The history of brucellosis in the Pacific Island and its re-emergence

Andrew Tukana[ab], Jeffrey Warner[a], Robert Hedlefs[a], Bruce Gummow[ac]

[a] College of Public Health, Medical and Veterinary Sciences, James Cook University, Townsville 4811, QLD, Australia.

[b] Animal Health and Production Thematic Team, Land Resources Division, Secretariat of the Pacific Community, Suva, Fiji.

[c] Faculty of Veterinary Science, University of Pretoria, Pretoria, South Africa.

Author correspondence details:

C/-Professor Bruce Gummow, Discipline of Veterinary Science, James Cook University, Townsville 4811, Queensland, Australia.

Email: bruce.gummow@jcu.edu.au

Abstract

Little has been published on brucellosis within the Pacific Island Countries and Territories (PICTs) and the cattle population has been reportedly free of the disease for many years until a re-emergence occurred in 2009. This paper reports on the outbreak of brucellosis in Fiji and its progression between 2009 and 2013 in the context of an overview of brucellosis in the Pacific Island community. Review of the literature found only 28 articles with the oldest record of brucellosis being in 1965 in Papua New Guinea (PNG) and from human cases in Tonga in 1980. The Fiji outbreak of *Brucella abortus* occurred in cattle in 2009 (Wainivesi basin) in the Tailevu province. Prior to this outbreak, Fiji declared freedom from *B. abortus* to OIE in 1989 after a successful eradication campaign. During the course of the outbreak investigation, serum samples were collected from between 9,790 – 21,624 cattle per annum between 2009 and 2013 from 87 farms on the main island of Fiji (Viti Levu). Blood samples were tested for brucellosis using the Rose Bengal Test (RBT) in 2009 and the indirect ELISA test in subsequent years. At the time of the outbreak in Fiji (2009) the apparent prevalence in cattle was 1.50% and this has fluctuated since the outbreak. The True Prevalence (TP) for the main island in Fiji for the indirect ELISA tests was 6.22% in 2010, reached a peak of 15.24% in 2011 then reduced to 0.40% by 2013. The significant reduction in prevalence compared to 2010 is most likely due to the control programs being implemented in Fiji. The re-emergence of *B. abortus* in Fiji could be attributed to the lack of monitoring of the disease until 2009, thus illustrating how important it is for authorities not to become complacent. Continued awareness and monitoring for brucellosis is essential if future outbreaks are to be avoided.

1. Introduction

Bovine brucellosis is a disease of importance in the Pacific island community (PIC) as it has the potential to adversely impact both human and animal health (Garner et al., 2003) and it is listed as a multi-species disease, infections and infestations under the World Animal Health Information Database (WAHID) interface (OIE, 2013). The disease is caused by the bacterium *B. abortus* and has been recorded in cattle since the early 1970s in the Pacific Islands and more specifically in the associated “Food Animal Biosecurity Network” (FABN) countries, (Saville, 1996a) (Brioudes et al., 2014).

Brucellosis can be found worldwide and is usually well controlled in developed countries (OIE, 2009). However in developing countries brucellosis maybe enzootic but is often not reported on as the disease is often not regarded as a priority (Garner, 1997). Brucellosis is an important zoonotic disease and like in animals, the epidemiology in humans has changed over the years due to various sanitary, socioeconomic and political factors, including increased international travel (Mohamed et al., 2010). Some areas, particularly the Middle East, appear to have an increasing prevalence of brucellosis (Pappas et al., 2006).

The economic impacts of *B. abortus* are diverse and costs are normally associated with the loss of animal production, impact on human health, eradication and control as well as losses due to restriction on trade (FAO, 2002). According to the USDA, annual losses from lowered milk production, aborted calves and reduced breeding efficiency have decreased in the USA from $400 million in 1952 to less than $1 million today and this is due to a successful eradication program. Furthermore if eradication program efforts were ceased, the costs of producing beef and milk would increase by an estimated $80 million annually in less than 10 years (USDA APHIS Veterinary Services Report, 2013).

Even though it has always been considered that the disease impacts Pacific Island economies both in the cattle industries as well as in public health, studies on the economic impacts and formal reports of the costs of eradicating and controlling brucellosis are limited (SPC Report, 2012).

This paper presents data from a systematic review of literature (grey and peer reviewed) in relation to the status and reporting of bovine brucellosis in the Pacific Island community and more specifically Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands, which form part of a Food Animal Biosecurity Network (FABN); it summarizes some of the key issues in relation to brucellosis reporting in these Pacific Island communities. In addition, this paper presents and discusses the brucellosis outbreak that occurred in Fiji in 2009 and the re-emergence of the disease in the Pacific Island Countries and Territories (PICTs) using retrospective data collected from the Fiji Veterinary Pathology Laboratory in Koronivia, Suva, Fiji.

2. Materials and Methods

2.1 Review of the literature

2.1.1 PubMed and Web of Knowledge

A systematic literature review was conducted to gather data on the extent of brucellosis in the Pacific Island communities and Territories. A search of peer reviewed studies was conducted using PubMed and Web of Sciences databases for brucellosis in the Pacific Island community. It was decided to use these search engines as the PubMed database consists of references and abstracts on life sciences for biomedical topics, which is relevant to brucellosis. While the Web of Knowledge, formerly known as ISI Web of Knowledge, is an academic citation indexing and search service and thus relevant to peer reviewed studies on brucellosis.

