced and took a longer time to collect the required blood samples.

Inaccessible geographical locations made it difficult to complete the survey, i.e. some farms that were selected to be sampled just could not be reached easily, due to the unavailability of roads for vehicles, so other options would mean that you would have to travel by boat or by trekking through the forest.

Security was also an issue, i.e. some farms, e.g. in PNG (highlands) were inaccessible as there was ongoing tribal fighting. This meant that the cost of the survey would have increased if we were to collect samples from those areas that were difficult to reach. PNG had a ranking of constraints different to the other countries, i.e. for the development and implementation of survey constraints, security issues affecting the accessibility of farms was ranked as number 3 and geographical difficulties as number 4. For the other countries security constraints were the least important.

For the detection survey results (Table 1), PNG and Vanuatu managed to collect all the required samples according to the random sampling frame developed while the Solomon Islands did not manage this. This could have been due to several reasons, i.e. PNG has a better animal health and production system in place where different departments supported each other, e.g. National Agriculture and Quarantine Inspection Authority (NAQIA) and Department of Agriculture and Livestock (DAL) working together to ensure information sharing and the collection of blood samples.

Vanuatu on the other hand currently is exporting beef, so they viewed the survey as important to support their status of disease freedom through scientific methods. The Solomon Islands planned to implement the detection survey to coincide with other animal health and production work, but unfortunately this resulted in not collecting all the required samples in one of the selected regions and no samples from the other. In addition some of the selected farms were only accessible by boat and this extended the planning process and implementation period. The low numbers of samples collected from the Solomon Islands could also be due to the limited capacity (inexperience) by the officers assigned to collect the required blood samples for the survey. The results from the indirect ELISA tests on all the samples performed at Kila Kila (PNG) and Koronivia (Fiji) have yielded negative *B. abortus*, however this does not necessarily prove disease freedom on a national basis as the survey was only carried out in selected regions of the countries, i.e. where most of the cattle farms were located according to local knowledge (Philips, 2014).

Since Fiji had a current outbreak of bovine brucellosis in its cattle population, sero positive cattle were expected during the survey, and the results were useful to the animal health authorities in Fiji to gauge the spread of the disease, i.e. during the study, the survey confirmed that 4 of the 24 farms were infected. The re-emergence of brucellosis in Fiji has been discussed in a separate paper (Tukana et al., 2015).

Conclusions

Lack of funds remains as one of the biggest problems that affect animal disease surveillance programs in developing countries of the Pacific, so there is a need to have more awareness on the impacts of zoonotic diseases on public health and trade; that should influence a priority shift towards support for animal disease surveillance in PICTs by national governments. There also needs to be more collaboration between research institutions and PICTs on the formulation and implementation of research projects to build capacities through practical disease surveillance training to establish better surveillance programs and improve biosecurity networks. The problem of lack of funds is further compounded by the shortage of veterinarians and high official turnover, so there is a need for continuous capacity building on animal disease surveillance to train country animal health officials to safeguard the livestock sector from re-emerging and exotic diseases in PICTs. The negative results from the detection survey for *Brucella* in PNG, Vanuatu and the Solomon Islands is a good starting point in the declaration of freedom, even though the results were from selected regions, there however needs to be monitoring for the disease done through the establishment of active animal disease programs.

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Conflict of interest The authors declare that they have no competing interests.

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