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The study of Brucellosis in cattle within the Pacific Island Community as a model for disease surveillance and reporting

Thesis submitted by

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STATEMENT OF SOURCES DECLARATION

I declare that this thesis is my own work and has not been submitted in any other form for another degree or diploma at any other university or institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Andrew Tukana
30 June 2018

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STATEMENT ON THE CONTRIBUTION OF OTHERS TO THE PhD STUDY

Title of thesis: The study of Brucellosis in cattle within the Pacific Island Community as a model for disease surveillance and reporting

Name of candidate: Andrew Tukana

Nature of assistance	Contribution	Names, Titles (if relevant) and Affiliations of Co-Contributors
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Supervision	All aspects of the project	Prof. Bruce Gummow
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STATEMENT ON THE CONTRIBUTION OF OTHERS TO THE PUBLICATIONS

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Chapter #	**Details of publication(s) on which chapter is based**	**Nature and extent of the intellectual input of each author**	**I confirm the candidate's contribution to this paper and consent to the inclusion of the paper in this thesis**
Chapter 2	**Publication reference:** "The history of brucellosis in the Pacific Island and its re-emergence". *Preventive Veterinary Medicine Journal, 122, 14–20, (2015).*	Andrew Tukana: Project design, conduct of the literature search and analysis, write up of the paper. Bruce Gummow: Project design, Supervision and guidance for the conduct of the activity and detailed editing and review of the paper, including methodology, results and discussion.	Name (please print): Andrew Tukana Signature: Name (please print): Bruce Gummow Signature:

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DECLARATION OF ETHICS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the National Statement on Ethics Conduct in Research Involving Human (1999), the Joint NHMRC/AVCC Statement and Guidelines on Research and Practice (1997), the James Cook University Policy on Experimentation Ethics Standard Practices and Guidelines (2001) and the James Cook University Statement and Guidelines on Research Practice (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (Approval number for animal ethics, A1740 and human ethics, H4414).

Andrew Tukana
30 June 2018

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30 June 2018

ACRONYMS AND ABBREVIATIONS

AAHL	Australian Animal Health Laboratory
ACIAR	Australian Centre for International Agricultural Research
AHP	Animal Health and Production
ANU	Australian National University
AP	Apparent Prevalence
AP	Animal Production
APHCA	Asia and the Pacific Animal Production and Health Commission for Asia and the Pacific
APHIS	Animal and Plant Health Inspection Service (USDA)
ATO	Agricultural Technical Officer
AusAID	Australian Agency for International Development
AVCC	Australian Code of Practice for the Care and Use of Animals for Scientific Purposes
B. abortus	*Brucella abortus*
BTEC	Brucellosis and Tuberculosis Eradication Campaign
CFT	Complement Fixation Test
CI	Confidence Interval
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVO	Chief Veterinary Officer
CW	Council Wards
DAL	Department of Agriculture and Livestock
ELISA	Indirect Enzyme-linked immunosorbent assay
FABN	Food Animal Biosecurity Network
FAO	Food and Agriculture Organisation (United Nations)
FCA	Fiji College of Agriculture
GDP	Gross Domestic Product
HIV	Human Immunodeficiency Virus
JCU	James Cook University
LGO	Local Government Officer
MAF	Ministry of Agriculture and Forests
MOPA	Ministry of Provincial Affairs
MOA	Ministry of Agriculture
MPI	Ministry of Primary Industries
NARI	National Agriculture Research Institute
NAQIA	National Agriculture Quarantine Inspection Authority

NC	New Caledonia
NCSS	Number Cruncher Statistical Software
NHMRC	National Health and Medical Research Council
NZ	New Zealand
OIE	Office International des Épizooties (World Organization for Animal Health)
OR	Odds Ratio
PAO	Principal Agriculture Officer
PAPP	Pacific Agriculture Policy Project
PhD	Philosophiae Doctor (doctor of philosophy)
PLO	Provincial Livestock Officer
PNG	Papua New Guinea
PPE	Personal Protective Equipment
PVO	Principal Veterinary Officer
Prof	Professor
PICTs	Pacific Island Countries and Territories
RBT	Rose Bengal Test
RDT	Rural Development Technician
RRA	Rapid Rural Appraisal
RVO	Regional Veterinary Officer
SAA	Senior Agricultural Assistant
Se	Sensitivity
SI	Solomon Islands
SINU	Solomon Islands National University
Sp	Specificity
SPC	The Pacific Community (formerly known as the Secretariat of the Pacific Community)
SWOT	Strengths Weaknesses Opportunities and Threats
SSC's	Surveillance System Components
TP	True Prevalence
TB	Tuberculosis
UN	United Nations
USA	United States of America
USDA	United States Department of Agriculture
USP	University of the South Pacific
VAC	Vanuatu Agricultural College
V	Variation
WAHID	World Animal Health Information Database

WAHIS	World Animal Health Information System
WHO	World Health Organisation
WTO	World Travel Organisation

SUMMARY

Brucellosis is an important zoonosis in the Pacific Island community, however most countries in the Pacific island community may not consider the disease important. This is due to the fact that there has been very little literature published on the disease over the last 20 years thus it has been difficult to gauge the impact of the disease. There also are national priorities ahead of the disease Brucellosis, e.g. HIV and Tuberculosis, etc.

Brucella abortus in particular has significance in the Pacific island community as it has recently re-emergence in Fiji and it has the potential to impact the cattle sectors in Papua New Guinea, Vanuatu and the Solomon Islands who all depend on cattle for food security and their livelihoods.

The Fiji re-emergence of *B. abortus* in cattle in 2009 was most likely caused by the lapse in monitoring with poor surveillance and reporting until the disease was well established in the Tailevu province of Fiji. Thus this study sought to examine ways to improve disease surveillance and reporting using Brucellosis in cattle as a model to reduce the impacts of zoonoses and protect the livelihoods of livestock farmers within the Pacific Island Community.

Five approaches (objectives) were used in this study to improve disease surveillance and reporting using *Brucella abortus* as the disease of interest and cattle as the animal unit studied and the countries covered were Fiji, Papua New Guinea, Vanuatu and the Solomon Islands. The five objectives were; (i) produce a better knowledge on the status of bovine brucellosis in the Pacific Island Community, using the current outbreak of the disease in Fiji as a model. (ii) Produce a better knowledge of which risk factors were associated with the outbreak of bovine brucellosis in Fiji and how some of those risks factors could be related to other Pacific Island Community countries, i.e. in terms of similarities of cultures and farming practices. (iii) Identify strengths, weaknesses, opportunities and threats (SWOT) for the current disease reporting structures in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands and how they impacted their surveillance system components. (iv) Improve disease surveillance through capacity building training, survey development and apply this training through a brucellosis freedom survey in PNG, Vanuatu and the Solomon Islands and a prevalence survey in Fiji. (v) Examine the sensitivities of the surveillance system components in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands to detect *B. abortus* in cattle.

The research first sought to gain a better understanding of the status of Brucellosis in the Pacific Island Community and the region; the research also examined retrospective data to calculate the prevalence of the disease to determine its spread in Fiji since Fiji had an outbreak of the disease at that time. The methods used were a systematic literature review and a prevalence study using retrospective data from Fiji (Chapter 2).

The research sought to further enhance the understanding of the disease by examining which risk factors could have been associated with the outbreak of *B. abortus* on Dairy farms in the Tailevu province of Fiji. The methods used were a cross-sectional survey on the risk factors associated with the farms in the locality where *B. abortus* re-emerged in 2009 in Fiji (Chapter 3).

After completing the research studies in Chapter 2 and Chapter 3 it was evident that there was a poor understanding of the disease and disease surveillance capacities were weak, so the research documented and examined the reporting structures to identify gaps and areas that could be improved as well as on how policy support was impacting disease surveillance in the Pacific Island Community (Chapter 4). The next step was to build surveillance capacities for Fiji, PNG, Vanuatu and the Solomon Islands through the research activities as this was lacking, i.e. through the development of surveys to detect *B. abortus* in selected regions as funding was limited (Chapter 5).

The final step was to improve disease surveillance and reporting by examining the surveillance system components (SSCs) of Fiji, PNG, Vanuatu and the Solomon Islands to analyse the sensitivity of the systems to detect *B. abortus*. This aspect of the work focussed on the documentation of the surveillance system components (SSCs) for Fiji, PNG, Vanuatu and the Solomon Islands enabling the analysis and identification of where weaknesses were in the reporting system, thus allowing for recommendations for improvements to be made (Chapter 6).

The key findings from the research were as follows; Chapter 2, Bovine brucellosis has been present in PICTs for many years, yet it may not be considered important in many Pacific Islands and Territories. There has been very little literature published on *B. abortus* in the Pacific Island region over the last 20 years making it difficult to gauge the impact of the disease (Conclusion 1). The re-emergence of *B. abortus* in Fiji was most likely due to the lack of monitoring for the disease while disease surveillance is limited and poor in PNG, Vanuatu and the Solomon Islands (Conclusion 2). Chapter 3, the risks of brucellosis transmission within cattle on dairy farms in Fiji are high (Conclusion 3) since the existence of other animal species on the dairy farms in Fiji may harbour the *B. abortus* organism. Reporting of diseases to the animal health authorities was poor with the farmers (Conclusion 4). The risk of human infection was high with the farmers in Fiji (Conclusion 5). Farms having a history of reactor cattle to brucellosis and or tuberculosis were 30 times (OR= 30) more likely of being infected with the *B. abortus* organism (Conclusion 6). Farms that practised sharing of water sources for cattle within and with cattle from outside farms were 39 times (OR= 39) more likely of being infected with the *B. abortus* organism (Conclusion 7). Chapter 4, Surveillance programs and reporting structures are impeded by the lack of policy to support them (Conclusion 8). Reporting structures are affected by the vacant positions and shortage of veterinarians (Conclusion 9). Reporting structures are too long, hierarchical in nature and have multiple reporting branches which are not functioning well (Conclusion 10). Chapter 5, Lack of funds impacted surveillance programs in PICTs (Conclusion 11). Lack of technical expertise reduced disease surveillance capacities in PICTs (Conclusion 12). Outdated data on cattle population impeded the development of surveys for disease surveillance in PICTs (Conclusion 13). PNG, Vanuatu and the Solomon Islands all tested negative to *B. abortus* based on the survey sample sizes for selected regions (Conclusion 14). Chapter 6, the proportions of reports being made for Brucellosis and other diseases are low (Conclusion 15). The proportions of disease investigations being carried out by the animal health authorities are low (Conclusion 16). The survivability of samples collected, processed and sent to reference laboratories is low (Conclusion 17). Data for certain nodes in the country SSC's were limited affecting the countries sensitivity for detecting *B. abortus* (Conclusion 18).

Disease surveillance and reporting in the Pacific Island community is limited and poor thus there needs to be training to build capacity to improve these. There also needs to be policy development to support disease surveillance and reporting programs in the Pacific Island community; however this is difficult as funds are limited and national governments often have other priorities ahead of disease surveillance. Thus there is an important need to improve collaboration between, donors such as FAO and ACIAR as well as academic institutions and national governments to develop projects to improve disease surveillance in the Pacific Island community. There is also a need to improve disease surveillance and reporting using a holistic and regional approach which this research has started doing in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands. This allows the detailed examination of the surveillance system components (SSC's) thus identifying components that are weak and allowing for their improvement, which will increase the ability of the countries to detect diseases. A multi-sectoral approach is also needed to improve disease surveillance and reporting in the Pacific Island community, i.e. since most animal diseases are zoonotic, there is a need for the human and animal sectors to work together to develop programs to improve surveillance and reporting, e.g. using a "One Health Approach".

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CHAPTER 1

GENERAL INTRODUCTION

BACKGROUND OF THE PACIFIC ISLAND COMMUNITY

The Pacific Island Community is also referred to as Oceania; this is a geographic region that covers Melanesia, Micronesia, Polynesia and Australasia. It covers an area of more than 8.5 million square kilometres and has a population of more than 40 million people. It consists of 25 nations and territories spread over more than 25,000 Islands and islets of the western and central Pacific Ocean. Reflecting the great diversity in the region, some 1,200 languages are spoken in the Pacific island community with English and French often being official languages (Costa and Sharp, 2011). The Pacific Island Community is a vast region with many people of different ethnicities, cultures and practices making it diverse.

The Islands can be classified as “high Islands” and “low Islands”. High Islands are formed by volcanoes, and often can support more people and have fertile soils. The “low Islands” are reefs or atolls and are relatively small and infertile. Melanesia is the most populous group and contains mainly high Islands, while most of Micronesia and Polynesia are low Islands.

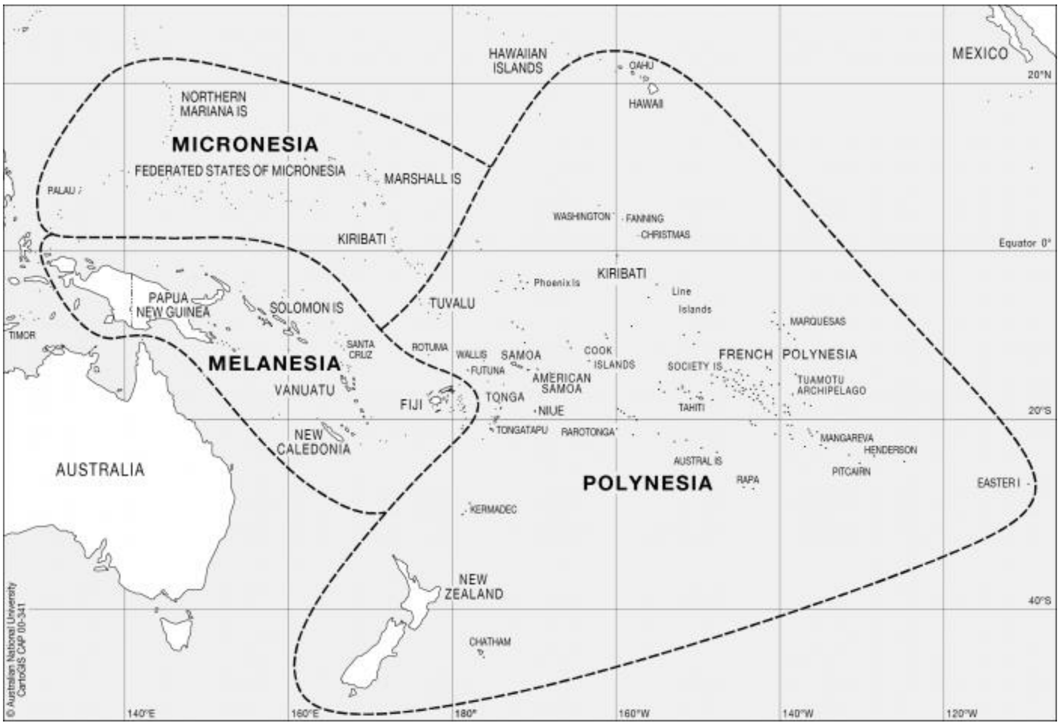

Figure 1-1: Sub regions in the Pacific island community
(Australian National University, 2018).

Pacific Island community (PICTs) are small countries and territories which are also referred to as areas, with populations ranging from 10,000 to 850,000, with the majority having a population of less than 200,000 people. A summary of geographic and demographic information of the countries and territories is provided in Table 1-1, (World Health Organisation, 2012).

Table 1-1: Key data for the 3 subregions in the Pacific island community

		Population		Per Capita (GDP)		Health Expenditure			General Government Expenditure on Health
Country or Territory	Year	Population (in '000s)	Urban Population (%)	Year	US$	Year	Per capita US$	As % of GDP	as % of Total General Government Expenditure
Melanesia									
Fiji	2010 est	854.0	51.9	2009	2978.95	2009 p	130.40	3.60	9.30
New Caledonia	2009 p	245.6	57.4	2008	36758.00	2008	3420.76	9.5	…
Solomon Islands	2009	515.9	18.6	2008	1014.00	2009 p	71.84	5.30	16.80
Vanuatu	2009	234.0	25.6	2009 p	2685.10	2009	104.00	3.90	13.60
Micronesia									
Federated States of Micronesia	2010 p	102.6	22.7	2008	2223.00	2009 p	333.33	13.80	20.60
Guam	2010 est	180.7	93.2	2005	22661.00	…	…	…	8.71
Kiribati	2010	103.5	48.3	2010 p	1307.40	2009 p	204.8	12.20	8.70
Marshall Islands	2012	54.4	71.8	2007	2851.00	2009 p	419.35	16.50	20.10
Nauru	2010 est	10.0	100.0	2006-07	2071.00	2009 p	625.00	10.85	18.50
Northern Mariana Islands	2010 est	63.1	91.3	2005	12638.00	2007	…	…	25.40
Palau	2010 est	20.5	83.4	2007	8423.00	2009 p	1000.00	11.20	16.70
Polynesia									
American Samoa	2010 est	65.9	93.0	2005 est	9041.00	2003	500.00	…	14.00
Cook Islands	2010 est	23.3	75.3	2009 p	10298.00	2009 p	503.60	4.50	10.60
French Polynesia	2010 est	268.8	51.4	2006	16803.36	2008	3361.57	13.09	29.00
Niue	2010 est	1.5	37.5	2006	8208.20	2009 p	1866.55	16.94	15.81
Pitcairn Islands	2009	.05	N	…	…	…	…	…	…
Samoa	2010 est	184.0	20.2	2009-10	2908.02	2009 p	161.04	5.30	14.50
Tokelau	2006	1.5	0.0	2003	612.50	2001-09	3705.64	…	10.46
Tonga	2010 est	103.4	23.4	2008-09	2988.00	2009 p	161.04	5.30	14.50
Tuvalu	2010 est	11.2	50.4	2002	1139.32	2009 p	312.50	10.50	11.00
Wallis and Futuna	2010 est	13.3	0.0	2004	3800.00	2008	…	…	24.00

Source: (World Health Organisation, 2012)

Agriculture plays a crucial role in economic development. Agriculture was the most dominant industry in all Pacific Islands in the 1950's and now can account for up to 28% of national GDP from the sector (Kakazu, 2003).

Livestock on the other hand also plays an important role in the lives of the people in the Pacific Island community in relation to livelihoods and food security. According to the Secretariat of the Pacific Community, Livestock is an important part of agriculture that supports food and nutritional security as well as livelihoods for the rural communities and should be enhanced to support future generations (Secretariat of the Pacific Communitiy, 2011).

THE SECRETARIAT OF THE PACIFIC COMMUNITY

This study was implemented in partnership with the Secretariat of the Pacific Community. The Secretariat of Pacific Community is now known as the Pacific Community (SPC) yet in some places in this document it is referred to as the Secretariat of the Pacific Community. This is because some of the publications in this thesis was published before the name change occurred.

SPC is a principal scientific and technical organisation in the Pacific region. It is an international development organisation owned and governed by 26 countries and territory members. The mission of SPC is to work for the well-being of the Pacific people through the effective and innovative application of science and knowledge, guided by a deep understanding of Pacific Island contexts and cultures. SPC is recognised for its ability to apply expertise in responding to the specific development needs of its members. SPC has a strong comparative advantage in being able to bring a multi-disciplinary approach to addressing some of the region's most complex development challenges, including climate change, disasters, non-communicable diseases, gender equality, youth employment, food and water security, and biosecurity for trade.

The member countries of SPC are; American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Mariana Islands, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, and Wallis and Futuna, and includes its four founding development partners which are; Australia, France, New Zealand and the United States of America (Pacific Communitiy, 2016).

THE FOOD ANIMAL BIOSECURIY NETWORK PROJECT

A Food Animal Biosecurity Network (FABN) was set up for Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands (SI) to make better use of the limited resources and build capacity for animal disease surveillance and enhance animal health field and laboratory capability in the Pacific Islands (Gummow, 2014). The work in this thesis formed part of those objectives and utilised the FABN network as a tool to communicate and coordinate activities in the countries. This enabled the collection of information on reporting structures, surveillance systems components (SSCs) as well as the implementation of the brucellosis risk factors survey in Fiji and the bovine brucellosis detection surveys in Papua New Guinea, Vanuatu and the Solomon Islands.

BRUCELLOSIS IN THE PACIFIC

Brucellosis remains as one of the most important zoonotic diseases worldwide, resulting in serious economic losses and public health impacts. The disease is caused by intracellular Gram-negative bacteria of the genus *Brucella*, which are responsible for a debilitating disease in humans and a chronic infection in domestic animals (Xavier et al., 2010). Division of the genus into six classical *Brucella* species is still widely used for historical and clinical reasons. These species are *Brucella melitensis, Brucella abortus, Brucella suis, Brucella ovis, Brucella canis,* and *Brucella Neotomae* (Neta et al., 2010). However, there is evidence supporting the notion that the genus *Brucella* should be re-classified as a monospecific genus with several biotypes (Verger et al., 1985). Eight biovars have been recorded for bovine brucellosis with biovar 1 being the most common isolated from cattle in countries where biovar prevalence has been studied, such as USA, Latin America and India (Neta et al., 2010). However other biovars have been isolated as well, e.g. biovar 2 was isolated from cattle in Fiji (Fiji Veterinary Pathology Report, 2014) and biovar 3 was isolated in Tanzania (Mathew et al., 2015).