A total of 29 key words were used to search for brucellosis articles for the different regions within the Pacific Island community. The key words used were; (“Brucellosis” AND “Pacific” AND “Oceania” AND “Micronesia” AND “Melanesia” AND “Polynesia” AND “American Samoa” AND “Cook Island” AND “Federated States of Micronesia” AND “Fiji” AND “French Polynesia” AND

“Guam” AND “Kiribati” AND “Marshall Islands” AND “Nauru” AND “New Caledonia” AND “Niue” AND “Northern Mariana Islands” AND “Palau” AND “Papua New Guinea” AND “Pitcairn Islands” AND “Samoa” AND “Solomon Islands” AND “Tokelau” AND “Tonga” AND “Tuvalu” AND “Vanuatu” AND “Wallis” AND “Futuna”)

The key words “Brucellosis” and “Pacific” were used to restrict the search to the Pacific Island community. The other key words used were the names of the countries that exist within the Pacific island community.

The “fields option” (PubMed) and “topic option” (Web of Science) were used to retrieve articles for the review. The articles were then screened for their relevance by reading through the abstracts and selecting them if they related to Pacific studies on the prevalence of brucellosis in relation to when and where the studies were conducted.

2.1.2 Secretariat of the Pacific Community

The Secretariat of the Pacific Community (SPC) has Pacific Island country mandates to carry out work in 22 countries in relation to agriculture (Land Resources Division) and was also used as a source of literature for the brucellosis study. Literature at the Secretariat of the Pacific Community library/database as well as electronic unpublished literature were searched and collated. These were then screened according to their relevance on brucellosis studies in the Pacific Island community in relation to when and where the studies were done.

2.1.3 WAHIS and WAHID databases

The World Animal Health Information System (WAHIS) and the World Animal Health Information Database (WAHID) databases of OIE were searched for reports of bovine brucellosis status in the Pacific Island community.

Two areas were searched on the WAHID database of OIE; these were (1) Disease distribution maps of bovine brucellosis for the Oceania region under the “Disease Information” tab and (2) country reports on *B. abortus* for Fiji, Papua New Guinea, Vanuatu and the Solomon Islands, under the “Animal Health Situation” and “Country Information” tab.

2.2 The re-emergence of brucellosis in Fiji

2.2.1 Outbreak investigation

Prior to the re-emergence of the disease in 2009, Fiji declared freedom from *B. abortus* in 1989 to OIE after a combination of vaccination (using S19 vaccine) as well as test and slaughter strategies using the RBT for screening herds and CFT for confirmation (Borja, 2014). The last case of brucellosis in cattle in Fiji before declaration of freedom to OIE was recorded in 1990 (Cokanasiga, 2015).

In June 2009, an outbreak of abortions were observed in cows and reported from a dairy farm in the Wainivesi basin of the Tailevu province on the main island of Fiji (Viti Levu). The farm was visited by the government veterinarian and the farm was quarantined. In total there were 12 farms in the Wainivesi basin and all the cattle on those farms were tested using the Rose Bengal Test (RBT). The RBT used spot agglutination methods where antigen was added to serum on a white tile plate, mixed, agitated and read after 4 minutes, visible reactions were considered positive (OIE, 2012b). In addition there were 11 localities in the Tailevu province with a total of 87 farms, and all the cattle (Table 1) on

Table 1
RBT Prevalence of brucellosis for the Tailevu province of Fiji in 2009

Nos	Localities	No. Farms	No. Cattle tested	RBT +ve	AP %	TP %
1	Wainivesi	12	1252	87	6.95	6.45
2	Waimaro	8	3551	9	0.25	0.00
3	Waidewara	11	912	5	0.55	0.05
4	Waidalice	15	690	6	0.87	0.37
5	Verata/Babavoce	4	315	4	1.27	0.77
6	Tailevu South	3	479	7	1.46	0.96
7	Sawakasa	12	723	0	0.00	0.00
8	Namalata	3	181	2	1.11	0.60
9	Naitutu	6	255	5	1.96	1.46
10	Nabilo	3	177	1	0.57	0.06
11	Deepwater	10	1255	21	1.67	1.17

RBT=Rose Bengal Test; AP=Apparent Prevalence; TP=True Prevalence

the remaining farms were also tested using the RBT. In 2010 samples (Table 2) were collected from farms that tested positive to RBT in 2009 and tested at the Fiji veterinary laboratory using the indirect ELISA test. The indirect ELISA test prepared microplates predetermined by OIE standard sera then

Table 2
Brucellosis RBT and ELISA prevalence results for Fiji (Viti Levu) for 2009 to 2013

Province & Sub districts	RBT Results (%)		ELISA Results (%)							
	2009		2010		2011		2012		2013	
	AP	TP	AP	TP	AP	TP	AP	TP	AP	TP
Tailevu	1.50	1.08	3.11	2.67	2.73	2.29	1.47	1.03	0.10	0.00
Naitasiri	-	-	2.82	2.38	11.35	10.91	6.60	6.16	0.69	0.25
Rewa	-	-	1.04	0.60	1.39	0.95	1.18	0.74	0.59	0.15
Serua Namosi	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Nadroga	-	-	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00
Nadi (sub district)	-	-	0.00	0.00	1.32	0.88	0.20	0.00	0.00	0.00
Tavua (sub district)	-	-	0.00	0.00	0.65	0.21	0.00	0.00	0.00	0.00
Ba	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lautoka (sub district)	-	-	1.00	0.56	0.00	0.00	0.00	0.00	0.00	0.00
Ra	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
95% Confidence intervals for TP on the main island of Fiji (Viti Levu)	-	0.17 to 2.83	-	0.00 to 6.51	-	0.00 to 9.26	-	0.00 to 4.14	-	0.00 to 0.62

RBT=Rose Bengal Test; AP=Apparent Prevalence; TP=True Prevalence; ELISA=Enzyme-linked immunosorbent assay test sera were added on, after washing, the test sera were compared to controls and test sera were deemed positive using the following calculation; Per cent positivity (%P) = absorbance (test sample)/absorbance (strong positive control) × 100 (OIE, 2012b). Samples that tested positive for *Brucella* antibodies were then sent for the Complement Fixation Test (CFT) at the Australian Animal Health Laboratory (AAHL), Australia. This was done to confirm the indirect ELISA positives from the Fiji Veterinary Pathology Laboratory.

Eradication efforts commenced with the culling of infected cattle on those farms based on the confirmation of the CFT from AAHL and this also prompted the sending of a report to OIE on the re-emergence of brucellosis in cattle based on the clinical symptoms presented and the screening tests done in Fiji with confirmation by CFT in Australia (AAHL).

More samples (Table 2) were collected in 2011, 2012 and 2013 from all farms in the Wainivesi and Waimaro basins in the Tailevu province as there had been numerous movements of cattle reported within those areas prior to the observed abortions in cows and the farms where samples were collected from were located close to where the infection had been recorded. From all the samples collected, 75.80% were from dairy farms, 20.77% were from beef farms and 3.43% were from mixed farms, i.e. farms having some dairy and beef cattle components. The samples collected covered the whole of the main island of Fiji (Viti Levu) which had 8 provinces. The samples were tested at the Fiji veterinary laboratory in Koronovia using the indirect ELISA test and culling of cattle took place based on the positive results obtained. The indirect ELISA test was used by the Fiji government as the confirmatory test for brucellosis between 2009 and 2013.

2.2.2 Structure of the brucellosis affected farms

2.2.2.1 Questionnaire survey

A questionnaire survey was developed to collect information on the structure and demographics of the farms that were initially diagnosed with brucellosis in Fiji in 2009. The questionnaire was developed using the Epi Info (version 7.1) software program (Centers for Disease Control, 2013) and consisted of five components, these were; Personal Information, Farm Structure, Livestock Production, Milk Production Process and Public Health Factors. Demographic information was collected from the survey to support this paper. The questionnaire was pretested with the 8 staff of the Fiji Veterinary Pathology Laboratory as well as with 10 farmers and improved before being implemented in the field. The survey was conducted on an interview basis and included the 87 farmers whose farms were those initially diagnosed as RBT positives for brucellosis when the outbreak occurred in 2009. The interview began at the end of 2012 and was completed in early 2013. All ethical requirements from James Cook University were adhered to and approval was obtained before the survey was carried out.

2.2.3 Post 2009 outbreak (Control measures)

Control measures followed the "test and slaughter" protocol where farms that test positive to RBT screening were whole herd tested using indirect ELISA. Cattle that tested positive to the indirect ELISA were quarantined on the farm and were only allowed to move from the farm to the abattoir for slaughter. There were no other control measures imposed apart from quarantining and restricting cattle movement and since the protocol (test and slaughter) was implemented in 2010, it remains in place at this time (Fiji Animal Health and Production Division Annual Report, 2014). Awareness programs have also been conducted by the animal health authorities on the farms in relation to the risks of movement of cattle out of the farms as well as the risks of bringing in new cattle onto the farm (Fiji Veterinary Pathology Report, 2014).

2.3 Prevalence analysis

Retrospective data for both the RBT (2009) and indirect ELISA tests (2010 – 2013) were analysed for apparent prevalence (AP) and true prevalence (TP). The clustering effect that was thought to exist between localities in the Tailevu province and between the provinces and subdistricts on the main island of Fiji was considered and accommodated for in the calculations for prevalence.

The following formulas were used;

Apparent Prevalence (AP) = total no. of seropositive Brucella cases at a given time ÷ total population at risk (Thrusfield, 1995)

After the calculation of AP, the three Equations presented below were used to calculate true prevalence. The true prevalence (TP) calculations also took into account the Sensitivity (Se) and Specificity (Sp) of both the RBT and indirect ELISA tests where applicable using Eq. 1 (Thrusfield, 1995).

Equation 1;

$$TP = \frac{AP + Sp - 1}{Se + Sp - 1}$$

In Equation 1, TP is the true prevalence, AP the apparent prevalence, Se the test sensitivity and Sp the test specificity. Since there was some uncertainty as to the sensitivities (Se) and specificities (Sp) for both the RBT and indirect ELISA tests, a search was conducted under the PubMed database and a total of 16 articles were obtained. The selected literatures (Matope et al., 2011), (Matovic, 2008), (Abernethy et al., 2012), (Sanogo et al., 2013) were then reviewed and averages were calculated for Sensitivity and Specificity values which were used in the calculations for prevalence. These were RBT; Se = 0.75, Sp = 0.92, indirect ELISA; Se = 0.73, Sp = 0.96.

Equation 2 and Equation 3 (Thrusfield, 1995) were then used in conjunction to derive the 95% confidence intervals for true prevalence after adjusting for the clustering effect between the eleven localities within the Tailevu province using the RBT serological data and between the eight provinces and subdistricts of Fiji using the indirect ELISA serological data.

Equation 2;

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

In Equation 2, Pe is the apparent prevalence for the localities as a whole, c the total number of localities (clusters) in the province. T is the total number of cattle in the province. V is calculated using Eq.3 (Thrusfield, 1995).

Equation 3;

$$V = Pe^2 (\sum n^2) - 2Pe (\sum nm) + (\sum m^2)$$

Where V is the variation that was likely to be taking place between the clusters, n was the number of cattle sampled in each locality and m the number of *Brucella* positive cattle in each locality. The V value was then inserted into Equation 2 to calculate the 95 % confidence intervals (CI) for TP after adjusting for clustering (Thrusfield, 1995).