In addition to the classical *Brucella spp*., the genus has recently been expanded to include marine isolates, which have been divided into two species, *Brucella ceti* and *Brucella pinnipedialis*, based on their preferential hosts i.e. cetaceans and pinnipeds, respectively (Foster et al., 2007).

Brucellosis can be found worldwide however the disease is well controlled in developing countries (OIE, 2009). Developing countries may not report brucellosis outbreaks as it is often not regarded as a priority and only countries that are members to OIE are obligated to report the disease (OIE, 2015). Papua New Guinea (PNG), Vanuatu and the Solomon Islands who were part of the Food Animal Biosecurity Network (FABN) of countries studied have not reported any clinical signs of bovine brucellosis since the 1980s (Martin and Epstein, 1999). Except for Fiji who currently have bovine brucellosis infection and are implementing disease control, there is no active animal disease surveillance programs being implemented to monitor the disease in the other Pacific island countries (Tukana et al., 2016).

Brucellosis remains to be an important re-emerging zoonosis worldwide and in particular developing countries as their surveillance capacities are limited (Tukana et al., 2016). Limited disease surveillance capacities mean that the Pacific island community countries are vulnerable to not only bovine brucellosis but to other transboundary zoonotic diseases as well and poor reporting is a major surveillance constraint to both emerging and endemic diseases (Halliday et al., 2012). Thus there is an important need to improve disease surveillance and reporting as well as have coordinated approaches to prevent and control transboundary and emerging diseases particularly in developing countries (Domenech et al., 2006). A more in depth review of brucellosis in the Pacific is given in Chapter 2.

PURPOSE OF THE RESEARCH

There have been no recent studies done on *Brucella abortus* in the Pacific island community so the status of the disease has been difficult to gauge and has been unknown for more than 15 years. Fiji had declared freedom from the disease to OIE in 1996 and had a re-emergence of the disease in 2009, so we suspected that poor monitoring for the disease could have contributed to this re-emergence in 2009 (Tukana et al., 2015). Once the disease was re-established in Fiji, it has been quite difficult to eradicate (Tukana and Gummow, 2016). On the other hand, Papua New Guinea, Vanuatu and the Solomon Islands have reported freedom from the disease however no active surveillance for the disease is currently being done in those countries (Tukana et al., 2016).

The disease is important in the sense that if surveillance systems and disease reporting are poor, the disease could re-emerge, which would have negative impacts on human and animal health. It would also impact the livelihoods of cattle farmers in the Pacific Island Community and this would increase the cost for island governments to control and eradicate the disease as well as increase the cost to the public health systems.

There is very little community awareness on the disease at the moment and with limited and poor surveillance capacities, the risks of the disease re-emerging in the Pacific Island Communities is high. Since there was a current outbreak of *B. abortus* in Fiji, it was a good opportunity to use that situation and study the cattle on those farms and use it as model for disease reporting and surveillance in the Pacific island community.

SCOPE OF THE THESIS

Since Fiji, Papua New Guinea, Vanuatu and the Solomon Islands had complex societies, i.e. with different ethnicities, languages, cultures and practices as well as brucellosis having a multifactorial nature, a structured approach was used to study the disease and to develop models to improve disease surveillance and reporting.

The study had five specific objectives:

1) Obtain a better knowledge on the status of bovine brucellosis in the Pacific Island Community.
2) Determine which risk factors were associated with the outbreak of bovine brucellosis in Fiji and how the risk factors could be related to the other Pacific Island Community countries cattle farming practices.
3) Identify weaknesses and strengths to improve the disease reporting structures in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands and how they impacted their surveillance system components.
4) Improve disease surveillance through capacity building training, survey development and implement a brucellosis freedom survey in PNG, Vanuatu and the Solomon Islands and a prevalence survey in Fiji.
5) Document and analyse the surveillance system components (SSCs) in place for the detection of bovine brucellosis in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands.

To achieve the first objective, a literature review was conducted on the status of bovine brucellosis (*B. abortus*) in the Pacific island community (Chapter 2). In addition, since there was an outbreak of *B. abortus* in Fiji, retrospective data from the Fiji Veterinary Pathology Laboratory was also compiled and analysed to determine the True Prevalence of *B. abortus* in the locality where the outbreak of the disease occurred in 2009. The True Prevalence of brucellosis was also calculated for the other provinces on the main island of Fiji (Viti Levu) to determine the spread of the disease, (Tukana et al., 2015). The serological tests used for *B. abortus* in Fiji were the Rose Bengal and indirect ELISA tests. The prevalence of *B. abortus* in Fiji and its serology was however based on the survey developed by the research for the PhD and are included in detail in Chapter 2 and Chapter 4.

To achieve objective 2 (Chapter 3), a survey was developed to collect information on the risk factors in Fiji on the farms in the locality where the outbreak of *B. abortus* had occurred. Univariate and multivariate analysis was then carried out on those risk factors to determine which ones had a strong association with the farms that had brucellosis.

To achieve objective 3 (Chapter 4), the disease reporting structures in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands were constructed with the country animal health and production officials and discussed before being finalised. A SWOT analysis was then carried out on the reporting structures to identify weaknesses and areas that could be improved to enhance disease surveillance and reporting.

To achieve objective 4 (Chapter 5) training was used as a tool to improve disease surveillance through the development and implementation of *Brucella* detection surveys in Papua New Guinea, Vanuatu and the Solomon Islands. Furthermore, a prevalence survey was also carried out in the Muaniweni district to determine the spread of the disease in the Naitasiri province in Fiji.

To achieve objective 5 (Chapter 6) descriptive models were developed using influence diagrams and stochastic scenario trees based on the surveillance system components (SSCs) documented for Fiji, Papua New Guinea, Vanuatu and the Solomon Islands. Probability information was further collected from the countries to populate the models to demonstrate the calculation of the sensitivities of the countries SSCs to detect bovine brucellosis. The use of influence diagrams and stochastic decision tree models were based on the approach for demonstrating disease freedom that was developed in this area by (Martin P.A.J. et al., 2007).

Figure 1-2 below represents the research process outlining the objectives and the methods used to achieve those objectives.

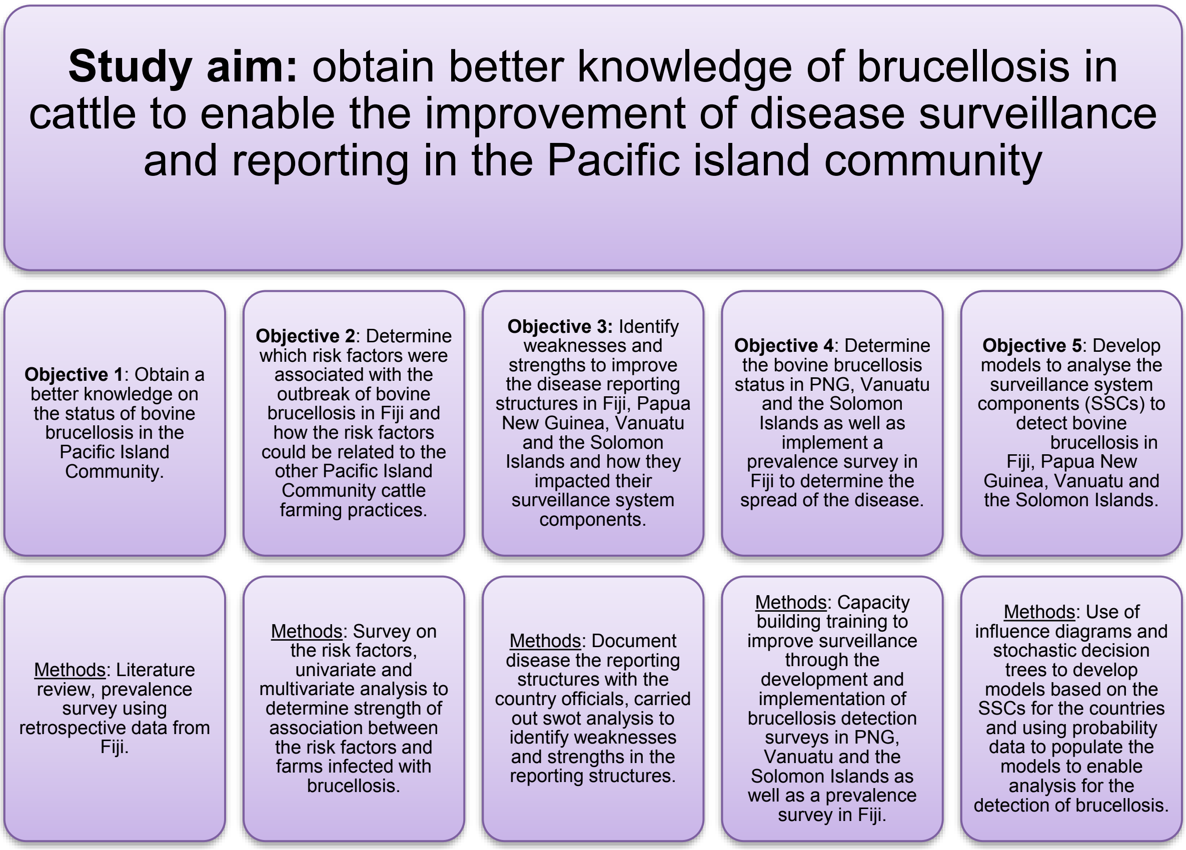

Figure 1-2: Diagrammatic representation of the research process

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CHAPTER 2

THE HISTORY OF BRUCELLOSIS IN THE PACIFIC ISLANDS AND ITS RE-EMERGENCE

Conference presentations relevant to Chapter

Tukana, A., Hedlefs, R., Warner, J., Gummow, B. The re-emergence of bovine Brucellosis in the Pacific Islands *(Oral presentation)*. 13th Australasia/Oceania Commonwealth Veterinary Association Conference, Nadi, Fiji, 2-6th September, 2013

Published as

Tukana, A., Hedlefs, R., Warner, J., Gummow, B., 2015. The history of brucellosis in the Pacific Island Countries and Territories and its re-emergence. *Preventive Veterinary Medicine Journal*, 122: 14–20; http://dx.doi.org/10.1016/j.prevetmed.2015.10.005

ABSTRACT

There are few publications on brucellosis within the Pacific Island Countries and Territories (PICTs). The reason is possibly because the cattle population has been reportedly free of the disease for many years until a re-emergence occurred in the Fiji Islands (Viti Levu) 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 the outbreak, Fiji declared freedom from *B. abortus* to OIE in 1996 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 2.40% in 2010, reached a peak of 3.49% in 2011 then reduced to 0.12% 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 management of exposed animals and monitoring for 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.

KEYWORDS

Brucellosis, Pacific Islands, Fiji, Cattle, Re-emergence, Review

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 human brucellosis (*Brucella melitensis*) (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 measures 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 sector 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 semi-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.

MATERIALS AND METHODS

Review of the literature

PubMed and Web of Knowledge

A semi-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 consisted of references and abstracts on life sciences for biomedical topics, which was 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.

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.

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.

The re-emergence of brucellosis in Fiji

Outbreak investigation

Prior to the re-emergence of the disease in 2009, Fiji declared freedom from *B. abortus* in 1996 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 for suspected presence of *B. abortus*. 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 2-1) on the remaining farms were also tested using the RBT. In 2010 samples (Table 2-2) were collected from farms that tested positive to RBT in 2009 and tested at the Fiji veterinary laboratory using the indirect ELISA test for confirmation of diagnosis, where standard procedures were used while testing the sera (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).

Sampling of cattle covered all farms in the 8 provinces on the main island of Fiji (Viti Levu) (Fig. 2-1 and Table 2-2) in 2011, 2012 and 2013. Dairy farms comprised the majority of blood samples (75.80%) followed by beef farms (20.77%) and mixed farms (3.43%), i.e. farms having some dairy and beef cattle. Samples collected were tested at the Fiji veterinary laboratory in Koronivia 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.

Structure of the brucellosis affected farms

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 by interview 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.

Post 2009 outbreak (Control measures)

Control measures followed the “test and slaughter” protocol where farms that tested 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 were also conducted by the animal health authorities on the farms in relation to the risks of movement of cattle on or off the farms (Fiji Veterinary Pathology Report, 2014).

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 and equations 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 2-1;

In Equation 1, TP is the true prevalence, AP the apparent prevalence, Se the test sensitivity and Sp the test specificity. The Se and Sp used for the RBT were: Se = 81.20%, Sp = 86.30% and for the Indirect ELISA, Se = 96.00%, Sp = 93.80%, (Gall and Nielsen, 2004).

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. Other methods of estimating prevalence exist from different authors but they do not account for clustering e.g. (Rogan and Gladen, 1978). Failure to account for clustering could bias the overall prevalence estimate if there is considerable variation between clusters.

Equation 2-2;

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 2-3;

$V = Pe2 (\sum n2) – 2Pe (\sum nm) + (\sum m\ 2)$

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).

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).

RESULTS

Semi-systematic Review of the Literature

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; 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, these are presented below.

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 on, 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 a significant percentage (9%) of men and women in rural areas had antibodies for *Brucella* possibly indicating a role of agriculture in transmission of the zoonotic disease (Ram et al., 1982). There were reports from Wallis and Futuna between 2003 and 2010 which provided evidence of a mean annual brucellosis 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 repeated public awareness campaigns.

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 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).

In 1991, a book published by the Fiji School of medicine on Food and Nutrition and related diseases had a small section which reported on the prevalence of bovine brucellosis in Fiji between 1983 and 1988, these were; 0.70% (1983), 1.70% (1984), 1.20% (1985), 0.90% (1986), 0.91% (1987) and 0.45% (1988), the results were for cattle in general and did not specify prevalence between dairy or beef cattle (Jansen et al., 1991).

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).

Past control measures and evaluation

As early as 1972, PNG reported the use of *B. abortus* 45/20 adjuvant vaccine to assist in the brucellosis eradication campaign. Using the 45/20 adjuvant vaccine was thought to provide protection from the disease in young, immune suppressed cattle and pregnant cows and did not interfere with the ability to pick up cattle positive to the disease during serology, however its success was limited, (Siadat et al., 2012). 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.

WAHID Database

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).

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).

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 2 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 2 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 0.12% and 2.02% 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 0.00% to 1.83% (2010), 0.00% to 4.19% (2011), 0.00% to 1.81% (2012), 0.00% to 0.21% (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 2-1. Table 2-2 presents the individual prevalence's of brucellosis for the 8 provinces and 2 subdistricts on the main island of Fiji. Table 2-2 also shows the 95% CI for estimated TP of brucellosis on the main island of Fiji each year of the study. Fig. 2-1 presents a map of the main island in Fiji showing provincial boundaries.

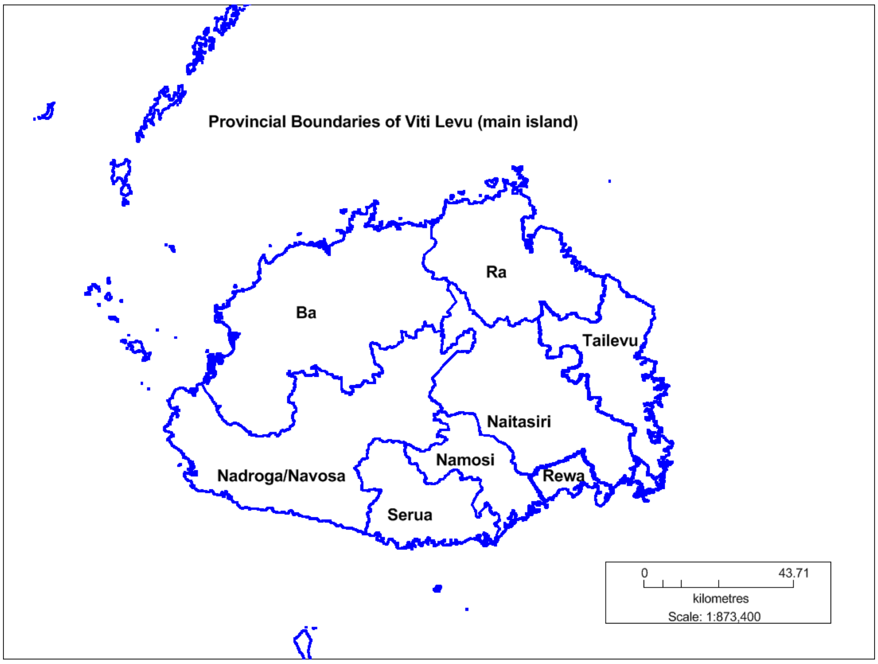

Figure 2-1: Map of the main island in Fiji showing provincial boundaries

Table 2-1: 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	6.43
2	Waimaro	8	3551	9	0.25	0.00
3	Waidewara	11	912	5	0.55	0.03
4	Waidalice	15	690	6	0.87	0.35
5	Verata/Babavoce	4	315	4	1.27	0.76
6	Tailevu South	3	479	7	1.46	0.95
7	Sawakasa	12	723	0	0.00	0.00
8	Namalata	3	181	2	1.10	0.59
9	Naitutu	6	255	5	1.96	1.45
10	Nabilo	3	177	1	0.56	0.05
11	Deepwater	10	1255	21	1.67	1.16

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

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

Province & Sub districts	RBT Results (%) 2009		Indirect ELISA Results (%) 2010		2011		2012		2013	
	AP	TP	AP	TP	AP	TP	AP	TP	AP	TP
Tailevu	1.50	0.99	3.11	2.95	2.73	2.57	1.47	1.31	0.10	0.00
Naitasiri	-	-	2.82	2.66	11.35	11.19	6.60	6.44	0.69	0.53
Rewa	-	-	1.04	0.88	1.39	1.23	1.18	1.02	0.59	0.42
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	1.15	0.20	0.00	0.00	0.00
Tavua (sub district)	-	-	0.00	0.00	0.65	0.49	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	0.84	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)	-	0.12 to 2.02	-	0.00 to 1.83	-	0.00 to 4.19	-	0.00 to 1.81	-	0.00 to 0.21

RBT=Rose Bengal Test; AP=Apparent Prevalence; TP=True Prevalence; ELISA=Enzyme-linked immunosorbent assay

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 ($P < 0.05$).

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).

DISSCUSSION

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 neither the FABN countries nor any of the other Pacific island countries except for Fiji which is 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.

A Brucellosis and Tuberculosis Eradication Campaign (BTEC) was implemented in the FABN countries in the late 1970's and early 1980's. Using the test and slaughter method, *B. abortus* was thought to be eliminated from the FABN project countries in the early to mid-1980 due to the absence of reported symptoms of cattle abortions (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 the detection 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. In addition, since the RBT has an average sensitivity of only 81% it is possible that infected cattle could be missed despite the RBT's widespread use as a screening test.(Gall & Nielsen, 20004) (OIE, 2012a), particularly if quarantine of affected farms is difficult to enforce. 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).

The re-emergence of Brucellosis in Fiji

The Wainivesi locality (Table 2-1) which had 12 farms, recorded the highest prevalence (6.44%) 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 pockets of cattle e.g. draught 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 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 2.40% (2010) to 0.12% (2013) could be attributed to the control programs implemented by the animal health authorities in Fiji. The highest true prevalence was 11.19% which was recorded for the Naitasiri province in 2011 and was followed by the Tailevu province with a prevalence of 2.59% (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 the 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.

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. Even though PNG, Vanuatu and the Solomon Islands declare freedom from brucellosis, there is no monitoring for the disease done. A study of the literature does not preclude the existence of the disease or the possibility of it going undetected. The lack of active animal disease surveillance to monitor for *B. abortus* in Fiji could have been one of the reasons why the disease was not detected earlier. The study therefore reinforces the need for continued active surveillance despite the disease being apparently absent. Even though the literature indicated that brucellosis has been found in pigs and dogs in Tonga, PNG and Wallis and Futuna and the Solomon Islands, it is most likely *B. suis* or *B. canis*. The demographics of the farms in Fiji indicate that fostering of calves and retention of heifers was a common practice and thus a potential reservoir for brucellosis, which 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. It seems therefore that once the dis-ease re-emerges it is very difficult to eliminate; this could be due to the unregulated movement of infected cattle to other provinces or to the practice of retaining heifers and affected herds, a known risk factor for recrudescence. The presence of other potential animal reservoirs should also be explored further. Awareness and monitoring in the Pacific Island countries and Territories is going to be important in future for the detection of brucellosis.