2.4 Chi-square test comparisons

Chi-square tests were done to establish if there had been a significant reduction in prevalence between consecutive years of the study. Retrospective data collected for the indirect ELISA positive samples was used for the chi-square tests. The 2010 prevalence was used as a baseline to compare consecutive years to and data were analysed to see if there were significant differences in prevalence's between the years. The calculations were done in the software package EPI Info 7. A P-value < 0.05 was considered significant (Centers for Disease Control, 2013).

3. Results

3.1 Semi-systematic Review of the Literature

3.1.1 PubMed and Web of Knowledge databases

The search under the "PubMed" and "Web of Knowledge" databases using key words to limit the search to brucellosis studies and reports in the Pacific Island community yielded 139 articles and 8 articles respectively. After screening both sets of articles, 28 were deemed to be relevant according to the criteria; as to where the studies were carried out, on which species, the year of the study, the prevalence of brucellosis as well as diagnostic tests used. The other articles that did not meet the criteria were excluded. The summary from the literature review was broken down into three areas, which are presented below.

3.1.1.1 Brucellosis within the Pacific Island human population

From the literature reviewed, the very first case of human brucellosis was reported in 1980 in Tonga (Finau and Reinhardt, 1980). Later, in 1982, 300 sera were obtained from a survey carried out among healthy people from a predominantly rural community of Fiji and the results indicated that the majority of people had antibodies for *Brucella abortus* (Ram et al., 1982). There were reports from

Wallis and Futuna between 2003 and 2010 which provided evidence of a brucellosis mean annual incidence of 19 cases/100,000 inhabitants (Guerrier et al., 2011). Until now, the control of brucellosis in this part of the globe remains a challenge as a recent study (Guerrier et al., 2013) showed that most of the interviewed people from Polynesia did not know about brucellosis, in spite of some repeated public awareness campaigns.

3.1.1.2 Animal brucellosis in the Pacific Islands and Territories (PICTs)

The oldest record from this literature review dates back to 1965 with the identification of two strains of *Brucella abortus* Biotype 1 and two strains of *Brucella abortus* Biotype 2 in PNG, out of 137 cultures received at the regional WHO brucellosis centre (Aldrick, 1968). Consecutively, a study initiated in 1967 among the cattle population of the Solomon Islands revealed at first very few reactors and the disease was no longer detected among the tested herds by the end of the study in 1977 (de Fredrick and Reece, 1980). Similarly, a study conducted in Vanuatu between 1971 and 1981 gave evidence of a favourable situation with regards to cattle diseases, except for brucellosis which was identified as the only serious disease present (Schandevyl and Deleu, 1985).

In 1985, a reference reveals the introduction of brucellosis into the Solomon Islands, this is highly suspected to have been introduced via the importation of breeding cattle from Queensland in Australia into the Solomon Islands during the 1970’s and the early 1980’s period (Hellyar, 1985), (Nonga, 2015). Another article published in 1987 also demonstrated serological evidence of brucellosis in the pig population of Wallis and Futuna (Giraud et al., 1987). Anecdotally, the only sample reacting positively to a serum agglutination test performed in 1984-1986 on 225 dogs’ serum from Papua New Guinea was actually from a dog directly imported from the United Kingdom (Patten, 1987).

During the 1990’s period, the Animal Health and Animal Production team of the Secretariat for the Pacific Community (SPC) conducted a series of animal health surveys in most of their member countries with brucellosis being one of the diseases being systematically investigated. While the disease was detected among the cattle population of Samoa and Cook Islands (Martin, 1999a; Saville, 1994), it was also confirmed among the pigs of Tonga (Saville, 1996c) and those of Wallis and Futuna, although the infection appeared to have greatly diminished later due to the introduction of compulsory penning of pigs in the late 1980s (Martin, 1999c). Brucellosis was declared absent from cattle herds of Solomon Islands, Niue and Palau in the 1990's (Martin and Epstein, 1999; Saville, 1996b; Saville, 1999). Findings from the SPC surveys suggested that the pig population of Tokelau and the pigs and goats populations of Solomon Islands also were free of the disease (Martin, 1999b; Martin and Epstein, 1999).

With an increasing number of human cases of brucellosis due to *Brucella suis* biovar 1, Wallis and Futuna recently carried out more serological surveys among 208 pig herds (Antras and Garin-Bastuji, 2011). Results provided an estimated sero-prevalence of infected herds of 22% and a mean intra-herd prevalence of 34%.

For aquatic animals, a recent study conducted in the Solomon Islands shows that the Pacific bottlenose dolphins (*Tursipa aduncus*) are infected with *Brucella* spp. or a brucella-like organism (Tachibana et al., 2006).

3.1.1.3 Past control measures and evaluation

As early as 1972, PNG reported the use of *B. abortus* 45/20 adjuvant vaccine to induce a serologically detectable (presence of antibodies) response among cattle as a diagnostic aid in the brucellosis eradication campaign, i.e. the vaccination would have played a role in the reduction of prevalence. Likewise because of enzootic *Brucella suis* biovar 1 spreading among the pig populations and leading to sporadic human cases, French Polynesia undertook very recently the evaluation of five serological tests in order to improve the diagnosis of porcine brucellosis (Praud et al., 2013). The five serological tests were; Rose Bengal test, fluorescence polarisation assay, indirect ELISA, and two competitive, ELISAs (C-ELISA), these could also be applied to test cattle samples.

3.2 WAHID Database

3.2.1 Reported disease distribution

The last updated *B. abortus* distribution maps under the WAHID database was in 2006, i.e. one for the period January to June and the other for July to December. Both maps were colour coded and the colour indicated that *B. abortus* was not reported during that period (2006) for the Oceania region which includes the FABN project countries (OIE, 2013).

3.2.2 Bovine brucellosis status

Fiji has reported the presence of *B. abortus* based on disease in cattle since 2010 (OIE, 2013). Culturing at the Fiji veterinary laboratory and bio typing at the Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia confirmed the *B. abortus* organism in Fiji as biovar 2 (Fiji Veterinary Pathology Report, 2014). PNG reported absence of *B. abortus* from the period 2010-2012 with no reports submitted for the 2013 period (OIE, 2013). Vanuatu reported absence of *B. abortus* for the four years from 2010-2013 and the Solomon Islands did not submit any reports for the four year period from 2010-2013 (OIE, 2013).

3.3 The re-emergence of Brucellosis in Fiji

Eleven localities in the Tailevu province comprising 9790 cattle were sampled in 2009. This was extended to cover the other 7 provinces and subdistricts on the main island of Fiji (Viti Levu) in 2010 and 2011 comprising 9829 and 12854 cattle respectively. In 2012 and 2013 the survey covered all the 8 provinces and subdistricts on the main island comprising 21624 and 18986 cattle respectively, where farms were resampled to test for brucellosis prevalence. Blood samples were tested for brucellosis using the Rose Bengal Test in 2009 and the indirect ELISA test in subsequent years. At the time of the outbreak in Fiji (2009) the apparent prevalence was 1.50% and the 95% confidence interval for true prevalence was calculated between 0.17% and 2.83% after accounting for the clustering effect of the 11 localities in the affected province. In 2010, 2011, 2012 and 2013 the apparent prevalence of brucellosis was 2.56%, 3.66%, 2.00% and 0.28% respectively. The 95% confidence intervals for the TP for the same years were calculated as -1.38% to 6.51% (2010), -1.95% to 9.26% (2011), -0.15% to 4.14% (2012), -0.06% to 0.62% (2013) accounting for the clustering effect between the different provinces.

The results of the prevalence of brucellosis at the time of the outbreak in 2009 for the different localities in the Tailevu province of Fiji are shown in Table 1. Table 2 presents the individual prevalence's of brucellosis for the 8 provinces and 2 subdistricts on the main island of Fiji. Table 2 also shows the 95% CI for estimated TP of brucellosis on the main island of Fiji each year of the study. Fig. 1 represents the true sero-prevalence of brucellosis in the different provinces in Fiji from 2009-2013.

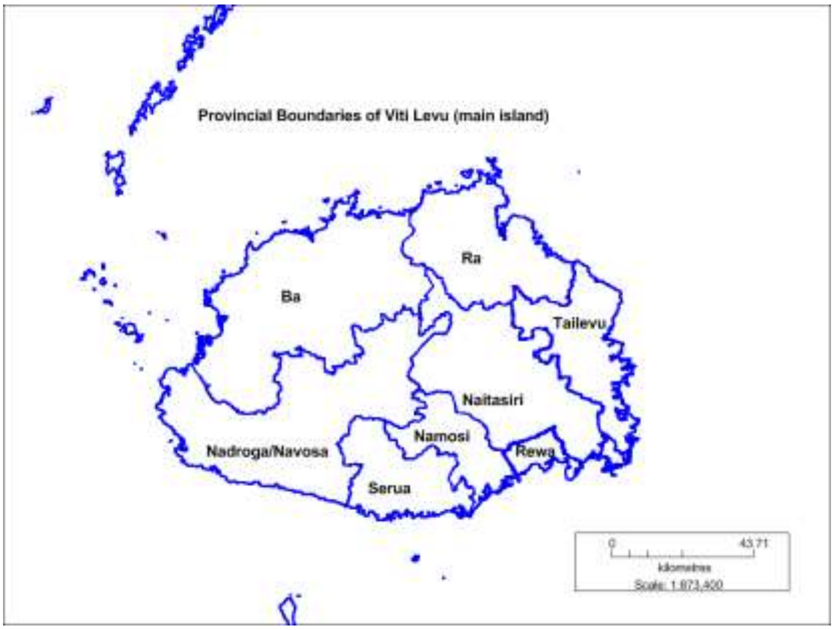

Figure 1: Map of the main island in Fiji showing provincial boundaries

There were significant reductions in prevalence from 2011-2013 compared to 2010 ($P < 0.01$) and also significant reductions in prevalence between the consecutive years from 2010 to 2013 ($P < 0.05$).

3.4 *Demographics of Brucella affected cattle farms in Fiji at the time of the outbreak*

The 87 cattle farms surveyed revealed that farms in Fiji were all managed by males (100%), as this was regarded as dirty hard work. The cattle farms in the area surveyed were made up of dairy (95%), beef (2.5%) or a mixture of dairy and beef type cattle (2.5%) herds. The most common breeds on dairy farms were Friesen (67.5%), Jersey (11.7%) and mixed breeds (19.5%). On beef farms the most common breeds were a mixture of Santa Getrudis, Hereford and Brahman (100%). Farm sizes ranged from < 1 ha to 100 ha. Dairy farms used pasture that is fed ("cut and carry") with molasses during milking and rotational grazing was practiced during other periods. Fostering of calves (29%) and retaining heifers (100%) to increase dairy cattle numbers on the farms were a common practice. Beef farms practiced rotational grazing all year around. Water for drinking was normally sourced from rivers and creeks, and there was sharing of water sources for cattle on farms that had common boundaries. Biosecurity measures were poor and details of this are as yet unpublished (unpublished data, Tukana, 2014).