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CHAPTER 3

DAIRY FARM DEMOGRAPHICS AND MANAGEMENT FACTORS THAT PLAYED A ROLE IN THE RE-EMERGENCE OF BRUCELLOSIS ON DAIRY CATTLE FARMS IN FIJI

Conference presentations relevant to Chapter

Tukana, A., Gummow, B. The risk factors for Brucellosis: A Cross Sectional study on cattle farms in Fiji *(Oral presentation)*. College Science Week Scientific Conference, QT Gold Coast, Surfers Paradise, Australia, 10-12th July 2014

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ABSTRACT

Little is published on risk factors associated with bovine brucellosis in Pacific island communities. The 2009 re-emergence of bovine brucellosis in Fiji enabled us to do an interview based questionnaire survey of 81 farms in the Wainivesi locality of the Tailevu province on the main island of Fiji to investigate what risk factors could have played a role in the re-emergence of the disease. The survey was conducted on 68 farms that had no positive cases of bovine brucellosis and on 13 farms in the same area where cattle had returned a positive result to the *Brucella* Rose Bengal Test. Descriptive statistical methods were used to describe the demographic data while univariate analysis and multivariate logistic regression were used to evaluate the association between the selected risk factors and the presence of brucellosis on the farms at the time of the outbreak. The demographics of Fijian dairy farms are presented in the article and the biosecurity implications of those farming systems are discussed. Two risk factors were strongly associated with farms having brucellosis, these were; history of reactor cattle to brucellosis and or bovine tuberculosis on the farm (OR=29, $P \leq 0.01$) and farms that practised sharing of water sources for cattle within and with outside farms (OR=39, $P \leq 0.01$). Possible reasons why these are risk factors are also discussed. The potential risks for human health was also high as the use of personal protective equipment was low (15%). A high proportion of farmers (62%) could not recognise brucellosis thus contributing to the low frequency of disease reports (44%) made. The article also highlights other important risk factors which could be attributed to farming practices in the region and which could contribute to public health risks and the re-emergence of diseases.

KEY WORDS

Cattle farming; demographics; brucellosis; risk factors; public health; Fiji

INTRODUCTION

Brucellosis is an important bacterial disease of cattle (Maia et al., 2013) which has the potential to infect both humans and animals (Garner et al., 2003). In humans brucellosis is debilitating and infects abattoir workers, veterinarians, and farmers while in animals the disease causes abortions and stillbirths (OIE, 2009).

People commonly contract brucellosis (*B. abortus*) infection through the ingestion of raw milk or direct contact with infected materials (Solorio-Rivera et al., 2007). Cattle are mainly infected through mucous membranes following contact with contaminated materials and by inhalation (OIE, 2009). The transmission of brucellosis occurs horizontally from animal to animal during parturition or vertically to calves in utero or via milk (Nicoletti, 1980).

The Pacific island region generally has been free of *B. abortus* due to eradication until 2009 when the disease re-emerged again in the Wainivesi locality of Fiji (Tukana et al., 2015). The Wainivesi locality which sits in the Tailevu province is a major dairy cattle area in Fiji and this was where abortion storms were first noticed and reported in 2009 to Fijian animal health authorities (Tukana et al., 2015). Fiji has high numbers of cattle, more than other countries in the Pacific island community except for Vanuatu and the re-emergence of brucellosis has had an impact on its economy, which is why it is important to have a better understanding of the reasons behind the outbreak (Secretariat of the Pacific Community, 2009). In addition to the outbreak of *B. abortus* in 2009, Fiji's cattle population also has bovine Tuberculosis (TB) and the Fijian animal health authorities have been implementing an eradication program to control both these diseases at the same time. These are based on the RBT to confirm herd infection and the ELISA test to confirm individual cow infection. The control program however has failed to eradicate both diseases over the last 7 years thus providing further evidence for the need to understand more about the risk factors associated with the 2009 outbreak of brucellosis in order to provide better targeted intervention (Tukana et al., 2015).

Fiji represents a large part of the Pacific island community with people mostly Melanesian, Polynesian and of other mixed ethnicities. Therefore, one can expect cultural practises similar to those of many Pacific Islands countries and Fiji is an ideal model for examining cattle farming practices in the Pacific Island community in general (Kayser et al., 2006). An understanding of these practices may provide insight into why infectious diseases of cattle re-emerge in the region as a whole.

It was therefore decided to investigate what risk factors could influence disease transmission of bovine brucellosis and similar communicable diseases with public health impacts within the dairy farms in Fiji. This was done in the context of the *B. abortus* outbreak reported in Fiji in 2009 (Tukana et al., 2015) (Gul and Khan, 2007). In addition, since little is published about the disease control behaviours of Fijian farmers and their farming practises, these were also examined in the context of the *Brucella* outbreak.

MATERIALS AND METHODS

Study design

The study area was located in the Tailevu province on the main island of Fiji, Viti Levu, (Fig.3-1). The climate in the Tailevu province is ideal for the maintenance of bacteria as it consists of a cooling trade wind from the east to south-east for most of the year with maximum temperatures rarely moving out of the 31C to 26C range throughout the year.

Annual rainfall on the province is between 2000mm and 3000mm on the coast and low lying areas and up to 6000mm in the mountains (Fiji Report, 2014). A total of 87 cattle farms were located in the selected province and they were all included in the study, however only 81 farmers participated in the survey as some farmers felt that providing information on their disease status was sensitive (Fig. 3-1). Those farms were studied because that was the area where in 2009 the outbreak was first reported and where all the farms were tested positive by the Department of Agriculture for brucellosis using the Rose Bengal Test prior to a control programme being implemented. These farms were later tested and confirmed positive for brucellosis using the indirect ELISA test. A cross sectional study of these farms was carried out where a *Brucella* positive farm was defined as a farm where one or more cattle had tested positive for *Brucella* on the RBT. A *Brucella* negative farm on the other hand, was a farm where no cattle had tested positive to the RBT (Tukana et al., 2015). These were then related to specific risk factors and discussed below.

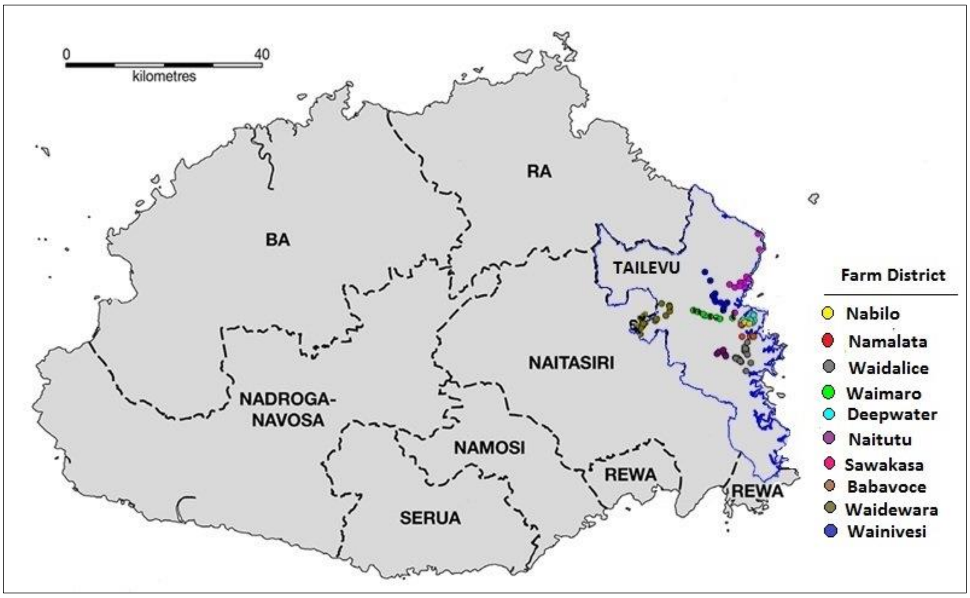

Figure 3-1: Map of the main island in Fiji showing provincial boundaries and the Tailevu Province indicating the dairy farms that were surveyed.

Developing the questionnaire

A draft questionnaire was developed in 2013 to collect information on the farms in the Tailevu province, which included risk factors that could have played a role in the brucellosis outbreak. The questionnaire was developed using the software EPi Info 7 (Centers for Disease Control, 2013) and included questions on farm demographics and risk factors associated with management, the milking process, disease transmission, public health and presence of other livestock species. Since the re-emergence of brucellosis occurred in 2009, farmers were asked to provide information based on their situation in 2009 and not 2013 when the questionnaire survey was carried out.

Pre-testing the questionnaire and implementing the survey

The questionnaires were pre-tested with the field staff of the Fiji Veterinary Laboratory in Koronivia. A half-day session was arranged with staff where the different sections of the questionnaire were explained to them. They then formed pairs where one acted as the farmer and the other as the animal health official interviewing them. After the mock interview, where the forms were filled out, a session took place where issues relating to clarity of the questionnaire were raised and possible solutions discussed to improve the final questionnaire. After incorporating the changes from the pre-test exercise, some questionnaires were then pre-tested with ten (11%) farmers in the field. Sections that were still unclear were further modified. The survey questionnaire was then implemented where the field staff of the Fiji Veterinary Pathology Laboratory carried out face to face interviews in the English language with the dairy cattle farmers in the Wainivesi locality (Tailevu province) in 2013 in conjunction with the testing programs that was being carried out to control bovine brucellosis and tuberculosis.

Ethics approval

Consideration for animal and human ethics was incorporated in the questionnaire using the James Cook University policy guidelines. Ethical approval to carry out the study was obtained from the human and animal ethics committees at the university (approval reference: A1740, H4414).

Univariate data analysis

Data from 157 factors collected from the survey questionnaires was entered into the software program Epi Info 7 and then grouped and analysed according to the following areas; farm demographics and management, the milk production process, disease transmission, public health, breed and the presence of other livestock species on the farm. Those variables that were irrelevant were removed from the process, e.g. name of the farmer, phone contact, email contact, date, etc. Frequency counts and means for each factor were then calculated using Epi Info 7 (Table 3-1). The Chi-square test (Table 3-2) was then used for univariate analysis to screen for the association between the risk factors and RBT positive farms. Factors that had P-values of ≤ 0.15 on the chi-square test were selected for multivariate logistic regression modelling (Katz, 1999). To test for possible collinearity between variables the correlation between each pair of risk factors were analysed using the Pearson's and Spearmean's correlation coefficients. Factors that had correlations > 0.5 were examined further for possible collinearity and if warranted these factors were run in separate multivariate logistic regression models.

Multivariate logistic regression modelling

Using the Number Cruncher Statistical Software (NCSS) program, multivariate logistic regression was used to identify significant risk factors and to control for potential confounding within the data (Hintze, 2013). A hierarchical forward selection method was employed in the multivariate logistic regression analysis where the Wald test was used to determine significant risk factors associated with farms that were confirmed as having brucellosis and a P-value of ≤ 0.05 was considered significant (Hintze, 2013). The goodness of fit was also tested by using the R^2 value, final likelihood ratio and the percentage (%) of the data correctly classified. The studied factors were first re-grouped into three categories, i.e. management factors, breed and the presence of other animal species on the farm and modelled separately. Some factors were producing quasi separation during the multivariate logistic regression analysis so were removed from the analysis and evaluated only on their univariate results, i.e., Odds Ratio (OR) and Chi-square results. Factors that had P-values ≤ 0.05 on the univariate analysis were considered important enough to warrant further discussion even though they were not significant in the multivariate logistic regression model.

RESULTS

Demographic data frequency and means

Frequencies and means for the demographic data are presented in Table 3-1 according to the different aspects of farming.

Table 3-1: Results of the questionnaire survey of cattle farmers in the Tailevu Province, Fiji for 2009

Farm demographics and management factors	Results
Farms that participated in the survey	93%
Farms being owned and managed by males	100%
Breakdown of cattle farm type; Dairy	97%
Breakdown of cattle farm type; Beef	3%
Mean no. of cattle per farm	134 (range; 15-951)
Mean no. of cattle per hectare of land (animal density)	2.3
Bulls left to run with dry cows and heifers	100%
Use of improved pastures	75%
Use of rotational grazing	95%
Use of supplementary feed	79%
Farms with night sheds for adult cattle	6%
Farms with calf sheds	67%
Type of cattle herds; closed	62%
The milk production process factors	
Farms that keep production records	84%
Farms with milking sheds	93%
Milking sheds with clean water available	95%
Milking sheds with good concrete floor	96%

Milking sheds with good hygiene	58%
Practice of hand milking (≤ 25 cows)	64%
Practice of machine milking (≥ 25 cows)	36%
Mean no. of milking cows per farm	43.94, (range; 2-300, median = 19)
Mean no. of dry cows per farm	27.65, (range; 2-225, median = 10)
Mean milk production per cow	6.36, (range; 2-12, median = 6)
Mean lactation period per cow	226, (range; 6-300, median = 225)
Farms that use water for cleaning the cows udder before milking	100%
Mastitis occurrence on the farms	39%
Farms monitoring for mastitis	5%
Use of antibiotics to treat mastitis in lactating cows	36%
Use of dry cow therapy for mastitis	8%
Farms that clean their milk machines	93%
Farms that use disinfectants to clean their milk machines	72%
Disease transmission factors	
Farms infected with bovine brucellosis	16%
Farms infected with bovine tuberculosis	9%
Farms infected with bovine brucellosis and tuberculosis	6%
Farmers able to recognise animal diseases	38%
Farmers who report animal diseases to the authorities	44%
Farmers who report animal diseases to only if it affected their livelihood	43%
Frequency of animal health authority farm visits	53%
Relationship between farmers and the animal health authorities	51%
Farms that practise fostering of calves to increase herd sizes	22%
Farms that restrict movement of animals from outside	14%
Farms that have people moving in and out daily	27%
Farms that had brucellosis reactor cattle on their farms	28%
Farms that isolated sick animals	14%
Farms that had livestock sharing water sources within and with other farms	26%
Farms that had proper fences	84%
Farms that purchased cattle from other farms to increase herd sizes	27%
Farms that isolated new cattle on the farm	6%
Public health, breed and the presence of other livestock species factors	
Farmers that reported knowing what brucellosis was	93%
Farmers that reported knowing the cause of brucellosis	73%
Farmers that reported brucellosis was caused by aborted materials	36%
Farmers that reported brucellosis was caused by faeces	7%
Farmers that reported brucellosis was caused by infected meat	32%
Farmers that reported brucellosis was caused by infected milk	5%
Farmers that reported brucellosis was caused by cattle urine	7%
Farmers that reported brucellosis was caused by other sources unknown to them	14%

Use of PPE for routine farm work	15%
Use of PPE during high risk situation	10%
Farmers that disposed aborted materials by burning	12%
Farmers that disposed aborted materials by burning and burying	9%
Farmers that disposed aborted materials by burying	41%
Farmers that disposed aborted materials by allowing dogs to consume them	1%
Farmers that did nothing at all to dispose aborted materials	37%
Farmers that consumed uninspected beef	47%
Farmers that consumed unpasteurised milk	100%
Farmers that handled unpasteurised milk to produce ghee	35%
Farms selling cattle to the traditional market	33%
Breed:	
Breed of cattle; Friesen	67%
Breed of cattle; Jersey	11%
Breed of cattle; Mixed breed (Cross bet. Friesen and Jersey)	21%
Breed of cattle; Other breeds	1%
Presence of other livestock and animal species:	
Mean no. of pigs	5.54, (range: 0-173, median=0)
Mean no. of chickens	15.25, (range: 0-207, median=0)
Mean no. of dogs	2.00, (range: 0-10, median=2)
Mean no. of cats	0.84, (range: 0-12, median=1)
Mean no. of horses	1.48, (range: 0-25, median=0)
Mean no. of sheep	0.68, (range: 0-35, median=0)
Mean no. of goats	6.00, (range: 0-170, median=0)
Mean no. of ducks	4.99, (range: 0-200, median=0)

Univariate analysis and multivariate logistic regression

After screening and analysing the different groups of risk factors, 17 factors (Table 3-2) were selected from the initial 157 factors for the multivariate logistic regression model based on a Chi-square P- value of ≤ 0.15 (Katz, 1999). Under the univariate analysis (Table 3-2) 8 factors were significant at P ≤ 0.05, these were; Having a history of reactor cattle on the farms (OR= 62, P ≤ 0.01), poor hygiene conditions within cattle infrastructures (OR= 11, P ≤ 0.01), fostering of calves (OR= 9, P ≤ 0.01), shared water sources (OR= 79, P ≤ 0.01), infected cattle not isolated (OR= 19, P ≤ 0.01), poor hygiene conditions within the milk shed (OR= 11, P ≤ 0.01), having bovine TB infection (OR= 21, P ≤ 0.01) and the sale of cattle to traditional markets (OR= 0.14, P ≤ 0.05).

From the 8 factors found to be significant ($P \leq 0.05$) under the univariate analysis, 3 caused quasi separation under the multivariate logistic regression and were removed from the process, these were; infected cattle not isolated, having bovine TB infection and the sale of cattle to the traditional markets.

During the multivariate analysis, two factors (Table 3-3) were strongly associated with farms having brucellosis ($P \leq 0.05$), these were; history of having reactor cattle to brucellosis and or tuberculosis on the farms (OR= 30, $P \leq 0.01$) and farms that practised sharing of water sources for cattle within and with outside farms (OR= 39, $P \leq 0.01$). Correlation between each pair of risk factors was generally poor with values < 0.05 indicating that collinearity was unlikely to be influencing the models, those that had correlation values ≥ 0.5 were run separately in the analysis but they did not show any significant association with farms having brucellosis in the final analysis. The final multivariate model was as follows; Model for Brucellosis Positive Status = - 4.02 + 3.67 * Shared Water Sources + 3.39 * History of reactor cattle. The Model R^2 was 0.62, the final likelihood ratio was -13.50 and the percent correctly classified was 93.80% which indicated that the model was a good predictor for having brucellosis on the farm.

Table 3-2: Univariate results for selected risk factors assumed to be associated with *Brucella* positive farms in the Tailevu Province in Fiji for 2009

Risk factors	Odds Ratio	95% CI		Chi-square	P-value	Disease status Cases (n=13)	Control (n=68)
Management factors		**Lower**	**Upper**			**Yes**	**Yes**
History of reactor cattle on the farm	62.18	7.32	528.36	27.48	< 0.01	12	11
No knowledge neighbouring farm status	0.33	0.1	1.12	2.28	0.13	6	49
No screening of farms	2.32	0.27	19.68	6.78	0.01	7	60
No proper fence lines	2.91	0.74	11.48	16.69	< 0.01	9	9
Poor hygienic conditions within infrastructures	10.76	2.19	52.67	8.90	< 0.01	11	24
Fostering of calves	9.28	2.52	34.17	48.97	< 0.01	13	5
Shared water sources	78.67	9.09	680.25	31.53	< 0.01	12	9
People movement within and from outside the farm on a daily basis	2.79	0.82	9.49	4.08	0.04	6	53
People movement within and from outside the farm on a weekly basis	1.34	0.39	4.52	6.78	0.01	7	60
People movement within and from outside the farm on a monthly basis*	0.32	0.04	2.67	22.57	< 0.01	1	54
Infected cattle not isolated*	18.67	4.22	82.53	12.85	< 0.01	7	64
Unavailable clean water in the milk shed*	2.90	0.47	17.85	7.68	0.01	2	4
Poor hygienic conditions within the milk shed	10.76	2.19	52.67	43.65	< 0.01	11	3
Poor floor condition of the milk shed*	2.61	2.19	0.58	25.33	< 0.01	10	7
Bovine TB infection*	20.63	3.42	124.34	13.23	< 0.01	5	2
Sale of cattle to the traditional market*	0.14	0.02	1.09	3.31	0.07	1	26
Infrastructure for young cattle	3.21	0.65	15.6	8.28	< 0.01	2	43

* Risk factors that caused quasi separation during the multivariate logistic regression analysis

Table 3-3: Multivariate logistic regression final model results for risk factors associated with *Brucella* positive farms

Independent factors	P-value (Wald test)	Odds ratio	Confidence interval 95%	
			Lower	Upper
History of reactor animals on the farm	< 0.01	29.55	2.81	311.98
Shared water sources	< 0.01	39.12	3.78	405.12

Model for Brucellosis Positive Status = - 4.02 + 3.67 * Shared Water Sources + 3.39 * History of reactor cattle; Model $R^2 = 0.62$. Percent correctly classified = 93.80%. Final likelihood ratio: -13.50.

DISCUSSION

There is little literature published on Polynesian and Melanesian cattle farming practices in the Pacific island community and this study provided an opportunity to present a better understanding of some of the risk factors related to cattle farming practices that could have played a role in the re-emergence of *B. abortus* in Fiji.

Having a history of reactor cattle on the farms to brucellosis and or tuberculosis, i.e., farms that were previously infected with brucellosis before eradication and declaration of freedom to OIE in 1996 was significant in the multivariate logistic regression final model, (Tukana et al., 2015). This could mean that some cattle may have been carriers of brucellosis for years, with signs going unnoticed until 2009 (Poester et al., 2013).