4. Discussion

4.1 Review of literature

The literature review revealed that not much has been published on the disease in Pacific Island Countries and Territories and most of the publications relate to human cases. This is not what one would expect given that the disease has been present in the Pacific Island community for some time and was recorded in animals in PNG as early as 1965 (Aldrick, 1968). To our knowledge no review of literature on brucellosis in the PICTs has been previously published. The fact that this review also includes hard to access SPC records makes it a valuable source of information for those working on brucellosis in the PICTs. The lack of published data is probably due to several reasons. Amongst these is the fact that there were few research activities occurring in the region partially because of political instability in these countries and partially because of an environment that is difficult to work in due to constraints in infrastructure, skilled manpower and climate.

Papua New Guinea, Vanuatu and the Solomon Islands have not reported any clinical signs of bovine brucellosis since the mid 1980's (Saville, 1996b), (Martin and Epstein, 1999). There is currently no active animal disease surveillance program for *B. abortus* being implemented in the FABN countries or any of the other Pacific island countries except for Fiji who are currently in eradication and control mode for brucellosis in cattle (Fiji Veterinary Pathology Report, 2014). Since there is no testing and monitoring for brucellosis done on cattle farms in most of the other Pacific Island Countries there is potential for the re-emergence of the disease.

Brucellosis and Tuberculosis Eradication Campaigns (BTEC) had been implemented in the FABN countries in the late 1970's and early 1980's. Using the test and slaughter methods, *B. abortus* was thought to be eliminated from the FABN project countries in the early to mid-1980 (Saville, 1996b), but since monitoring has not been ongoing, there is no way of knowing this for sure.

The methods employed in the past for confirmation of *B. abortus* in the FABN project countries mainly were the use of the Rose Bengal Test (RBT) for screening herds. Infected farms were then whole herd tested and confirmation of positives was done using the complement fixation tests either in-country or sending samples from infected herds directly to the reference laboratories in Australia and New Zealand (Saville, 1996b). This was an expensive exercise and if processing and shipping samples were not done appropriately, then the results could have been doubtful. The sensitivity of the RBT is on average poor (75%), which means the test may affect the capacity for screening. In addition the RBT produces a higher proportion of false positives thus despite its widespread use it could result in positive cattle not being detected (OIE, 2012a). The history in the region therefore makes it possible for brucellosis to have gone undetected despite claims of freedom.

Reports of freedom of bovine brucellosis to WAHID (OIE, 2013) from Fiji, PNG and Vanuatu, who are OIE members, are based on past history as well as the non-presentation of disease. The Solomon Islands are currently not a member of OIE and this could be the reason why they have not made any effort to submit reports to OIE over the last few years. Papua New Guinea, Vanuatu and the Solomon Islands indicate that they are currently free of *B. abortus* even though there is no monitoring of the disease being done, this could result in a false sense of security in the region (SPC Report, 2012).

4.2 The re-emergence of Brucellosis in Fiji

The Wainivesi locality (Table 1) which had 12 farms, recorded the highest prevalence (6.45%) in 2009 and this supports the report that the outbreak of abortions started from this locality in 2009 where it was first detected. The local livestock officers reported that the frequency of cattle movement within the 12 farms in that area had been high thus explaining the dispersion of the disease to other localities (Fiji Animal Health and Production Division Annual Report, 2014). Where the disease originated from is unknown, and it is difficult to pinpoint a farm where it originated. The farmers in those areas do not import cattle from other countries so the disease is unlikely to have been illegally imported, however given the history of the brucellosis in the region it is possible the organism may have been present for some time and possibly in another reservoir and has now re-emerged from this undetected or unknown source. It is possible that *B. abortus* bacteria could have been maintained in pig populations, dogs or pockets of cattle e.g. draft cattle which have never been tested around the country (OIE, 2009), (Fiji Animal Health and Production Division Annual Report, 2014). In addition, the practice of fostering calves and the retention of heifers to increase the cattle numbers in Fiji could also be likely sources and reservoirs for brucellosis as getting in calves from outside is a potential route for the disease to enter the farm while the retained heifers could have been chronically infected thus show symptoms of the disease later on (Hellyar, 1985).

The reduction of the true prevalence (indirect ELISA) on the main island of Fiji from 6.22% (2010) to 0.40% (2013) could be attributed to the control programs implemented by the animal health authorities in Fiji. The highest prevalence was 10.19% which was recorded for the Naitasiri province in 2011 and was followed by the Tailevu province with a prevalence of 2.29% (2011). Both provinces are major dairy and beef producers in Fiji, which could explain why the disease was most prevalent in those regions (Fiji Agricultural Census Report, 2009). Both provinces also share a common border, thus it is likely that the infection of brucellosis had spread from the Tailevu province to the Naitasiri province via the movement of infected cattle. Whether this took place prior to or after movement controls were put in place is unknown but it does illustrate difficulty of controlling the disease in Pacific Island countries.

The other provinces (Serua Namosi, Nadroga, Nadi, Tavua, Ba, Lautoka and Ra), which are all situated in the mid-west and western parts of the main island of Fiji, had a much lower sero-prevalence of brucellosis compared to the three provinces in the central division (Tailevu, Naitasiri and Rewa) from 2010 to 2013. This supported the reports that there was not much movement of cattle from the Central division to the Western division. Movement control of cattle therefore is one of the key factors in controlling brucellosis in the PICTs but also one of the most difficult to control due to co-mingling, poor fencing, island hopping and trading practices.