The other significant factor in the final multivariate logistic regression model was shared water sources. The practice is normal in Fiji where rivers border farms and cattle from different farms share the same water sources increasing the risks of brucellosis transmission. It is also normal that water sources are placed between fences so cattle from different paddocks could share the same water source.

It was also evident from the questionnaire survey that the type of farming systems practiced in Fiji had a high percentage of open and mixed herds, thus allowing different classes of cattle to mingle within and from outside farms. Having a high density of cattle also created opportunity for greater contact and for the spread of brucellosis (Baudracco et al., 2011). The existence of other animal species on the farm could also be important as they could have acted as potential carriers of *B. abortus* and Mycobacterium bovis, but these however were only present in large numbers on a few farms and the univariate and multivariate analysis failed to show any association with other animal species. Hygiene was poor on many of the farms surveyed and this was evident in the milking sheds, creating an environment where infectious diseases could be maintained and spread, particularly during milking. Poor hygiene could also account for the high occurrence of mastitis reported on the farms surveyed, which were often left untreated.

Knowledge of brucellosis and other livestock diseases was low, i.e. most farmers reported knowing what brucellosis was, yet about a third of them did not know what caused it. In addition, a high number of farmers were not able to effectively recognize diseases unless cattle became lame or died. Hence by the time a disease is recognised by the farmer in those communities the disease is likely to be widespread within the herd especially for a disease such as brucellosis which does not show clear symptoms.

Reporting animal diseases to the relevant authorities (veterinary services) was very poor as less than half of the farmers interviewed indicated that they would only report diseases if they felt it would affect their livelihoods. This was compounded by the fact that routine farm visits by the veterinary services was limited. More than half of the farmers interviewed, indicated that veterinary services visits were irregular. Farm visits by the human health authorities was even poorer with almost all the farmers interviewed indicating that this did not occur. This was probably due to the fact that human health authorities would only visit cattle farms if people were getting sick. This means that authorities were unlikely to identify emerging or re-emerging diseases until the disease is well established and having a major impact.

Unregulated sale of breeding cattle to other farms and the traditional markets from infected farms could also be potential routes for the spread of brucellosis within cattle herds in Fiji even though the factor was insignificant on logistic regression. About a third of the farmers interviewed indicated that this was being practiced. The animal health and production authorities have legislation forbidding the movement and sale of cattle from infected farms as all infected cattle must only go to the abattoir for slaughter and inspection (Laws of Fiji, 2012). However with limited manpower and resources such as vehicles, regulating unwarranted movement of cattle is difficult in Fiji.

In Fiji it is quite normal to see people working on farms with minimum or no personal protective equipment (PPE) at all. Using minimum or no PPE at all is due to not having the financial resources to procure PPE and because most farmers are not aware of the risks of exposure to zoonotic diseases. This is evident in the study which indicated that the use of PPE for routine work was very low, and surprisingly even lower when dealing with high risk situations, e.g. when delivering calves. Handling of cow afterbirth and aborted materials was another area of concern as more than one third of the farmers interviewed indicated that they did nothing in relation to disposing of those materials. The low levels of PPE use on the farms in Fiji increases the risk of exposure to zoonotic infectious diseases.

The practice of using cattle in traditional Fijian ceremonies is common in Fiji where raw meat is distributed to different hierarchal groups and households at village level. If the meat was infected with brucellosis then those handling it could get infected with the bacteria during that process (OIE, 2009). Cattle offal such as lymph nodes, udder and the liver are considered a delicacy and Fijians eat these before the main course, i.e. they roast them over hot stones while preparing food in the earth oven (lovo) for the main feast. Increasing awareness on the public health risks of handling infected meat and offal could be an important factor to consider in controlling brucellosis in Pacific Island countries.

The consumption of unpasteurised milk in Fiji is common and this has public health risks, i.e. both brucellosis and tuberculosis could be spread to humans through this practice (Jeffrey and Pa¨ ivi, 2009). Therefore there is a need for more awareness on the public health risks associated with the practice of consuming unpasteurised milk as well as regulation by the authorities to prohibit the sale of unpasteurized milk if there is a current infection of bovine brucellosis and bovine tuberculosis in the country.

A weakness of the study was the small number of *Brucella* infected (n=13) farms in the survey. This reduced the power of the multivariate logistic regression making it difficult to show association between risk factors and infected farms. The total number of farms surveyed (81) were also relatively small for an ideal multivariate logistic regression model resulting in quasi separation and the maximum model converging at a very low iteration level leading to wide confidence intervals and high P-values i.e. > 0.05 for some risk factors (Hintze, 2013). The fact that the study was also carried out in 2013 whilst the re-emergence occurred in mid-2009 could have created some recall bias when the farmers were surveyed. However, this is the first in-depth study of dairy farming practices in Fiji and we feel the results still carry enough weight to highlight important weaknesses in farm management as well as in animal and public health practices that could contribute to the spread of important zoonotic diseases like brucellosis in PICTs.

CONCLUSIONS

It can be concluded that having a history of reactor cattle to brucellosis and or tuberculosis on the farm and sharing water sources for cattle are two important risk factors in the spread of brucellosis within the Fijian farming communities.

The lack of hygiene, on farm biosecurity and cultural practices in Fijian as well as Pacific Island communities are likely to play a role in the spread of brucellosis and other infectious diseases as people animal contact and contact with raw meat and organs during ceremonies is high. Training to improve hygiene, management, biosecurity capacities and increasing awareness of the risks of brucellosis in the farming communities could potentially reduce the spread of the disease.

The monitoring of unregulated movement and sale of cattle from infected farms needs to be improved to help reduce the spread of brucellosis. By monitoring and having increased awareness programs, farming communities are expected to have better knowledge of the risks and impacts of brucellosis and thus contribute more effectively to the reporting and control of animal diseases. The results of our study present an ideal opportunity for implementing a one health approach to reduce the risk of further spread and outbreaks of brucellosis in Fiji and Pacific Island Countries and Territories (PICTs).

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COMPLIANCE WITH ETHICAL STANDARDS

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving humans and animals were in accordance with the ethical standards of the James Cook University policy and guidelines. Ethical approval to carry out the study was obtained from the human and animal ethics committees at the university (approval reference: A1740, H4414).

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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CHAPTER 4:

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 the 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 that 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 demonstrating 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, improves surveillance capacity in resource poor countries.

KEYWORDS

B. abortus, Cattle, Animal disease surveillance, Prevalence, Training, Pacific Islands, Tropics

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 310C to 260C 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 are 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 Community, 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 are 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 Community, 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 Community, 2009). Smaller cattle farmers meet the demands for the domestic markets and cattle play an important source of milk, beef, and 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 were 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 Community, 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, (Cannon and Roe, 1982).

Equation 4-1; n = [I - (I -a) 1/D] [N - (D - 1)/2] (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 5th 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.4-1a, (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.4-1b). 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).

Vanuatu

Two Islands were focused on in Vanuatu. These were Efate and Santo Islands (Fig.4-1c). 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, 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 (N1) 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 (N1) 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.4-1d.). 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 (N1) 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).

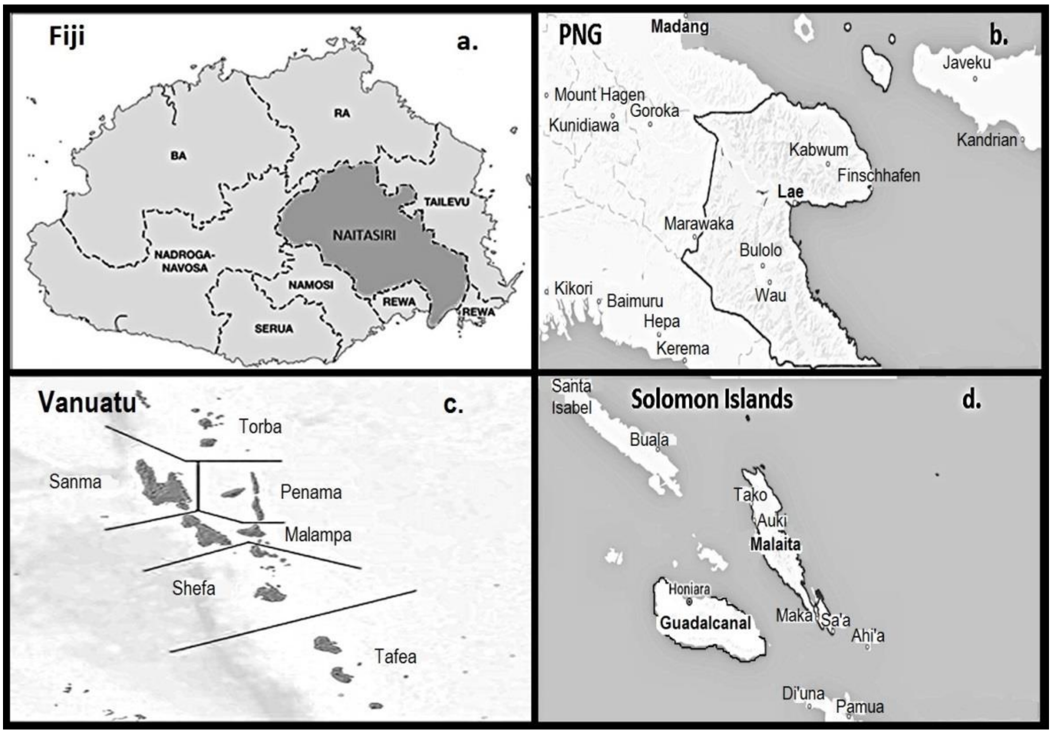

Figure 4-1: Map of countries surveyed, Fiji (a), PNG (b), Vanuatu (c) and the Solomon Islands (d), (Australian National University, 2015), (Macfarlane, 2009).

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 4-2 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, (Cannon and Roe, 1982).

Equation 4-2; D = [1 - (1 - a) 1/n) (N - [(n - 1)/2]) (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 4-3 to 4-6.

Equation 4-3; *Apparent Prevalence (AP):* (3)

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

Equation 4-4; *True Prevalence (TP):* $\mathrm{TP} = \dfrac{\mathrm{AP} + \mathrm{Sp} - 1}{\mathrm{Se} + \mathrm{Sp} - 1}$ (Thrusfield, 1995) (4)

In Eq. (4-4) 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).

Equation 4-5; $$\mathrm{Pe} - 1.96\left\{\frac{c}{T}\sqrt{\frac{V}{c(c-1)}}\right\};\mathrm{Pe} + 1.96\left\{\frac{c}{T}\sqrt{\frac{V}{c(c-1)}}\right\}$$ (5)

In Eq. (4-5) 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.

Equation 4-6; $$V = Pe^2(\sum n^2) - 2Pe(\sum nm) + (\sum m^2)$$ (6)

In Eq. (4-6) 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. (4-5) 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 4-1). 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 4-1.

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 4-2). 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.

Table 4-1: *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 4-2: 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

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 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 is 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 have 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 4-1), 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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COMPLIANCE WITH ETHICAL STANDARDS

Consideration for animal and human ethics was incorporated in the questionnaires for the surveys using the James Cook University policy guidelines. Ethical approval to carry out the study was obtained from the human and animal ethics committees at the university (approval references: A1740, H4414).

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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CHAPTER 5

THE IMPACT OF NATIONAL POLICIES ON ANIMAL DISEASE REPORTING WITHIN SELECTED PACIFIC ISLAND COUNTRIES AND TERRITORIES (PICTS)

Conference presentations relevant to this Chapter

Tukana, A., Hedlefs R., Gummow, B. The impact of national policies on animal disease reporting within selected Pacific Island Countries and Territories *(Oral presentation)*. Third International Conference on Animal Health Surveillance, Rotorua, New Zealand, 30 April – 4 May 2017

Published as

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ABSTRACT

A semi-systematic literature review of national policies was carried out in relation to surveillance and disease reporting in Pacific Island Countries and Territories (PICTs). It also analysed the animal disease reporting structures in Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands. The strengths, weaknesses, opportunities and threats (SWOT) of those reporting structures were examined in relation to how they impact the detection and management of animal diseases in PICTs. Field missions collected information on animal disease reporting structures and these were discussed in detail with country officials and documented. The findings from the literature review indicated that there is very little policy to support work in surveillance and disease reporting within national government structures of the countries studied. This increases the potential for disease transmission and the introduction of exotic diseases as the efficiency of disease reporting is low. The findings from the SWOT analysis of the reporting structures indicated that there were commonalities across the countries studied, i.e. reporting structures were long with multiple legs that were not functioning properly and this was worsened when positions were vacant in the reporting structure. The hierarchical nature of the reporting structure also reduced reporting efficiency as reports took a longer time to reach decision makers at the top of the structure. High officer turnover and the shortage of veterinarians in the countries studied also affected the efficiency of disease reporting as most in-county officials were inexperienced and could not recognise disease signs and there were no veterinarians to supervise them. Existing reporting structures need to be reviewed to remove duplication and shorten the chain. However this could override existing command structures and would need to be documented and awareness created with the officers involved. There also needs to be more collaboration with FAO, OIE, academic institutions and national governments to create an environment conducive for the development of policies that support work on surveillance to improve disease reporting in PICTs. The shortage of veterinarians could be addressed by influencing national governments to create better policies to retain veterinarians in the animal health services; this should be supported by creating reasonable work conditions and remuneration packages. This should also be supported with policies to send young graduates to study veterinary science overseas and have a career path for them when they return. Engagement of retired veterinarians from developed countries and re-evaluating the criteria for veterinarian registration could be short term solutions to address the shortage of veterinarians in PICTs.

KEYWORDS

National policies; Animal Disease; Reporting; Challenges; Pacific Island Countries

INTRODUCTION

In 2013 a Food Animal Biosecurity Network (FABN) was successfully set up between Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands (SI). The network implemented disease surveillance training to enhance capacities for animal health workers in the countries enabling them to identify animal diseases, collect samples, process samples appropriately and send samples to reference laboratories in the Pacific island community and to reference laboratories in Australia for analysis. However, the FABN is dependent on the reporting systems of each country to identify animal disease, generate reports and implement appropriate responses. Little has been published on those reporting systems in the Pacific Island Countries and Territories (PICTs). If existing animal reporting systems are limited and not structured well this could affect the reporting of animal diseases thus having the potential to affect the livestock sector and impact human health (Ryan S. Miller et al., 2013).

Policy support for animal disease surveillance and reporting seems to be poor in developing countries thus limiting the capacity to detect and control emerging and re-emerging zoonotic diseases (FAO, 2015).

In the Pacific island community there seems to be a shortage of veterinarians as well as a tendency for high official turnover within the various animal health organisations (Tukana et al., 2016). This could lead to poor reporting of diseases, which limits early detection and management of animal diseases, as in-country official capacity to recognise diseases is limited and therefore they do not make reports (MAF New Zealand, 2008). In addition to poor reporting structures, field services are also weak thus limiting the capacities to collect and process as well as pack samples for shipment to reference laboratories for analysis. Laboratory capacities and services in PICTs are also limited as there are no clear policies to strengthen them (FAO, 2015). Part of this limitation could be due to the perception that animal diseases are not seen as a priority since the awareness of the impacts of zoonoses has been low. Generally laboratories in PICTs do not have the capacity to carry out basic testing, i.e. officer capacities and basic facilities for both the field and laboratory analysis are low, and expendable items such as vaccutainers, needles, centrifuge; reagents, etc. are normally out of stock (Borja, 2016), (Mosese, 2016).

The lack of policies and appropriate structures for reporting animal diseases supports a systematic loss of recognition of the potential social disruption caused by diseases of even minor trade or zoonotic potential. The lack of market access penalties for producers who do not report disease strengthens the policy perception that diseases of significance are not present or a significant cause for action. This cycle was reflected in the dropout rate of producers who initially volunteered to report disease in PNG but ceased to continue when no market advantage was evident for their work (Yombo, 2010), (Gummow et al., 2013).

This study sought to examine and compare the animal disease reporting structures in Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands and the related agricultural policies with the aim of assessing their impact on a functional disease surveillance system.

MATERIALS AND METHODS

Literature

A semi-systematic literature review was conducted to gather data on national policies and other policies that supported animal disease reporting systems and structures. A search of peer reviewed studies was conducted on 286 databases hosted by James Cook University, Townsville, Australia. The databases were screened for those associated with “agriculture”, “social sciences” and which included crops and animal sciences. Eleven databases were selected based on the above criteria, these were; Agicola, CSIRO, Green file, Google scholar, PubMed, Sage journals, Science Direct, Science Direct Reference Works, Scopus, Spring Link and Web of Science. The selected databases were then searched using the following key words; “Agriculture” AND, OR “National Policy” AND, OR “Animal Disease Surveillance” AND, OR “Animal Disease Reporting” AND, OR “Pacific Island Countries”

The Secretariat of the Pacific Community (SPC), which has the mandate to work in 22 island countries in the Pacific region in relation to agriculture (Land Resources Division), was also a source of information on policies. This in particular was the policy inventory for Pacific Island Countries and Territories (PICTs) hosted by the Pacific Agriculture Policy Project (PAPP) under the Land Resources Division (Secretariat of the Pacific Community, 2016). The inventory was accessed and the agricultural policies for Fiji, PNG, Vanuatu and the Solomon Islands were screened to determine if there were provisions for livestock production, health, disease surveillance and disease reporting. Other grey literature such as unpublished reports was also reviewed for relevance to animal disease surveillance and disease reporting policies.

Countries reviewed

Fiji

Fiji is a Melanesian country which has 300 Islands where 109 are permanently inhabited (Fig. 5-1). There are two main Islands supporting the majority of the total population of 860,623 (Fletcher et al., 2013). Food animals are more common on the two main Islands of Fiji, i.e., Viti Levu and Vanua Levu and comprise cattle (no buffalo included), pigs, goats, sheep and chickens. The small Islands to the North, South and East have some food animals but with very small numbers. In 2009 there were 134,411 cattle, 14,068 sheep, 101,196 goats, 73,698 pigs, 3,734,835 poultry (chickens and ducks), (National Agriculture Census Report, 2009). Animal disease reporting structures in Fiji fall under the Ministry of Agriculture (MOA).

Papua New Guinea

Papua New Guinea (PNG) is the largest and most populous of the countries in the Pacific region with a population of 6.5 million people (Fig. 5-1). PNG is predominantly a Melanesian country consisting of more than 600 Islands with more than 700 language groups (Monica and Rhonda, 2011). In 2009 food animals recorded in PNG were 1,832,000 pigs, 80,000 cattle (no buffalo included), 15,000 sheep, 25,000 goats, 1,661,000 chickens and 30,000 rabbits (Ayalew et al., 2009). Animal disease reporting structures studied in PNG fall within the Ministry of Agriculture (NAQIA) and Ministry of Provincial Affairs (MOPA). There however, is no formal consultative mechanism between these two agencies. NAQIA has responsibilities for import and export as well as domestic and exotic disease surveillance while the provinces retain the ability to implement programs for animal production but have no responsibility for reporting.

Vanuatu

Vanuatu is a 900 kilometre-long, volcanic archipelago that consists of more than 80 Islands (Fig. 5-1). Most of the Islands are inhabited, and around half are mountainous and densely forested with narrow strips of farming land on the coasts. The cattle sector in Vanuatu is quite large compared to other developing PICTs with a population of 211,152. Cattle (no buffalo included) are therefore important for the livelihood of its people. In addition, Vanuatu has 88,694 pigs and 8,797 goats (Secretariat of the Pacific Community, 2009). Animal disease reporting structures studied in Vanuatu fall within the Ministry of Agriculture, Fisheries, Forests and Biosecurity departments.

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 (Fig. 5-1). 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). The livestock sector in the Solomon Islands had diminished significantly during the ethnic conflict from the years 2000-2003. Food animals recorded in 2009 were; 30,363 cattle (no buffalo included), 120,971 pigs, 20,222 goats and 349,991 poultry in the Solomon Islands. Even though livestock numbers have diminished, small holder livestock production is still viewed as important as it has a role to play in food and income security for the rural population (FAO, 2016).

Animal disease reporting structures studied in the Solomon Islands fall under the Ministry of Agriculture and Livestock.