5. Conclusions

Examination of the literature indicates that brucellosis has been in the Pacific for many years, but may not be considered important as there has not been much awareness about the disease within the communities in the Pacific Island Countries and Territories. Very little literature has been published on the disease for the last 20 years and our study serves as the first review of available literature. The lack of literature makes it difficult to gauge the impact of the disease in the Pacific Island Countries and Territories. Papua New Guinea, Vanuatu and the Solomon Islands are currently indicating freedom from *B. abortus* and this is based on none presentation of the disease and past history. There is currently no monitoring for bovine brucellosis done in the Pacific Island community yet a study of the literature does not preclude the existence of the disease or the possibility of it going undetected. Fiji had not carried out any active animal disease surveillance program to monitor for *B. abortus* soon after declaration of freedom to OIE in 1989 until it had an outbreak in 2009. The lack of active animal disease surveillance to monitor for the status of *B. abortus* could have been one of the reasons why the disease was not picked up earlier. The study therefore reinforces the need for continued active surveillance despite the disease being apparently absent. The literature also indicates that brucellosis has been found in pigs and dogs, this was evident in Tonga, PNG and Wallis and Futuna and the Solomon Islands, the possibility of them being reservoirs however need to be explored further. The demographics of the farms in Fiji indicate that fostering of calves and retention of heifers was a common practice thus a potential reservoir for brucellosis, thus should also be investigated further (Hellyar, 1985). It has been 5 years since the outbreak of brucellosis on cattle farms and Fiji has still not eliminated the disease. Thus it seems that once the disease re-emerges it is very difficult to eliminate; this could be due to the unregulated movement of infected cattle to other provinces as well as the presence of other potential animal reservoirs. Awareness and monitoring in the Pacific Island countries and Territories is going to be important in future for the detection of brucellosis.

6. Acknowledgements

The authors wish to thank the staff of the Ministry of Primary Industries (MPI), Animal Health and Production Division, Fiji, particularly the Director for the Animal Health Division, Mr Tomasi Tunabuna, as well as the field and laboratory staff of the Fiji Veterinary Pathology Laboratory in Koronivia, in particular, Dr Leo Borja. Without their approval, cooperation and support, this project would not have progressed. The authors also wish to thank the Secretariat of the Pacific Community, particularly the Animal Health and Production thematic team advisor, Dr Ken Cokanasiga for the support provided to the FABN project researchers. In addition, the authors also thank the Australian Aid program (AusAid) for approving and supporting the research technically and financially.

7. References

Abernethy, D.A., Menzies, F.D., McCullough, S.J., McDowell, S.W.J., Burns, K.E., Watt, R., Gordon, A.W., Greiner, M., Pfeiffer, D.U., 2012. Field trial of six serological tests for bovine brucellosis. The Veterinary Journal 191, 364-370.

Aldrick, S.J., 1968. Typing of Brucella strains from Australia and Papua-New Guinea received by the regional W.H.O. Brucellosis Centre. Australian veterinary journal 44, 130-133.

Antras, V., Garin-Bastuji, B., 2011. La brucellose porcine a Wallis et Futuna, Bulletin epidemiologique, sante animale et alimentation, pp. 31-34.

Brioudes, A., Warner, J., Hedlefs, R., Gummow, B., 2014. A review of domestic animal diseases within the Pacific Islands region. Acta tropica 132, 23.

Centers for Disease Control, 2013. Data collection, management, analysis, visualisation and reporting software for public health professionals., Epi Info™ Help Desk, Centers for Disease Control and Prevention,1600 Clifton Rd, Mail Stop E-91 Atlanta, GA 30333, USA.

Cokanasiga, K., 2015. Personal communication from the Former Director for the Animal Health and Production Division, Ministry of Agriculture, Fiji, currently Deputy Director, Trade and Agribusiness, Land Resources Division, Secretariat of the Pacific Community.

de Fredrick, D.F., Reece, R.L., 1980. Diseases of cattle in the Solomon Islands. Australian veterinary journal 56, 522-525.

FAO, 2002. Some Issues of Livestock of the Asia-Pacific region, RAP publication no. 2002/06. 15. FAO (2002), Some Issues of Livestock of the Asia-Pacific region, RAP publication no. 2002/06, Food and Agriculture Organization of the United Nations,Regional Office for Asia and the Pacific Animal Production and Health Commissionfor Asia and the Pacific (APHCA), Bangkok.

Fiji Agricultural Census Report, 2009. Fiji National Agricultural Census. Economic Planning and Statistics Division, Ministry of Primary Industries, Raiwaqa, Suva, Fiji.

Fiji Animal Health and Production Division Annual Report, 2014. Annual Report. Ministry of Primary Industries, Suva, Fiji Islands, Animal Health and Production Division, Toa street, Vatuwaqa, Suva, Fiji Islands, p. 21.

Fiji Veterinary Pathology Report, 2014. Annual report for the Central Division. Ministry of Primary Industries of Fiji., Veterinary Pathology Laboratory, Koronivia, Nausori, Fiji., p. 10.

Finau, S.A., Reinhardt, G.N., 1980. Human brucellosis in Tonga. The New Zealand Medical Journal 91, 386.

Garner, G., 1997. Animal Health Information Systems and Epidemic Diseases of Livestock, Report of the 2nd Mission 30/12/1997 ed, Food and Agricultural Organisation of the United Nations, Canberra, December 1997, p. 21.

Garner, G., Saville, P., Fediaevsky, A., 2003. A manual for recognition of exotic diseases of livestock. FAO, Rome, Italy.

Giraud, P., Toutain, B., Domenech, J., Bregeat, D., 1987. Presentation de l'elevage aux iles Wallis et Futuna. Rev. Elev. Med. vet. Pays trop. 40, 173-179.

Guerrier, G., Daronat, J.M., Morisse, L., Yvon, J.F., Pappas, G., 2011. Epidemiological and clinical aspects of human Brucella suis infection in Polynesia. Epidemiology and infection 139, 1621-1625.

Guerrier, G., Foster, H., Metge, O., Chouvin, C., Tui, M., 2013. Cultural contexts of swine-related infections in Polynesia. Clinical microbiology and infection : the official publication of the European Society of Clinical Microbiology and Infectious Diseases 19, 595-599.

Hellyar, A.G., 1985. The introduction of brucellosis into the Solomon Islands. Transactions of the Royal Society of Tropical Medicine and Hygiene 79, 567-568.

Martin, T., 1999a. The Animal Health Status of Samoa. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 42.

Martin, T., 1999b. The Animal Health Status of Tokelau. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 23.

Martin, T., 1999c. The Animal Health Status of Wallis & Futuna. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 29.

Martin, T., Epstein, V., 1999. The animal health status of the Salomon Islands. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 44.

Matope, G., Muma, J.B., Toft, N., Gori, E., Lund, A., Nielsen, K., Skjerve, E., 2011. Evaluation of sensitivity and specificity of RBT, c-ELISA and fluorescence polarisation assay for diagnosis of brucellosis in cattle using latent class analysis. Veterinary immunology and immunopathology 141, 58-63.

Matovic, K., et al, 2008. Examination of Sensitivity and Specificity of some Serological Tests in Diagnostics of bovine Brucellosis. Acta Veterinaria (Beograd), Vol. 58, No. 5-6, 467-476, 2008.

Mohamed, N.S., Stephen, M.B., Nammalwa, r.S., 2010. Brucellosis: A re-emerging zoonosis. Veterinary Microbiology 140, Elsevier; www.elsevier.com/locate/vetmic (accessed 15/03/2014).

Nonga, N., 2015. Personal communication from the Former Director of Veterinary and Livestock Services Division, Ministry of Agriculture and Livestock, Solomon Islands, currently Animal Health and Production Officer, Land Resources Division, Secretariat of the Pacific Community.

OIE, 2009. Brucellosis. The Center for Food Security and Public Health, Iowa State University, USA.

OIE, 2012a. Guidelines for animal disease control, World Organisat ion for Animal Heal th (OIE) , 2012.

OIE, 2012b. Standards for bovine bucellosis tests, OIE Terrestrial Manual OIE, 12, rue de Prony, 75017 Paris, France. , p. 35.

OIE, 2013. WAHID interface; http://www.oie.int/en/animal-health-in-the-world/oie-listed-diseases-2013/ (accessed 29/04/2014).

Pappas, G., Papadimitriou, P., Akritidis, N., Christou, L., Tsianos, E., 2006. The new global map of human Brucellosis. PubMed.

Patten, B.E., 1987. Antibodies to B. canis in dogs in Papua New Guinea. Australian veterinary journal 64, 355.

Praud, A., Gimenez, O., Zanella, G., Pozzi, N., Antras, V., Meyer, L., Garin-Bastuji, B., 2013. Evaluation of five serological tests for the diagnosis of porcine brucellosis in French Polynesia. Trop Anim Health Prod 45, 931-933.

Ram, P., Mataika, J.U., Metcalfe, R.V., Bettelheim, K.A., 1982. Antibody levels to Brucella abortus, Toxoplasma gondii, and Leptospira serogroups, in sera collected from healthy people in Fiji. Comparative immunology, microbiology and infectious diseases 5, 397-403.

Sanogo, M., Thys, E., Achi, Y.L., Fretin, D., Michel, P., Abatih, E., Berkvens, D., Saegerman, C., 2013. Bayesian estimation of the true prevalence, sensitivity and specificity of the Rose Bengal and indirect ELISA tests in the diagnosis of bovine brucellosis. Veterinary journal (London, England : 1997) 195, 114.

Saville, P., 1994. The Animal Health Status of the Cook Islands. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 14.

Saville, P., 1996a. The animal health status of the Cook Islands. South Pacific Commission, Suva Regional Office, Suva, Fiji.

Saville, P., 1996b. The animal health status of the Pacific Island countries and territories 1994. South Pacific Commission, Suva Regional Office, Suva, Fiji.

Saville, P., 1996c. The Animal Health Status of Tonga. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 20.

Saville, P., 1999. The Animal Health Status of Palau. Secretariat of the Pacific Community, Suva Regional Office, Suva, Fiji, p. 21.

Schandevyl, P., Deleu, D., 1985. Diseases and parasites of cattle in Vanuatu. Australian veterinary journal 62, 297-300.

SPC Report, 2012. Livestock disease survey planning for Pacific Island Countries and Territories. Secretariat of the Pacific Community, 3 Luke street, Nabua, Suva, Fiji Islands.

Tachibana, M., Watanabe, K., Kim, S., Omata, Y., Murata, K., Hammond, T., Watarai, M., 2006. Antibodies to Brucella spp. in Pacific bottlenose dolphins from the Solomon Islands. Journal of wildlife diseases 42, 412-414.

Thrusfield, M., 1995. Veterinary Epidemiology, Second Edition ed. Blackwell Science Pty Ltd, 54 University Street, Carlton, Victoria 3053, Australia.

USDA APHIS Veterinary Services Report, 2013. Brucellosis Fact Sheet. USDA, APHIS, Veterinary Services, National Animal Health Programs, 4700 River Road, Unit 43 Riverdale, MD 20737-1231,USA.