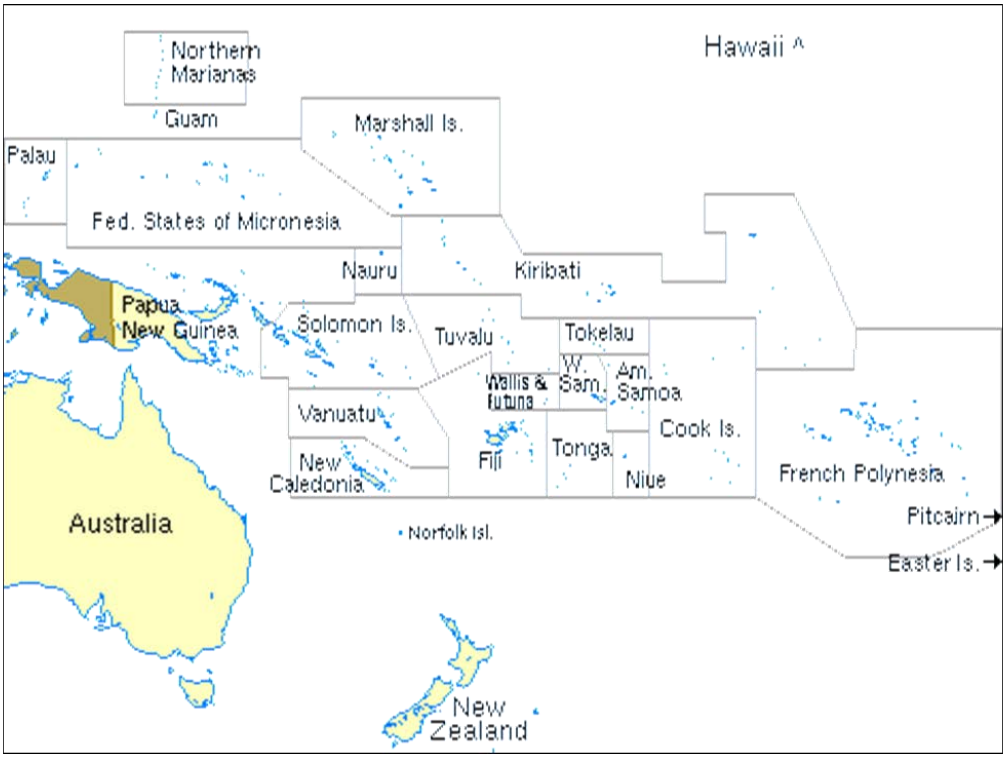

Figure 5-1: Map of the Pacific Island countries, showing Fiji, PNG, Vanuatu and the Solomon Islands, countries that were involved in the study (https://www.google.com.au/search?q=images+oceania+map&biw)

Documentation of disease reporting structures and SWOT analysis

During the 2014 FABN training program, existing animal disease reporting structures for Fiji, Papua New Guinea, Vanuatu and the Solomon Islands were documented and analysed with the officials for each country (Tukana et al., 2016). Fifty three country officials were involved in the exercise and their breakdown was as follows; Fiji (16), PNG (12), Vanuatu (15) and the Solomon Islands (10). The officials involved were the directors and field officials for each country, who held qualifications of 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). Officials were first asked to discuss and document on butchers papers their respective disease reporting structures. The draft reporting structures were then displayed up front and the strengths, weaknesses, opportunities and threats (SWOT) were discussed in detail and recorded for each of the different countries. The reporting structures were then documented and circulated via email to the country officials for constructive comments before being finalised. The finalised reporting structures (Fig. 2-5) were then presented to the countries during a final project reporting mission (Gummow, 2014).

RESULTS

Review of published literature

Nineteen references that had some relevance to policies on disease surveillance and disease reporting were reviewed. All the references however were from outside Pacific Islands Countries and Territories (PICTs) and there was nothing on national policies in the Pacific Islands that related specifically to disease surveillance or animal disease reporting. The available references reviewed indicated that policies for surveillance and reporting diseases are important to support decisions on interventions such as the removal or vaccination of diseased animals to protect human and animal health and to promote animal welfare; however these were limited to national government policies (Ha¨sler and Howe, 2012). The literature also indicated that the world animal health organisation, OIE, recognises the fact that national governments lack policy support for animal disease surveillance and disease reporting due to financial and technical capacity constraints so they have established a global web based information system for countries to report notifiable animal diseases of concern, i.e. the 'World Animal Health Information System' (WAHIS) database. This enables the provision of high quality animal disease information to be provided to stakeholders including; all national veterinary services worldwide, international organisations, livestock owners, industry, academia, media and the general public (OIE, 2010). It must be noted that this system is passive, it does not require countries to report on diseases that were not part of active surveillance programs and many fields in the database had no information available.

Literature also indicated that "resource and capacity constraints" in most national governments in PICTs, limit policy support for disease surveillance and reporting (FAO, 2015). The current trend is that there is very little policy support provided for disease surveillance as well as reporting, and resource allocation in the animal and human health sectors is poor, prompting them to work in their own silos even though many human diseases could be associated with animal hosts (Kline et al., 2013).

The Pacific Community Database

According to the inventory that was carried out by the Pacific Agriculture Policy Project (PAPP), 16 countries out of the 22 countries that the Secretariat of the Pacific Community has a mandate to work in, have national agricultural policies. From the 16 countries that had national agricultural policies, only three had livestock policies, these were Fiji, Solomon Islands and Vanuatu. The livestock policies however were more focussed on livestock production and had little on animal health and disease surveillance (SPC, 2016).

Animal disease reporting structures

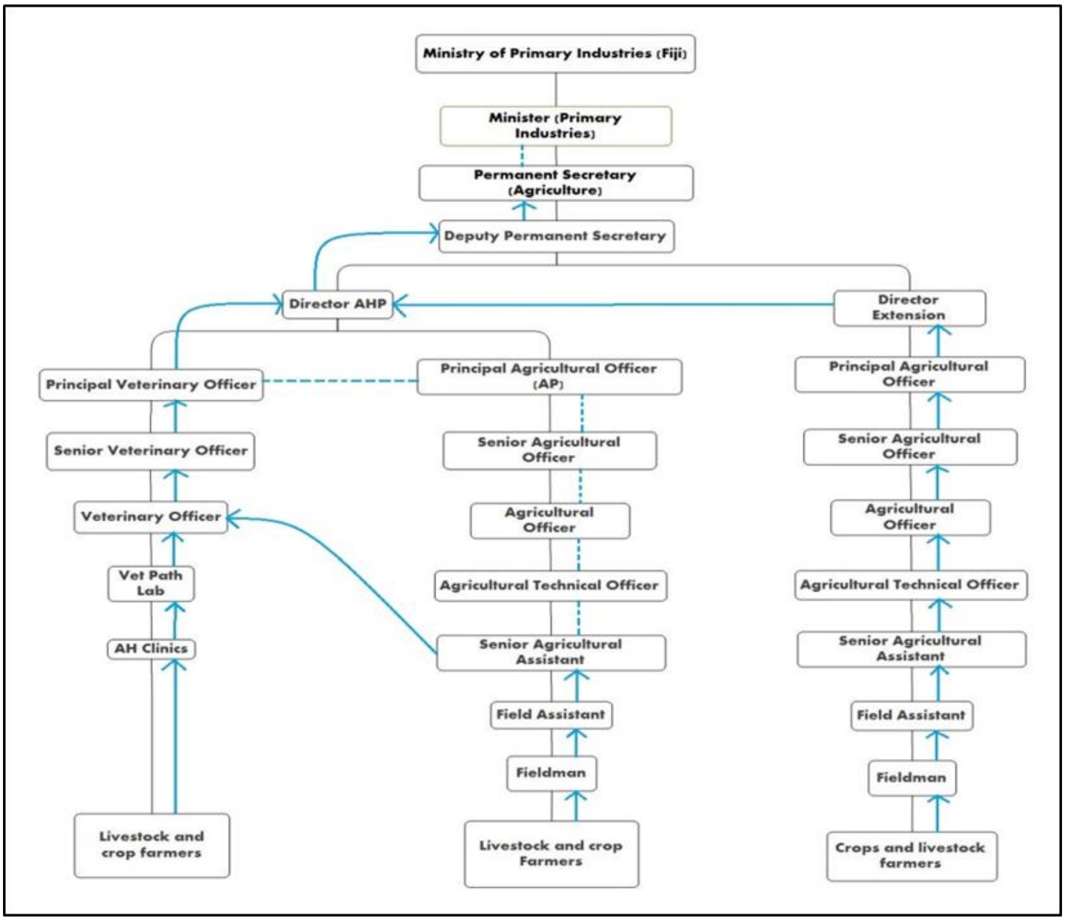

Figure 5-2: Fijian animal disease reporting structure (2015)

Horizontal broken lines indicate that there is opportunity to share information at that level; Vertical broken lines indicate that officers below are briefing officers above them on the disease situation and the response taken.

Animal disease reporting channels in Fiji come under the Minister for Primary Industries (MPI). Under the minister there is the Director for Animal Health and Production and the Director for Extension Services. Under the Director for Animal Health and Production, there are two branches that intercept animal disease reports from the animal level. The two branches are (i) the veterinary branch that come under the Principal Veterinary Officer and (ii) the animal production (AP) branch that come under the Principal Agricultural Officer Animal Production. Under the veterinary branch, i.e., Principal Veterinary Officer, animal disease reports come straight up from the animal level, right up through the Principal Veterinary Officer, through the Director upwards to the Minister for Agriculture. The Minister then makes a decision on the direction to take as well as allocates resources for the response action. Under the animal production branch, i.e., Principal Agricultural Officer (AP), reports come up from the animal level up to the Agricultural Technical Officer (ATO) level where it is then communicated to the Senior Veterinary Officer level, this report then goes straight up to the Minister for Agriculture. Under the extension services branch (Director Extension), reports come all the way up from the animal level to the Director Extension, the report is then communicated with the Director Animal Health and Production who then communicates this report to Minister for Agriculture after consultation with the Principal Veterinary Officer.

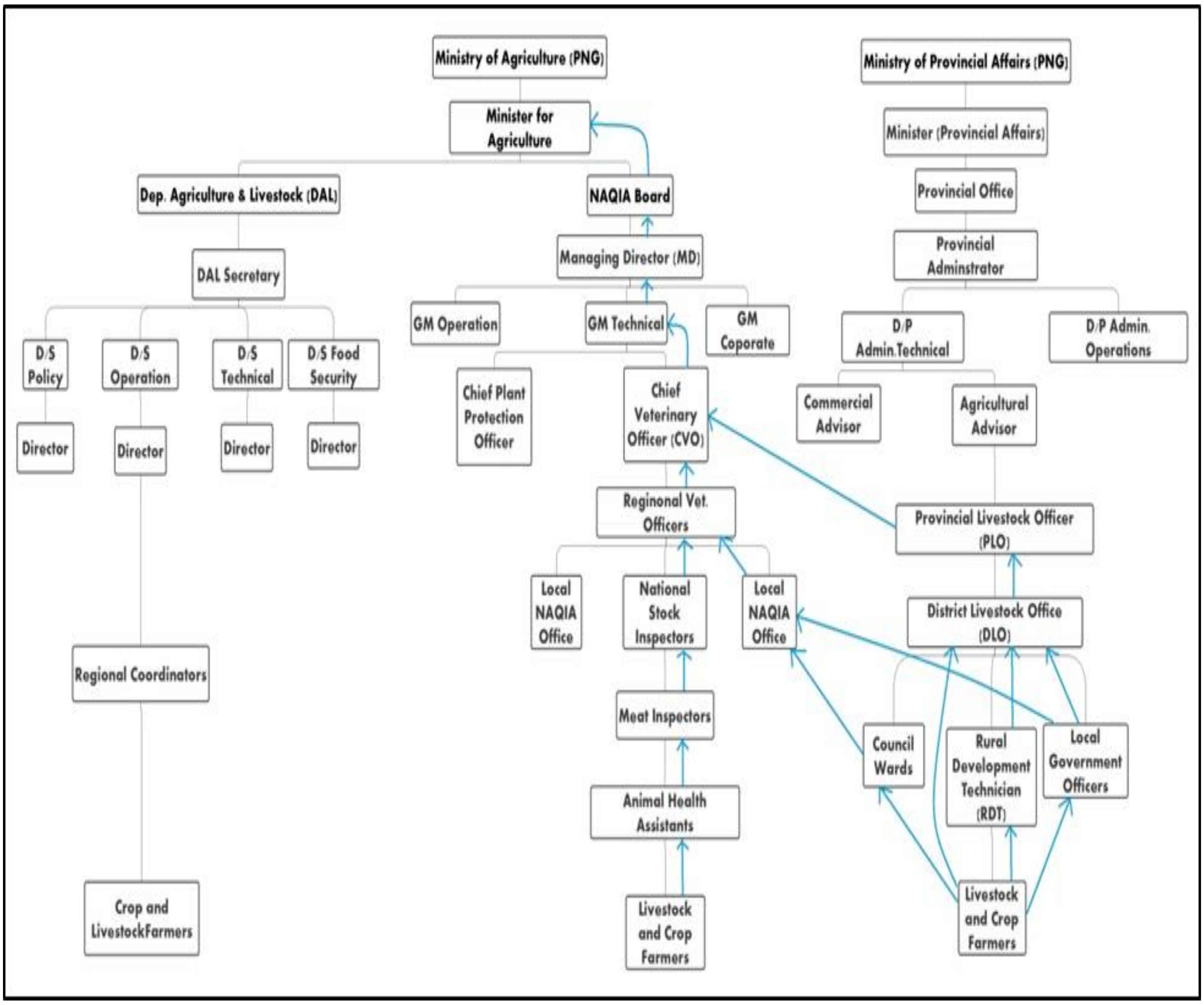

Figure 5-3: Animal Disease Reporting structure (PNG)

Animal disease reporting channels in Papua New Guinea come under two ministries, i.e. the Ministry of Agriculture and the Ministry of Provincial Affairs. Under the Ministry of Agriculture, there is one branch i.e. NAQIA. Under the NAQIA branch, reports come straight up from the animal level to the Chief Veterinary Officer through the Managing Director then to the Minister for Agriculture who makes a decision on the direction to take as well as allocate resources for response action. Under the Ministry of Provincial Affairs branch, reports come straight from the animal level through the Rural Development

Technician and up to the District Level Officer who then communicates the report to the either the Regional Veterinary Officer if there is one or the Chief Veterinary Officer, this then goes through the NAQIA channel to the Minister for Agriculture.

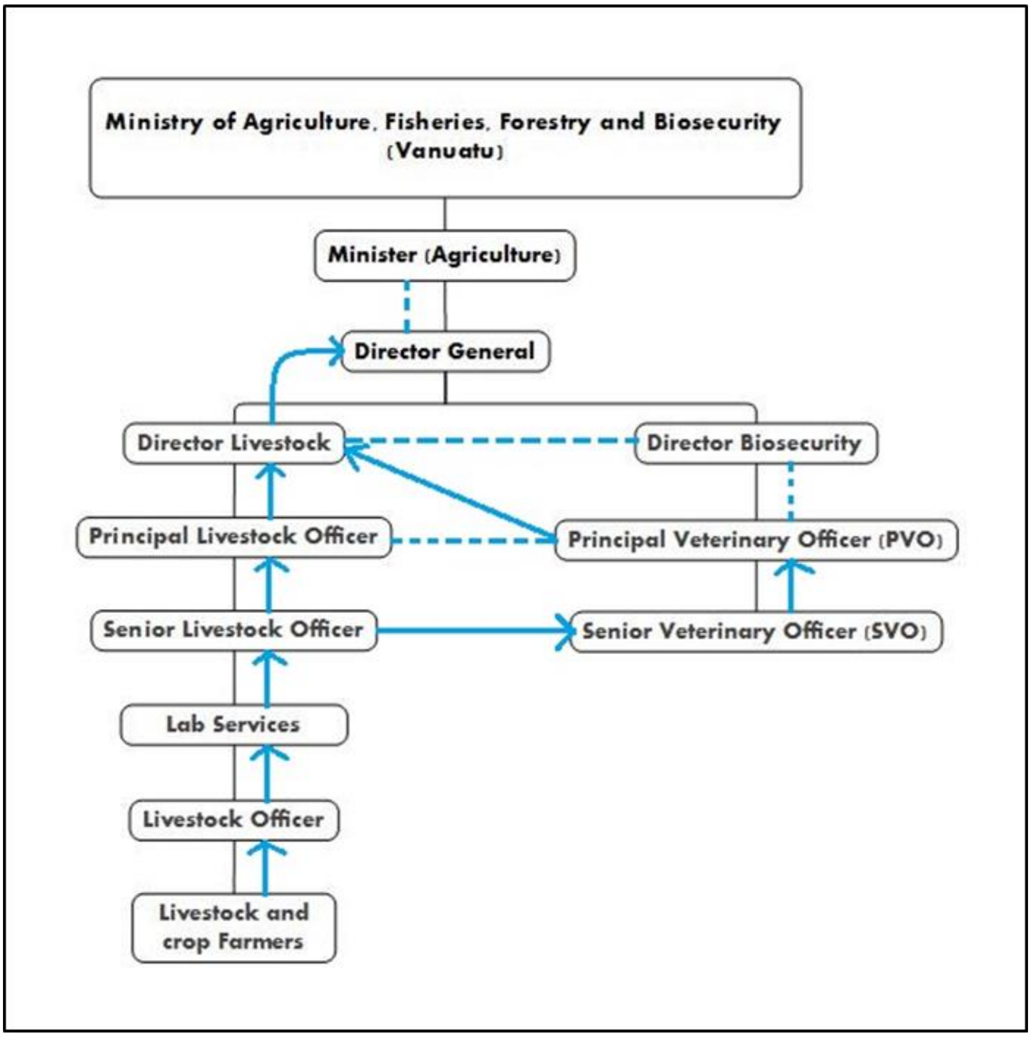

Figure 5-4: Animal disease reporting structure (Vanuatu)

Horizontal broken lines indicate that there is opportunity to share information at that level; Vertical broken lines indicate that officers below are briefing officers above them on the disease situation and the response taken.

Animal disease reporting channels in Vanuatu come under two branches under the Minister for Agriculture. Under the Minister for Agriculture is the Director General for Agriculture, under this is the Director for Livestock and the Director for Biosecurity. Under the Livestock branch, animal disease reports come from the animal level right up to the Director Livestock and at the same time the Senior Livestock Officer communicates the report to the Senior Veterinary Officer who then passes on the communication to the Principal Veterinary Officer. The Principal Veterinary Officer confirms this report to the Director Livestock who reports through the Director General to the Minister for Agriculture who makes a decision on the direction to take as well as allocate resources for response efforts. The Principal Livestock Officer and the Principal Veterinary Officer also communicate which eases the flow of animal disease reporting for both branches.

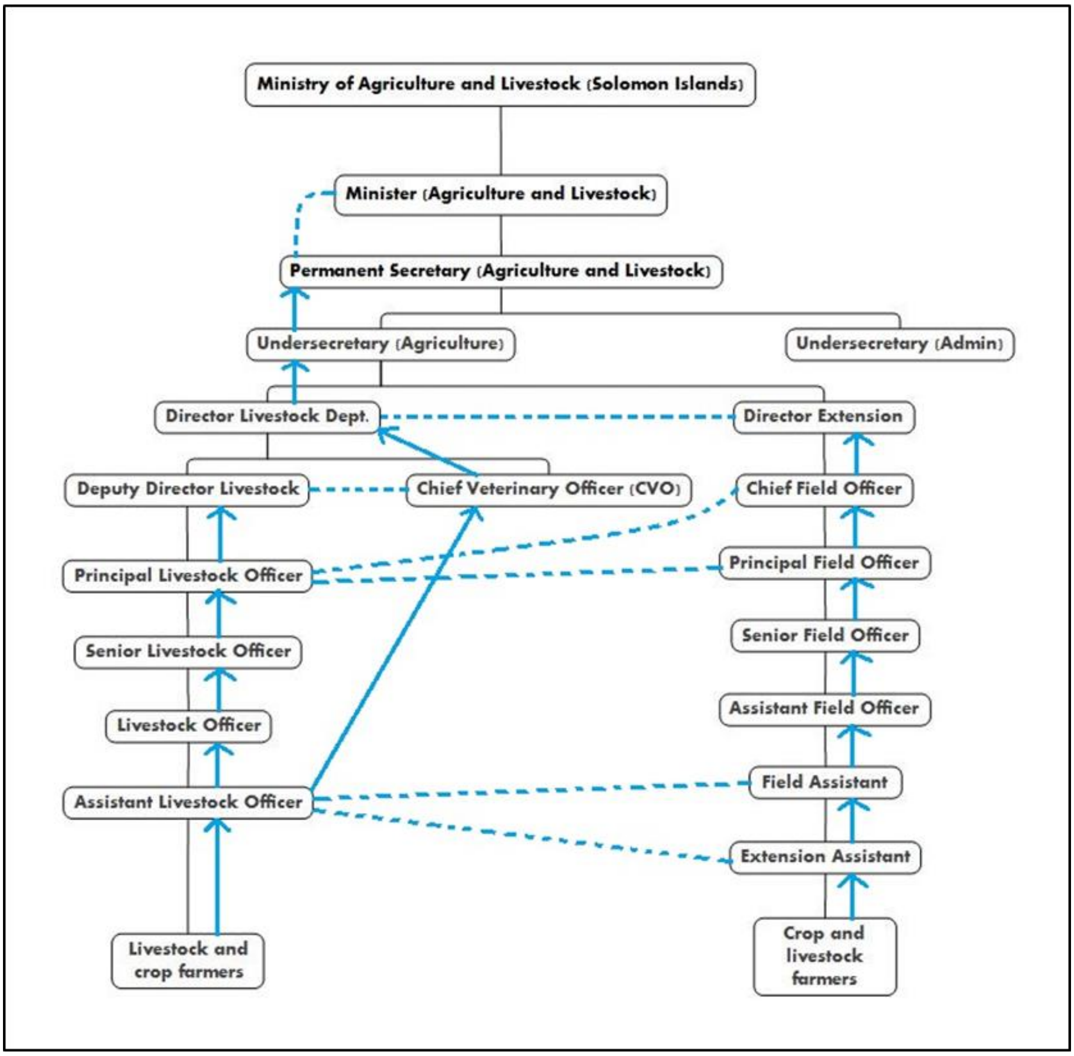

Figure 5-5: Animal disease reporting structure (Solomon Islands)

Horizontal broken lines indicate that there is opportunity to share information at that level; Vertical broken line indicates that the Minister for Agricultural is briefed on disease situations and the response taken.

Animal disease reporting channels for the Solomon Islands fall under the Ministry of Agriculture. Under the Minister of Agriculture and Livestock is the Permanent Secretary (Agriculture and Livestock) are two Under-Secretaries, i.e., (i) Under-Secretary (Agriculture) and (ii) Under-Secretary (Admin). Animal disease reporting channels fall under the Director of Livestock and the Director for Extension services. The reporting channel under the Director of Livestock branch starts from the livestock and crop farmers' right at the bottom upwards to the Deputy Director for Livestock who then passes on the report to the Chief Veterinary Officer (CVO). The CVO then passes on the report to the Director for Livestock with advice on the response to be taken. The Director

Livestock then reports to the Under-secretary for Agriculture, the Under-secretary for Agriculture then reports to the Permanent Secretary for Agriculture and Livestock then briefs the Minister for Agriculture and Livestock on the disease situation and the advice from the CVO on the response needed to be taken. The other branch of reporting starts at the bottom from the crop and livestock farmers right up to the Director for the Extension Division who then passes on the information to the Director for the Livestock Division at their senior meetings at that level.

Animal disease reporting structures analysis (SWOT)

The results for the SWOT analysis for reporting structures in Fiji, PNG, Vanuatu and the Solomon Islands reveal several strengths, weaknesses, opportunities and threats (Table 5-1). Each country's reporting structure was different to some extent while some issues were common for all of them and these are discussed below.

Table 5-1: Summary of SWOT Analysis for animal disease reporting structures for Fiji, PNG, Vanuatu and the Solomon Islands

Internal		External	
Strengths	Weaknesses	Opportunities	Threats
Fiji (Fig. 5-2)			
1. Structure and office locations allows for interaction between the officers of both the AHP and Extension to share information. 2. The SAA which is the lowest official that is linked to field assistants and field man are allowed to report directly to the Senior Veterinarian. 3. The PVO and PAO interact frequently enabling disease information to be shared. 4. The Director AHP and Director Extension interact frequently, sharing information.	1. Reporting structure falls under 2 divisions with 3 branches, i.e. AHP and Extension which is quite large. 2. Protocol of reporting upwards and not by-passing superior officers directly above reporting officers. 3. Some positons in the structure are vacant. So reports may not reach the decision makers.	1. Enhance information sharing and networking between AHP and Extension officers at the locality level. 2. Enhance networking and information sharing between locality officers and farmers. 3. Provide training of officer to recognise disease signs enabling reports to be made. 4. Create policy to retain veterinarians in key positions.	1. Inexperienced officials who do not recognise disease signs. 2. Some crop extension officers do not have experience in recognising animal diseases so will not make reports. 3. Vacant positions in the reporting structure due to shortage of funds and a slow recruitment process. 4. Veterinarian positions vacant due to low salary scale. 5. Political instability.
PNG (Fig. 5-3)			
1. The creation of council wards shortens reporting channel. 2. PLO reporting to CVO shortens the reporting process so it enhances the reporting structure. 3. LGO being able to report directly to LNO enhances the reporting structure. 4. Farmers' reporting directly to the DLO also enhances the reporting structure.	1. Reporting structure has omitted the Dep. Of Agriculture and Livestock (DAL). 2. Current reporting structure falls within NAQIA and the Provincial Office which is quite large. 3. Some positions are vacant in the reporting structure so reports do not reach the decision makers, e.g. RVO.	1. Enhance information sharing and networking between council wards (CW), rural development technicians (RDT) and local government officers (LGO) and the farmers. 2. Provide training on animal health issues and recognition of animal diseases for frontline officers, i.e. CW, RDT and LGO. 3. Create policies to retain RVOs in strategic locations.	1. Some provincial office officials are inexperienced. 2. Vacant positions in the reporting structure due to shortage of funds and a slow recruitment process. 3. Veterinarian positions due to a low salary scale. 4. Security risks. 5. Geographical isolation.
Vanuatu (Fig. 5-4)			
1. The reporting structure is short. 2. PLO and PVO link frequently, enabling disease information sharing. 3. PVO communicates directly with the Director Livestock on disease reports. 4. Director Livestock communicates frequently the Director for Biosecurity.	1. The Biosecurity department have the veterinarians and they focus mostly on border control. 2. Interaction between the PVO and PLO is weak. 3. Interaction between the PVO and Director Biosecurity with Livestock issues is weak.	1. Enhance information sharing and networking between the Livestock department and Biosecurity department. Strengthen weak links 2. Create policy to retain veterinarians in key positions. 3. Create awareness on the impacts of animal diseases. 4. Capacity building training surveillance.	1. Some livestock officials are new and inexperienced. 2. Vacant veterinarian positions due to low salary scale and slow recruitment process. 3. Vacant positions in the livestock department due to a shortage of funds.
Solomon Islands (Fig. 5-5)			
1. The Assistant Livestock officer is allowed to report directly to the CVO. 2. The CVO is allowed to report directly to the Director for Livestock. 3. The Field assistant and Extension Assistant under the Extension Division are allowed to report to the Assistant Livestock Officer.	1. Reporting structure is quite large. 2. Link between the field assistant and extension assistant with the assistant livestock officer is weak. 3. The link between the Chief Field Officer and Principal Field Officer with the Principal Livestock Officer is weak. 4. Protocol of reporting upwards and not by-passing officers directly above them.	1. Enhance information sharing and networking between the frontline officers for both the Livestock and Extension Divisions. 2. Create policy to retain veterinarians in key positions. 3. Create awareness on the impacts of animal diseases and authorities to contact. 4. Capacity building training on surveillance.	1. Inexperienced officers at the Extension Division. 2. Inexperienced officers at the Livestock Division. 3. Vacant livestock positions due to limited funding. 4. Vacant veterinarian positions due to low salary scale and slow recruitment process.

AHP; Animal Health and Production, SAA; Senior Agriculture Assistant, PVO; Principal Veterinary Officer, PAO; Principal Agriculture Officer, PLO; Provincial Livestock Officer, DAL; Department of Agriculture and Livestock, NAQIA; National Agriculture Inspection Authority, RVO; Regional Veterinary Officer, CW; Council Wards, RDT; Rural Development Technician, LGO; Local Government Officer

DISCUSSION

The literature review revealed that there is very little national policy for animal disease surveillance and animal disease reporting in the Pacific Island Countries and Territories (PICTs). Since there are little or no specific policies in PICTs to support disease reporting and surveillance, this could increase the chances of the spread of transboundary animal diseases as diseases are not detected and contained until they have been well established (Tukana et al., 2015).

Furthermore the lack of national policies to support animal disease surveillance and or animal disease reporting could be due to the perception that animal health is of minor importance compared to other issues such as HIV and TB in the region. The limited priority placed on animal diseases by national governments leads to a lack of resource allocation from national government budgets (Rich et al., 2013).

Literature also indicated that use of the World Animal Health Information System (WAHIS) is a good platform for countries to use to report notifiable animal diseases and their country disease status. However only those countries that are World Animal Health Organisation (OIE) members are obligated to submit animal disease reports as they are supported through training on how to use the database and have nominated OIE delegates for reporting. Very few Pacific Island Countries and Territories (PICTs) in the South West Pacific region are members of OIE, and those countries that are not, are not obliged to submit reports of disease occurrence. Apart from New Zealand and Australia, only Fiji, Papua New Guinea, Vanuatu, New Caledonia and the Federated States of Micronesia are members of OIE in the South West Pacific region (Tukana et al., 2016).

Furthermore there are no frameworks in place particularly in PICTs, to bring different sectors together to address animal disease surveillance. The World Health Organisation views this as important and have been doing work in this area in collaboration with OIE and FAO, e.g. a workshop was held recently in Fiji (March 2017) in Fiji for different stakeholders to address the Human Animal Ecosystem Interface (HAEI). The aim was to strengthen collaboration and coordination between the public health and animal health sectors to improve the prevention and control of zoonotic diseases (WHO, 2017).

The SWOT analysis (Table 5-1) of reporting structures for Fiji, PNG, Vanuatu and the Solomon Islands reveals that each country had their own strengths, weaknesses, opportunities and threats, however some issues were common across the countries studied.

In Fiji the reporting structure allowed for interaction between field officers based in different localities in the country; this allowed for the sharing of information on animal diseases and disease reporting. The lowest ranking officer in the animal production (AP) branch, i.e. the Senior Agriculture Assistant (SAA) has the ability to report directly to the

Senior Veterinary Officer shortening the reporting process, but other SAA under the extension division do not have that opportunity. The reporting structure however is too long and cumbersome, as it falls under two ministries and three divisions and some positions in the structure are vacant. Officers are expected to report directly above them as there is a culture of not by-passing immediate supervising officers. This created a challenge in reporting animal diseases as the process is time consuming and if supervising officers are away from the office, the reports may not reach their destination. The number of government veterinarians in Fiji has been limited to non-existent in the past; this has also created a gap in the detection of animal diseases as subordinate officers do not have the capacity to recognise animal diseases and thus do not make reports, e.g. in the outbreak of bovine Brucellosis in Fiji, there were no definite signs of the disease until there was a re-emergence of the disease in 2009 (Tukana et al., 2015). The high turnover of animal health officers in the reporting structure means that the capacities of existing officers to carry out reporting is weak, as most of them are inexperienced. Recruitment policies which do not provide a reasonable remuneration and the reduction of the retirement age in Fiji from 60 years to 55 years have also contributed to this inexperience. The political environment at the moment in Fiji is stable; however the instability in the past may have contributed to the migration of a lot of skilled people out of Fiji. Opportunities exist when the senior officers in the reporting structure have the opportunity to share disease information when they meet at senior officers meetings (horizontal broken lines Fig. 5-2), e.g. the Principal Agricultural Officer (PAO) and the Principal Veterinary Officer (PVO) have the opportunity to share information during senior officer meetings that they attend. Briefing on disease situations and response also take place (vertical broken lines, Fig. 5-2), i.e. officers report upwards in the structure, even though it is not compulsory but done out of courtesy and this improves reporting efficiency.

In Papua New Guinea, disease reporting is challenging as the reporting channels fall under two separate ministries making it more complex for information sharing. Regional Veterinary Officers (RVO) are supposed to be present in each of the four regions (Lae, Rabaul, Goroka and Port Moresby) in Papua New Guinea. However, because the posts are often vacant, the chances of animal disease reports coming from the different provinces are limited, e.g. in 2013, only 1 RVO existed, i.e. in Lae (AusAID Report, 2010). Farmer capacities to recognise signs of disease are limited in Papua New Guinea and reports of animal disease would be made only when high mortality in animals is observed. The exclusion of the Department of Agriculture and Livestock (DAL) from the reporting structure reduces the sensitivity of the system as DAL also deal with livestock. Opportunities in reporting eventuate when interaction and information sharing occurs between the local NAQIA office and council wards under the Ministry of Provincial Affairs, as this shortens the time for reports to reach the decision makers at NAQIA.

In Vanuatu, disease reporting is challenging as numbers of veterinarians are limited and often non-existent, and subordinate officers (non-veterinarians) do not have the authority to confirm animal diseases (Mosese, 2016). The available veterinarian normally spends more time doing border control work rather than work on livestock farms, so disease reporting is normally handled by the livestock department workers. Capacities of the livestock department workers and farmers in recognising animal diseases are also limited so this affects the frequency of animal disease reports submitted (Philips, 2014). Opportunities eventuate as the reporting channel is shorter compared to the other countries studied, so information reaches the Minister for Agriculture in a shorter time. Initial investigation by a qualified veterinarian for disease outbreaks is quick as there is interaction between the Senior Livestock Officer and the Senior Veterinary Officer at their level (horizontal broken lines, Fig. 5-4), The Director for Livestock and Director for Biosecurity, as well as the Principal Veterinary Officer and Principal Livestock Officer, have the opportunity to share information during senior officer meetings. The vertical broken lines (Fig. 5-4), i.e. officers' report upwards in the structure, even though it is not compulsory it is done out of courtesy and this improves reporting efficiency.

In the Solomon Islands, reporting is challenging due to limited and to the unavailability of veterinarians, i.e. the Chief Veterinary Officer post has been vacant for many years and when the post is filled, normally it is not for long, and the subordinate livestock officers do not have authority to confirm signs of diseases and take appropriate action (Atalupe, 2014). The numbers of livestock workers in the provinces are lower compared to field assistants and extension assistants under the extension division so the probability is high that the extension officers may not be able to recognize animal disease signs as they have had no training and therefore do not make reports. Capacity for farmers to recognize disease signs is low, so reports may only be made if high mortality occurs. Opportunities eventuate when there is interaction (horizontal broken lines, Fig. 5-5) between the officers from different branches at their level to share information, i.e. the Assistant Livestock Officer with the Field Assistant and Extension Assistant, the Principal Livestock Officer with the Principal Field Officer and Chief Field Officer, the Director Livestock and the Director Extension, This interaction promotes information sharing and increases the efficiency of disease reporting. The broken vertical lines (Fig. 5-5) indicate the briefing to the Minister by the Permanent Secretary the disease situation and response taken.

In general, the reporting structures for the countries studied were too long and cumbersome except for Vanuatu. All the reporting structures were created during the colonial days and may no longer be suited to the present environment, thus limiting the capacity for disease surveillance and reporting. A shortage of veterinarians and high in-country officer turnover were common across the countries studied. This affected the capacities for disease surveillance and reporting as most of the officers on the ground were inexperienced.

CONCLUSIONS

Animal disease reporting structures in the Pacific Island Countries and Territories (PICTs) have the potential to impact the detection of animal diseases as well as how those diseases are managed if reporting structures are improved, but this is affected by the lack of policies to support work in this area (FAO, 2002). This is compounded by the fact that Pacific island communities and the countries studied are affected by a shortage of veterinarians and a high officer turnover, which was evident in the SWOT analysis carried out in this study (MAF New Zealand, 2008).

The lack of veterinarians and high officer turnover mean that most frontline animal health officials are inexperienced and not able to recognise disease signs so are not able to make disease reports. Furthermore, the lack of policies to support work in animal health and surveillance in PICTs, leads to a reduction in the efficiency of reporting systems in PICTs. The multiple reporting branches in the reporting structures for the countries studied are not functioning properly so are also contributing to reducing the efficiency of reporting diseases in Fiji, PNG, Vanuatu and the Solomon Islands. The upward hierarchical nature of the reporting systems is also affecting the efficiency of reporting as the normal practice in the countries studied is that officers in a branch cannot bypass immediate superior officers.

RECOMMENDATIONS

The reporting structures in the PICTs studied should be restructured to remove duplication and shorten the chain of reporting. The shortened chain could override existing command structures that exist within the countries studied and the actual reporting chain should be documented and more awareness should be created with the officers that are part of the command structure for Fiji, PNG, Vanuatu and the Solomon Islands.

There needs to be more collaboration with FAO, OIE, academic institutions and national governments to create policies that support work on animal health, surveillance to improve disease reporting in PICTs. Increased opportunity for internal collaboration between ministries and directorates should be supported to improve networking and sharing of animal health information.

The shortage of veterinarians could be addressed by having national governments create better policies to retain veterinarians in the animal health services; this should be supported by creating reasonable work conditions and remuneration packages. The policy should create programs to support young graduates to study veterinary sciences overseas in universities that have good track records. The policy should also provide scholarships and career pathways, i.e. a position for graduates when they return from studies and a pathway for promotion.

The program could also collaborate with other developed countries and engage retired veterinarians to support surveillance and disease reporting work in the short term when there currently is a shortage of veterinarians in PICTs.

The veterinary registration criteria in PICTs could also be re-evaluated to accommodate veterinarians with qualifications from countries that have competent veterinary institutions, e.g. in Fiji, veterinarians with qualifications from New Zealand, Australia and England are allowed to practice in the country while veterinarians with qualifications from other countries cannot do so.

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COMPLIANCE WITH ETHICAL STANDARDS

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving humans and animals were in accordance with the ethical standards of the James Cook University policy and guidelines. Ethical approval to carry out the study was obtained from the human and animal ethics committees at the university (approval reference: A1740, H4414).

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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CHAPTER 6

AN ANALYSIS OF SURVEILLANCE SYSTEM COMPONENTS AND THEIR INFLUENCE ON ANIMAL DISEASE REPORTING IN FIJI, PAPUA NEW GUINEA, VANUATU AND THE SOLOMON ISLANDS USING *Brucella abortus* AS A MODEL

Unpublished

Tukana, A., Gummow, B., 2018. An analysis of surveillance components and their influence on animal disease reporting in Fiji, Papua New, Vanuatu and the Solomon Islands using *Brucella abortus* as a model

ABSTRACT

This study examined the surveillance system components (SSC's) associated with animal disease reporting in four Pacific island countries (Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands) using *Brucella* abortus as a model disease. During the course of disease surveillance training in the countries, information on the *Brucella* SSC's were collected, discussed in detail with the country officials and documented. The structures of the SSC's were developed using Influence diagrams and scenario tree methods based on the information collected. A questionnaire collected information from animal health officials and farmers in the four countries on their disease reporting behaviours, which was used to populate the scenario tree flow diagrams for the SSC's in each country studied. A holistic approach was used to develop and document the SSC's which enabled a detailed examination and recommendation for improvement of certain components of the SSC's to increase each country's ability to detect *Brucella*. Findings indicated that reporting, investigation, test for Brucellosis, collection and submission of brucellosis samples for diagnosis within the SSC's were weak and could be improved through shortening the reporting structures as well as through capacity building training in disease surveillance to improve recognising disease signs, investigation and the collection of samples.

Keywords

Sensitivities; Disease; Surveillance Systems; Brucellosis; Pacific Island countries

Introduction

Demonstrating freedom from animal diseases is important to Pacific Island Countries and Territories (PICTs) because this is a requirement for international trade in animal and animal products. The Sanitary and Phytosanitary (SPS) agreement of the World Trade Organization (WTO) requires that, for international trade, measures taken to protect animal, plant or human health should be based on scientific principles and not maintained in the absence of sufficient evidence (WTO, 1995).

Surveillance to determine zone or country freedom from diseases has been based on two approaches, i.e., either quantitative analysis of the results of structured representative surveys, or qualitative assessments of multiple sources of evidence, including complex non-representative sources However weaknesses exist for both approaches, i.e. structured surveys using representative sampling are expensive, difficult to implement, and ephemeral in their applicability. Reliance solely on the results of such surveys ignores the potential value of all other sources of evidence (Martin P.A.J. et al., 2007). Qualitative assessments on the other hand may consider all sources of evidence, but the outcome is influenced by the assessors involved, and it is difficult to achieve a transparent and repeatable process. So there is a need for better methods to substantiate claims to freedom including evidence from both structured, random surveys and non-random surveillance data (Doherr M.G. et al., 2003).

Except for Fiji who currently has bovine brucellosis, PNG, Vanuatu and the Solomon Islands have all claimed freedom from brucellosis. The claim of freedom from brucellosis can be impacted by the ability of the surveillance system components (SSC's) to detect brucellosis in each of the countries studied. This study sought to examine the surveillance systems components (SSC's) in Fiji, PNG, Vanuatu and the Solomon Islands with the aim of identifying those components that are impacting on the sensitivity of detecting diseases in those countries. Because of the importance of brucellosis, this disease was used as the disease model and cattle were used as the species of interest.

Materials and methods

The Food Animal Biosecurity Network Project

A Food Animal Biosecurity Network (FABN) was set up for Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands (SI) to make better use of the limited resources and build capacity for animal disease surveillance and enhance animal health field and laboratory capability in the Pacific Islands (Tukana et al., 2016). The work in this article formed part of those objectives and utilised the FABN network as a tool to communicate and coordinate activities in the countries as well as enabled the collection of information on the surveillance systems components (SSC's) for brucellosis that existed in Fiji, PNG, Vanuatu and the Solomon Islands.

Study area

The study areas (Fig. 6-1) were the areas where cattle farms were surveyed for brucellosis under the FABN project and were as follows; Fiji, Central, Western, Northern and Eastern divisions, i.e. the main island in Fiji (Viti Levu), the second main island (Vanua Levu) and Maritime zones. In Papua New Guinea, the areas studied were the lower and upper regions of the Markham valley that lie within the Morobe province (Macfarlane, 2009). In Vanuatu the areas studied were; the Islands of Santo (Sanma province), Malo (Sanma province) and Efate (Shefa province). In the Solomon Islands, the areas studied were; the Guadalcanal and Malaita provinces. The brucellosis surveillance system components for each study area began with cattle farmers and followed the reporting of brucellosis (disease) to the closest diagnostic laboratory for bovine brucellosis.

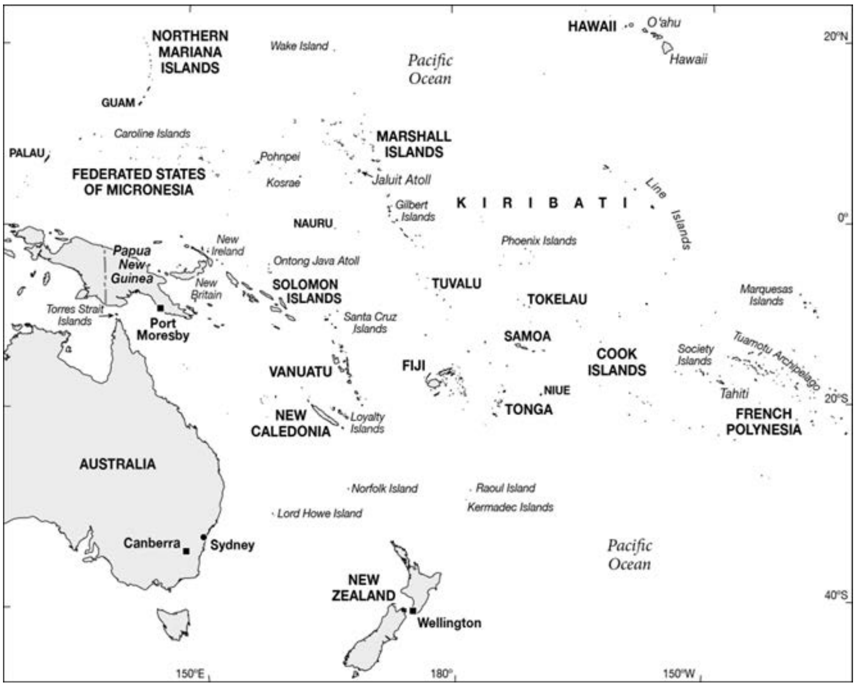

Fig. 6-1. Map of the Pacific Island countries (Australian National University, 2018)

Documentation of the *Brucella* surveillance system components (SSC's)

During the 2014 FABN surveillance training program, existing *Brucella* surveillance system components (SSC's) for Fiji, Papua New Guinea, Vanuatu and the Solomon Islands were constructed by the officials for each country (Tukana et al., 2016). Fifty-three country officials were involved in the exercise and the number of officials from each country was as follows; Fiji (16), PNG (12), Vanuatu (15) and the Solomon Islands (10). The officials involved were the animal health directors and field officials for each country, who held qualifications of 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). Officials were first asked to discuss and document on butchers papers their respective disease surveillance system components (SSC's) for *Brucella*.

The draft surveillance system components were then displayed to the participants and discussed to see how the components related to each other in the reporting system and rearranged if necessary. The surveillance system components were then documented and circulated via email to the country officials for constructive comments before being finalised.

Developing the surveillance system components scenario trees

Based on the actual surveillance system components (SSC's) recorded and documented during the FABN disease surveillance capacity building training in the countries, influence diagrams were first used to develop scenario trees for the SSC's using the Precision Tree program, which was part of a Decision Tools Suite software (Albright, 2016). The programme allows for the conversion of the influence diagrams into scenario tree models to demonstrate the chronological and numerical details of the surveillance decisions made for each branch in the SSC's and for each country studied.

Collection of information to populate the scenario trees

After constructing the *Brucella* Surveillance System Components for each country, a questionnaire was developed to collect probability information to populate the nodes in the scenario trees for Fiji, PNG, Vanuatu and the Solomon Islands. The same 53 country officials that constructed the SSC's were asked to complete the questionnaire. Time was also allocated for the officials to interview the farmers in the areas they were responsible for in order to complete some of the questions related to farmers (Tukana et al., 2016).

Literature on cattle population was obtained from country national census reports and reviewed to support information collected from the questionnaires and this contributed to the probability for the type of farms in the scenario trees. Information on Division, Region, Island, Province (Decision nodes) and Farm Type (Chance nodes) and probability values were from the following sources: Fiji, the 2009 Fiji Agriculture Census Report (Fiji Agricultural Census Report, 2009), PNG, a 2009 Food and Agriculture Report (Bourke and Harwood, 2009), Vanuatu, the Census of Agriculture Report (Vanuatu Statistics Office, 2007), the Solomon Islands, the 2009 Population and Housing National Report (Solomon Islands Statistical Office, 2009).

Personal communication with senior staff in the countries as well as at SPC was also used to verify the information collected to populate the nodes in the scenario trees that were developed. The scenario trees were then reviewed to ensure they accurately represented the situation in each country. A number of iterations of the influence diagrams were required before the final scenario tree structure was accepted.

Description of the scenario trees

The scenario trees (Fig. 6-2 to Fig. 6-5) used the following types of nodes; decision (green squares), chance (red circles) and payoff (blue triangles). The structure of the scenario trees for the surveillance system components (SSC's) was based on what was happening on the ground for each of the countries studied and this was converted from the influence diagrams that were developed earlier in the process (Albright, 2016).

The scenario trees for the SSC's started from the left with a decision as to what area the model applies to, then moving to the right onwards it had the following nodes; the type of farms (Farm Type) *Brucella* status of the herd (Herd Status), the probability of the farmer reporting (Farmer reports), the probability of the authority carrying out investigation (Investigation), the probability of carrying field tests for brucellosis (Test for Brucellosis), the probability of Submitting Samples, the results from the Rose Bengal Test (RBT) and the results for the indirect enzyme ELISA test (ELISA). The Decision and Farm Type nodes were populated with probability data collected from literature backed up by personal communication information from senior staff in the four countries. We did not know the status of the cattle herds in the four countries, so the Herd Status node was allocated with a Yes and a No rather than a probability value. The Farmer Reports, Investigation, Brucellosis Suspicion and Submit Sample nodes were populated with probability data collected from the questionnaires. The serological tests used i.e. the Rose Bengal Test (Decision node) and indirect enzyme linked immunosorbent assay (ELISA) (Decision node) were also populated with a Yes and No rather than a probability value as these were decisions whether to do the test in this context.

Results

Surveillance system components scenario tree flow diagrams

The scenario trees for Fiji, PNG, Vanuatu and the Solomon Islands have been shortened significantly by collapsing all of its branches except for one to illustrate a completed branch which could have sensitivity values at its payoff nodes (Fig. 6-2 to 6-5). The actual scenario trees for each country are quite large and cannot be viewed on a single A4 page. However, their sizes were as follows; the Fiji scenario tree had 274 nodes, 4 major branches and 18 sub-branches, the PNG scenario tree had 315 nodes, 2 major branches and 24 sub-branches, the Vanuatu scenario tree had 274 nodes, 3 major branches and 18 sub-branches, while the Solomon Islands scenario tree had 117 nodes, 2 major branches and 6 sub-branches.

For Fiji (Fig. 6-2), areas were divided by Division as these are separately managed. The Divisions were; Central, Western, Northern and Eastern. Farms in the Divisions were classified as Small Holder, Dairy and Beef farms (Farm type). Small holder farms consisted of cattle numbers from 1-50 and had mixed breeds, dairy farms consisted mainly Friesian and Jersey breeds and specialised in milking for the production of whole milk, while the beef farms consisted of mainly cattle for beef, e.g. Hereford and Santa Gertrudis breeds of cattle. Within those farms, Herds could either be infected or not infected (Herd Status) and within the herds individual animals could either be infected and not infected (Animal Status). If the cattle were infected then, symptoms (infection) would either be presented (Yes) or (No). Farmers could then either report their suspicions to the Laboratory Office, Local Livestock Office or not make a report at all. After receiving reports the authorities responsible for Investigation (category), would either carry out an investigation (Yes) or (No) based on the farmer report. If investigation was done then the investigator would decide to test for brucellosis or not. If the RBT (detection) was conducted in the field, this would either be positive or negative for brucellosis. If positive, then samples would have to be submitted (detection) for analysis; these would either survive or not during collection, processing and transporting to the laboratory. The final confirmatory test was the indirect ELISA (detection) and this would yield either a positive or negative result to brucellosis.

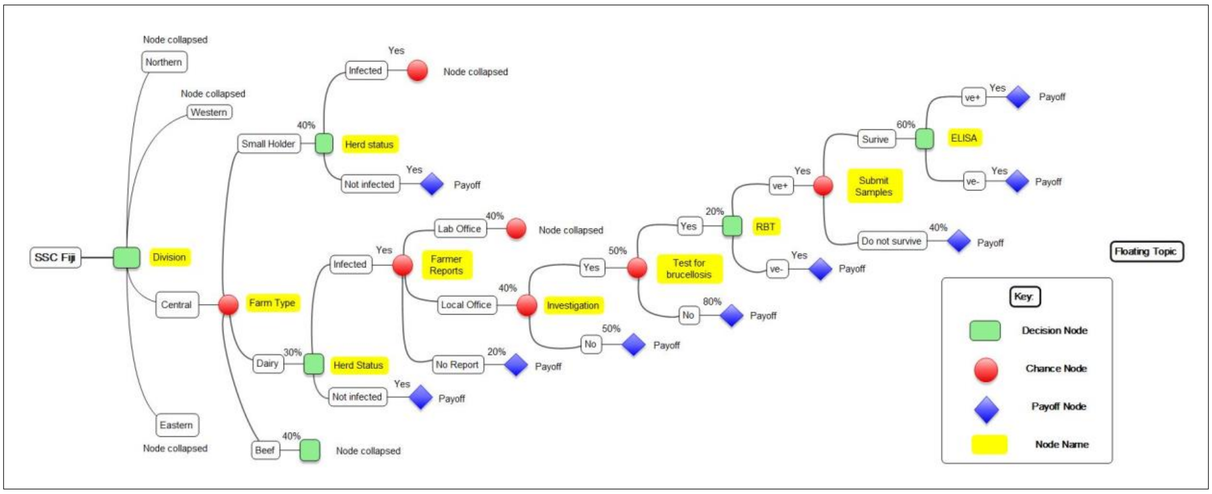

Fig. 6-2. Scenario tree for the surveillance system components in Fiji

PNG (Fig. 6-3) differed in the sense that, reporting was divided into different Regions, i.e. the Lower Markham and Upper Markham valley regions. Farms in the regions were classified as Large Beef Farms (> 100 cattle), Medium Beef Farms (50 -100 cattle) and Small Beef Farms (≤ 50 cattle). The other differences were with the reporting channels that farmers would make reports to, these were; either to the Council Wards, Rural Development Technicians, Local Government Office, Animal Health Assistants or not make any reports at all. The rest of the surveillance system components were the same as for Fiji.

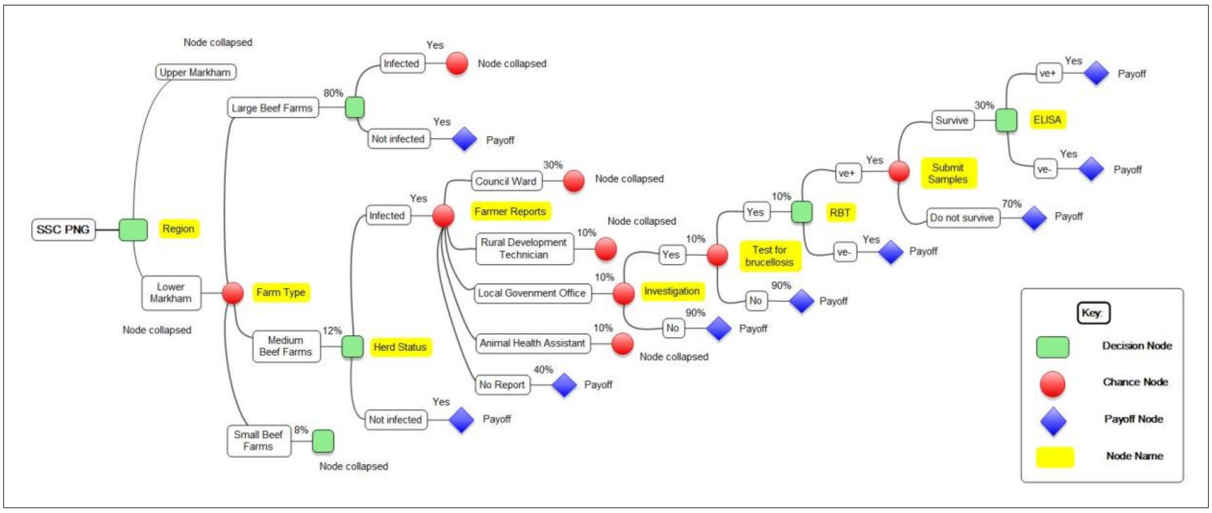

Fig. 6-3. Scenario tree for the surveillance system components in PNG

Vanuatu (Fig. 6-4) differed whereby, reporting was divided into the different Islands and for this study these were the Santo, Malo and Efate Islands. Farms on the Islands were classified as Large Beef Farms (> 100 cattle), Medium Beef Farms (50 – 100 cattle) and Small Beef Farms (≤ 50); farm type was the same as PNG but differed from Fiji. The other difference lay with where farmers would then make reports (detection), i.e., either to the Local Livestock Office, Village Headman or not make any reports at all. The rest of the surveillance system components were the same as for Fiji and PNG.

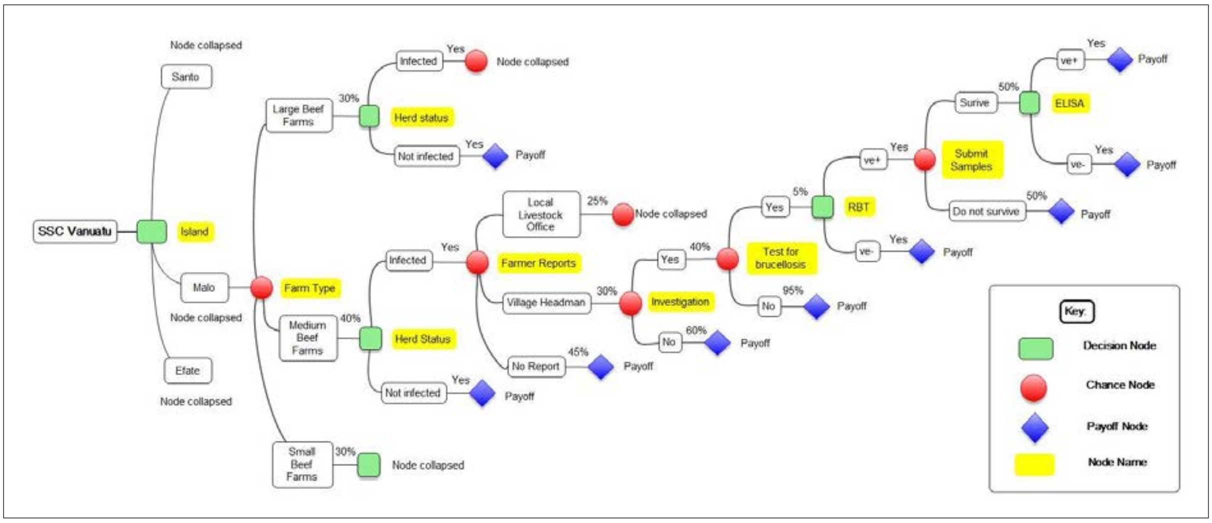

Fig. 6-4. Scenario tree for the surveillance system component in Vanuatu

The Solomon Islands (Fig. 6-5) differed in the sense that the reporting was divided by Provinces into Guadalcanal and Malaita Provinces. Farms in the provinces were classified as Large Cattle Farms (> 100 cattle), Medium Cattle Farms (50 – 100 cattle) and Small Cattle Farms (≤ 50 cattle), this was the same for PNG and Vanuatu. The other difference lay in where the farmers would make reports (detection), i.e., either to the

Local Livestock Office or not make reports at all. The rest of the surveillance system components were the same as those of Fiji, PNG and Vanuatu.

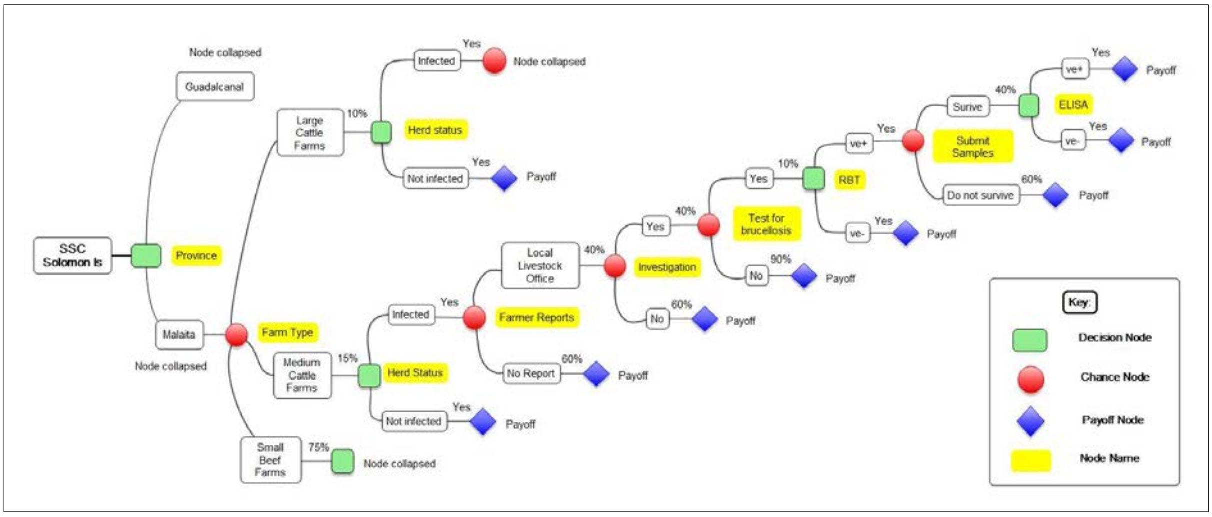

Fig. 6-5. Scenario tree for the surveillance system in the Solomon Islands

Probability of detecting brucellosis

The results (Tables 6-1 to 6-4) also covered the probabilities of farmers reporting diseases, the authorities carrying out investigation after receiving reports, the authorities carrying out the Rose Bengal Tests (RBT), suspecting brucellosis and the survival of samples that are sent for the indirect ELISA test for diagnosing brucellosis. The probability of detecting brucellosis for each of the branches in each of the countries based on Bayes Theorem and the inputs of the model was not calculated because there were gaps in the information required and the current probabilities were largely dependent on opinion that could not be easily verified. However, the structure of the trees can be used as a basis for this should more reliable data become available.

Table 6-1 *Brucella* surveillance system components probabilities for Fiji

Division	Farm type	Prob %	Herd Status	Prob %	Farmer reports	Prob %	Carry out investigation	Prob %	Test for Brucellosis	Prob %	RBT	Prob %	Sumbit samples	Prob %	ELISA	Prob %
Central	Small holder	30	Infected	Yes	Lab officer	10	Yes	40	Yes	10	pos	Yes	Survive	80	pos	Yes
			Not infected	Yes			No	60	No	90	neg	Yes	No	20	neg	Yes
					Local livestock office	50	Yes	40	Yes	10	pos	Yes	Survive	60	pos	Yes
							No	60	No	90	neg	Yes	No	40	neg	Yes
					No reports	40										
	Dairy	40	Infected	Yes	Lab officer	40	Yes	60	Yes	20	pos	Yes	Survive	80	pos	Yes
			Not infected	Yes			No	40	No	80	neg	Yes	No	20	neg	Yes
					Local livestock office	40	Yes	50	Yes	20	pos	Yes	Survive	60	pos	Yes
							No	50	No	80	neg	Yes	No	40	neg	Yes
					No reports	20										
	Beef	30	Infected	Yes	Lab officer	30	Yes	40	Yes	20	pos	Yes	Survive	80	pos	Yes
			Not infected	Yes			No	60	No	80	neg	Yes	No	20	neg	Yes
					Local livestock office	40	Yes	40	Yes	20	pos	Yes	Survive	60	pos	Yes
							No	60	No	80	neg	Yes	No	40	neg	Yes
					No reports	30										
					No Avg.	*30*	*No Avg.*	*55*	*No Avg.*	*83.33*			*No Avg.*	*30*		
Western	Small holder	75	Infected	Yes	Lab officer	10	Yes	40	Yes	10	pos	Yes	Survive	80	pos	Yes
			Not infected	Yes			No	60	No	90	neg	Yes	No	20	neg	Yes
					Local livestock	40	Yes	40	Yes	10	pos	Yes	Survive	60	pos	Yes

					office											
							No	60	No	90	neg	Yes	No	40	neg	Yes
					No reports	50										
	Dairy	3	Infected	Yes	Lab officer	40	Yes	60	Yes	20	pos	Yes	Survive	80	pos	Yes
			Not infected	Yes			No	40	No	80	neg	Yes	No	20	neg	Yes
					Local livestock office	40	Yes	60	Yes	20	pos	Yes	Survive	60	pos	Yes
							No	40	No	80	neg	Yes	No	40	neg	Yes
					No reports	20										
	Beef	22	Infected	Yes	Lab officer	30	Yes	40	Yes	20	pos	Yes	Survive	80	pos	Yes
			Not infected	Yes			No	60	No	80	neg	Yes	No	20	neg	Yes
					Local livestock office	40	Yes	40	Yes	15	pos	Yes	Survive	60	pos	Yes
							No	60	No	85	neg	Yes	No	40	neg	Yes
					No reports	30										
					No Avg.	*33.33*	*No Avg.*	*53.33*	*No Avg.*	*84.17*			*No Avg.*	*30*		
Northern	Small holder	84	Infected	Yes	Lab officer	10	Yes	20	Yes	10	pos	Yes	Survive	70	pos	Yes
			Not infected	Yes			No	80	No	90	neg	Yes	No	30	neg	Yes
					Local livestock office	50	Yes	40	Yes	10	pos	Yes	Survive	40	pos	Yes
							No	60	No	90	neg	Yes	No	60	neg	Yes
					No reports	40										
	Dairy	2	Infected	Yes	Lab officer	10	Yes	20	Yes	10	pos	Yes	Survive	70	pos	Yes
			Not infected	Yes			No	80	No	90	neg	Yes	No	30	neg	Yes
					Local livestock office	50	Yes	40	Yes	10	pos	Yes	Survive	40	pos	Yes

							No	60	No	90	neg	Yes	No	60	neg	Yes
					No reports	40										
	Beef	14	Infected	Yes	Lab officer	10	Yes	20	Yes	10	pos	Yes	Survive	70	pos	Yes
			Not infected	Yes			No	80	No	90	neg	Yes	No	30	neg	Yes
					Local livestock office	50	Yes	40	Yes	10	pos	Yes	Survive	40	pos	Yes
							No	60	No	90	neg	Yes	No	60	neg	Yes
					No reports	40										
					No Avg.	*40*	*No Avg.*	*70*	*No Avg.*	*90*			*No Avg.*	*45*		
Eastern	Small holder	75	Infected	Yes	Lab officer	5	Yes	5	Yes	5	pos	Yes	Survive	20	pos	Yes
			Not infected	Yes			No	95	No	95	neg	Yes	No	80	neg	Yes
					Local livestock office	50	Yes	10	Yes	10	pos	Yes	Survive	20	pos	Yes
							No	90	No	90	neg	Yes	No	80	neg	Yes
					No reports	45										
	Dairy	12	Infected	Yes	Lab officer	5	Yes	5	Yes	5	pos	Yes	Survive	20	pos	Yes
			Not infected	Yes			No	95	No	95	neg	Yes	No	80	neg	Yes
					Local livestock office	50	Yes	20	Yes	10	pos	Yes	Survive	20	pos	Yes
							No	80	No	90	neg	Yes	No	80	neg	Yes
					No reports	45										
	Beef	13	Infected	Yes	Lab officer	5	Yes	5	Yes	5	pos	Yes	Survive	20	pos	Yes
			Not	Yes			No	95	No	95	neg	Yes	No	80	neg	Yes

			infected													
					Local livestock office	50	Yes	10	Yes	10	pos	Yes	Survive	20	pos	Yes
							No	90	No	90	neg	Yes	No	80	neg	Yes
					No reports	45										
					No Avg.	*45*	*No Avg.*	*90.83*	*No Avg.*	*92.5*			*No Avg.*	*80*		
					No Avg.	*37.08*	*No. Avg.*	*67.29*	*No Avg.*	*87.5*			*No Avg.*	*46.25*		

Table 6-2 *Brucella* surveillance system components probabilities for PNG

Region	Farm type	Prob %	Herd Status	Prob %	Farmer Reports	Prob %	Carry out investigation	Prob %	Test for Brucellosis	Prob %	RBT	Prob %	Submit samples	Prob %	ELISA	Prob %
Lower Markham	Large beef farms	80	Infected	Yes	Council wards	10	Yes	20	Yes	10	Pos	Yes	Survive	50	pos	Yes
			Not infected	Yes			No	80	No	90	Neg	Yes	No	50	neg	Yes
					Rural Development Technician	20	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Local government office	20	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Animal health assistant	20	Yes	20	Yes	10	Pos	Yes	Survive	50	pos	Yes
							No	80	No	90	Neg	Yes	No	50	neg	Yes
					No reports	30										

	Medium beef farms	12	Infected	Yes	Council wards	30	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
			Not infected	Yes			No	80	No	90	Neg	Yes	No	60	neg	Yes
					Rural Development Technician	10	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Local government office	10	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Animal health assistant	10	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
							No	80	No	90	Neg	Yes	No	60	neg	Yes
					No reports	40										
	Small beef farms	8	Infected	Yes	Council wards	30	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
			Not infected	Yes			No	80	No	90	Neg	Yes	No	60	neg	Yes
					Rural Development Technician	10	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Local government office	10	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Animal health assistant	10	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
							No	80	No	90	Neg	Yes	No	60	neg	Yes
					No reports	40										

					No Avg.	*36.67*	*No Avg.*	*85*	*No Avg.*	*90*			*No Avg.*	*63.33*		
Upper Markham	Large beef farms	80	Infected	Yes	Council wards	15	Yes	20	Yes	10	Pos	Yes	Survive	50	pos	Yes
			Not infected	Yes			No	80	No	90	Neg	Yes	No	50	neg	Yes
					Rural Development Technician	20	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Local government office	20	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Animal health assistant	20	Yes	20	Yes	10	Pos	Yes	Survive	50	pos	Yes
							No	80	No	90	Neg	Yes	No	50	neg	Yes
					No reports	25										
	Medium beef farms	12	Infected	Yes	Council wards	30	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
			Not infected	Yes			No	80	No	90	Neg	Yes	No	60	neg	Yes
					Rural Development Technician	10	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Local government office	10	Yes	10	Yes	10	Pos	Yes	Survive	30	pos	Yes
							No	90	No	90	Neg	Yes	No	70	neg	Yes
					Animal health assistant	10	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
							No	80	No	90	Neg	Yes	No	60	neg	Yes

					No reports	40										
	Small beef farms	8	Infected	Yes	Council wards	30	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
			Not infected	Yes			No	80	No	90	Neg	Yes	No	60	neg	Yes
					Rural Development Technician	10	Yes	10	Yes	15	Pos	Yes	Survive	30	pos	Yes
							No	90	No	85	Neg	Yes	No	70	neg	Yes
					Local government office	10	Yes	15	Yes	20	Pos	Yes	Survive	45	pos	Yes
							No	85	No	80	Neg	Yes	No	55	neg	Yes
					Animal health assistant	10	Yes	20	Yes	10	Pos	Yes	Survive	40	pos	Yes
							No	80	No	90	Neg	Yes	No	60	neg	Yes
					No reports	40										
					No Avg.	*35.00*	*No Avg.*	*84.58*	*No Avg.*	*88.75*			*No Avg.*	*62.08*		
					No Avg.	*35.83*	*No. Avg.*	*84.79*	*No Avg.*	*89.38*			*No Avg.*	*62.71*		

Table 6-3 Brucella surveillance system components probabilities for Vanuatu

Island	**Farm type**	**Prob %**	**Herd Status**	**Prob %**	**Farmer reports**	**Prob %**	**Carry out Investigation**	**Prob %**	**Test for Brucellosis**	**Prob %**	**RBT**	**Prob %**	**Submit samples**	**Prob %**	**ELISA**	**Prob %**
Santo	Large beef farms	70	Infected	Yes	Local livestock office	40	Yes	60	Yes	20	pos	81.2	Survive	60	pos	Yes
			Not infected	Yes			No	40	No	80	neg	18.8	No	70	neg	Yes
					Village headman	30	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes

					No Reports	30										
	Medium beef farms	20	Infected	Yes	Local livestock office	30	Yes	60	Yes	15	pos	81.2	Survive	70	pos	Yes
			Not infected	Yes			No	40	No	85	neg	18.8	No	30	neg	Yes
					Village headman	25	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	45										
	Small beef farms	10	Infected	Yes	Local livestock office	30	Yes	60	Yes	10	pos	81.2	Survive	70	pos	Yes
			Not infected	Yes			No	40	No	90	neg	18.8	No	30	neg	Yes
					Village headman	40	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	30										
					No Avg.	*35*	*No Avg.*	*50.00*	*No Avg.*	*90*			*No Avg.*	*46.67*		
Malo	Large beef farms	30	Infected	Yes	Local livestock office	30	Yes	60	Yes	10	pos	81.2	Survive	60	pos	Yes
			Not infected	Yes			No	40	No	90	neg	18.8	No	40	neg	Yes
					Village headman	30	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	40										
	Medium beef farms	40	Infected	Yes	Local livestock office	25	Yes	40	Yes	10	pos	81.2	Survive	50	pos	Yes

			Not infected	Yes			No	60	No	90	neg	18.8	No	50	neg	Yes
					Village headman	30	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	45										
	Small beef farms	30	Infected	Yes	Local livestock office	30	Yes	60	Yes	10	pos	81.2	Survive	50	pos	Yes
			Not Infected	Yes			No	40	No	90	neg	18.8	No	50	neg	Yes
					Village headman	40	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	30										
					No Avg.	*38.33*	*No Avg.*	*53.33*	*No Avg.*	*92.5*			*No Avg.*	*48.33*		
Efate	Large beef farms	70	Infected	Yes	Local livestock office	40	Yes	80	Yes	20	pos	81.2	Survive	70	pos	Yes
			Not Infected	Yes			No	20	No	80	neg	18.8	No	30	neg	Yes
					Village headman	30	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	30										
	Medium beef farms	20	Infected	Yes	Local livestock office	30	Yes	60	Yes	20	pos	81.2	Survive	70	pos	Yes
			Not Infected	Yes			No	40	No	80	neg	18.8	No	30	neg	Yes
					Village headman	40	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes

					No Reports	30										
	Small beef farms	10	Infected	Yes	Lab officer	30	Yes	60	Yes	10	pos	81.2	Survive	70	pos	Yes
			Not Infected	Yes			No	40	No	90	neg	18.8	No	30	neg	Yes
					Local livestock office	40	Yes	40	Yes	5	pos	81.2	Survive	50	pos	Yes
							No	60	No	95	neg	18.8	No	50	neg	Yes
					No Reports	30										
					No Avg.	*30*	*No Avg.*	*46.67*	*No Avg.*	*89.17*			*No Avg.*	*40*		
					No Avg.	*34.44*	*No Avg.*	*50*	*No Avg.*	*90.56*			*No Avg.*	*45*		

Table 6-4 *Brucella* surveillance system components probabilities for the Solomon Islands

Province	**Farm type**	**Prob %**	**Herd status**	**Prob %**	**Farmer reports**	**Prob %**	**Carry out investigation**	**Prob %**	**Test for Brucellosis**	**Prob %**	**RBT**	**Prob %**	**Submit samples**	**Prob %**	**ELISA**	**Prob %**
Guadalcanal	Large cattle farms	10	Infected	Yes	Local livestock office	50	Yes	50	Yes	20	Pos	Yes	Survive	50	pos	Yes
			Not infected	Yes			No	50	No	80	Neg	Yes	No	50	neg	Yes
					No Reports	50										
	Medium cattle farms	15	Infected	Yes	Local livestock office	45	Yes	45	Yes	10	Pos	Yes	Survive	40	pos	Yes
			Not infected	Yes			No	55	No	90	Neg	Yes	No	60	neg	Yes
					No Reports	55										
	Small cattle farms	75	Infected	Yes	Local livestock office	40	Yes	45	Yes	10	Pos	Yes	Survive	40	pos	Yes

			Not infected	Yes			No	55	No	90	Neg	Yes	No	60	neg	Yes
					No Reports	60										
					No Avg.	*55.00*	*No Avg.*	*53.33*	*No Avg.*	*86.67*			*No Avg.*	*56.67*		
Malaita	Large cattle farms	10	Infected	Yes	Local livestock office	50	Yes	50	Yes	10	Pos	Yes	Survive	50	pos	Yes
			Not infected	Yes			No	50	No	90	Neg	Yes	No	50	neg	Yes
					No Reports	50										
	Medium cattle farms	15	Infected	Yes	Local livestock office	40	Yes	40	Yes	10	Pos	Yes	Survive	40	pos	Yes
			Not infected	Yes			No	60	No	90	Neg	Yes	No	60	neg	Yes
					No Reports	60										
	Small cattle farms	75	Infected	Yes	Local livestock office	30	Yes	30	Yes	10	Pos	Yes	Survive	35	pos	Yes
			Not infected	Yes			No	70	No	90	Neg	Yes	No	65	neg	Yes
					No Reports	70										
					No Avg.	*60*	*No Avg.*	*60*	*No Avg.*	*90*			*No Avg.*	*58.33*		
					No Avg.	*57.5*	*No Avg.*	*56.67*	*No Avg.*	*88.33*			*No Avg.*	*57.5*		

1

The average probabilities for the four countries were as follows; Fiji (4 Divisions), farmers not making disease reports (37%), the authorities not carrying out investigation after receiving reports (67%), the investigators not testing brucellosis (87%), and samples not surviving when being sent for the indirect ELISA test (46%). For PNG (2 Regions), farmers not making disease reports (35%), the authorities not carrying out investigation after receiving reports (84%), the investigators not testing brucellosis (89%), and samples not surviving when being sent for the indirect ELISA test (62%). For Vanuatu (3 Islands), farmers not making disease reports (34%), the authorities not carrying out investigation after receiving reports (50%), the investigators not testing brucellosis (90%), and samples not surviving when being sent for the indirect ELISA test (45%). For the Solomon Islands (2 Provinces), farmers not making disease reports (57%), the authorities not carrying out investigation after receiving reports (56%), the investigators not testing brucellosis (88%), and samples not surviving when being sent for the indirect ELISA test (57%).

Discussion

The population data used from the literature reviewed were quite outdated and may not have been accurate in relation to the actual cattle population existing on the ground in the areas of the countries that were studied at that time. Nevertheless, it was a good starting point as the documented reports on cattle population numbers were considered more accurate compared to the opinions recorded from the questionnaires.

The reporting structures (Fig. 6-2 to Fig. 6-5) and surveillance system components are long and complex making it difficult for reports to filter through to the decision makers and for reports to be followed through with investigation, this affects the sensitivity of the surveillance system to detect Brucellosis and other animal diseases (Tukana et al., 2018)

Information collected from the questionnaires which populated the following chance nodes (Fig. 6-2 to Fig. 6-5); Farmer Reports, carrying out investigation, Test for Brucellosis and Submitting Samples were based mainly on opinions and some experiences (not rigorous studies) from a few older officials as there has been very few reports on outbreaks of *Brucella* in PNG, Vanuatu and the Solomon Islands (Tukana et al., 2016). This would have resulted in some bias as the results (probability values used in the models) may have varied if different sets of officials were used to fill the questionnaires in each country.

In addition, only the scenario trees for the surveillance system components were used and not the models as data for some nodes were limited and needed more rigorous studies to collect them, so the findings are limited however it gives some important insights on where weaknesses lie in the SSC's for Fiji, PNG, Vanuatu and the Solomon Islands.

The information collected from personal communication that supported the questionnaires were considered very important as these were views from very experienced officers who were around when bovine brucellosis was endemic in their countries, some of them were involved right from sample collection in the field to serological diagnosis in the laboratory (Nonga, 2016), (Puana 2015).

The proportion of farmers not making reports of brucellosis was quite high for Fiji, PNG (Yombo, 2010), Vanuatu (Mosese, 2016) and the Solomon Islands (Atalupe, 2015) and possible reasons for this was that farmer capacity to recognise signs of brucellosis were low and also some farmers would only report diseases if there was mortality observed in their cattle (Tukana and Gummow, 2017).

The proportion of authorities not carrying out investigation was also high for the 4 countries; this could have resulted from the fact that the authorities were just not following up on reports that were made by the farmers; this may have resulted from low staff numbers or vacant positions in the SSC's.

The proportion of authorities not testing for brucellosis was also high for the 4 countries and this could have been due to the fact that investigation not being done by the authorities was also high.

The proportion of samples not surviving was also high, this could have resulted from inexperience as well as reduced capacities to from the officers to properly collect and process samples for the indirect ELISA test.

The Herd Status, RBT and ELISA nodes were not populated with a probability as the information collected from the questionnaires were based on opinions and not rigorous scientific studies, this meant that the results from the SSC's were incomplete, i.e. it they did not indicate a sensitivity value for detecting a positive and negative *Brucella* case (case). However, the holistic approach used to document and analyse the *Brucella* surveillance system components (SSC's) is important for PICTs in the sense that it looks at each component in detail and allows the researchers and decision makers to pinpoint weaknesses in the system and develop strategies to improve them so as to increase the overall sensitivities for SSC's in the countries to detect *Brucella*.

Conclusions

Reporting, investigation, testing for Brucellosis, collection and submission of samples to the laboratory for brucellosis analysis were noted to be weak. That is, the farmers in the four countries studied are just not making enough reports. In addition, the animal health authorities are not following up on disease reports that are made by the farmers. The SSC's are further impacted by the limited capacities to carry out proper investigation and recognise signs of brucellosis (Fiji) and other diseases in Papua New Guinea and the Solomon Islands. The capacities to properly collect samples; process those samples and send them to the subregional and reference laboratories for analysis were low, reducing the number of samples that survived before being analysed at the laboratory. This reduces the probabilities for the countries surveillance system components to detect brucellosis as well as other important diseases.

Thus there is an important need to improve the efficiency of *Brucella* surveillance system components to increase their probabilities to detect positive and negative cows to safeguard the cattle sectors in the countries studied and the other Pacific Island communities. As was the case in Fiji, i.e. since the sensitivity of its *Brucella* surveillance system components was weak, brucellosis was not detected until there was an advanced outbreak in 2009.

Recommendations

Reporting should be improved by increasing awareness on the impacts of animal diseases and zoonoses as well as developing routine surveillance programs to monitor for Brucellosis.

Training to build capacity for frontline animal health officials in Pacific Island countries to investigate suspected *Brucella* cases, recognise disease signs, collect samples, process those samples, pack them appropriately and send them to reference laboratories will improve the survival of samples when they arrive at the laboratory for analysis.

Training to build capacity for laboratory staff carrying out serological tests for *Brucella* needs to be continuously done as well for the subregional laboratories in Fiji and PNG as staff turnover continues to be high and in light of new diagnostic technologies.

Rigorous scientific studies are recommended to determine the herd prevalence, RBT and ELISA probabilities for the surveillance system components for Fiji, PNG, Vanuatu and the Solomon Islands.

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Compliance with ethical standards

All applicable international, national, and/or institutional guidelines for the care and use of animals were followed. All procedures performed in studies involving humans and animals were in accordance with the ethical standards of the James Cook University policy and guidelines. Ethical approval to carry out the study was obtained from the human and animal ethics committees at the university (approval references: A1740, H4414).

Conflict of interest

The authors declare that they have no competing interests.

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CHAPTER 7

GENERAL DISCUSSION

This chapter summarises the key findings and conclusions of the research activities conducted under this study and discusses the research outputs and outcomes in relation to the thesis objectives. Furthermore it provides a statement of how this research advances the way of thinking in animal disease surveillance and reporting in the Pacific Island Community context.

Five approaches were used in this study to improve disease surveillance and reporting using *Brucella* abortus as the disease of interest and cattle as the animal unit studied and this chapter demonstrates how these approaches relate to each other and how they are applied.

RECAPITULATION OF RESEARCH AIM AND OBJECTIVES

This study aimed to examine ways to improve disease surveillance and reporting using Brucellosis in cattle as a model to reduce the impacts of zoonoses and protect the livelihoods of livestock farmers within the Pacific Island Community.

The study had five objectives:

1. Obtain a better knowledge on the status of bovine brucellosis in the Pacific Island Community, using the current outbreak of the disease in Fiji as a model.
2. Determine which risk factors were associated with the outbreak of bovine brucellosis in Fiji and how some of those risks factors could be related to other Pacific Island Community countries, i.e. in terms of similarities of cultures and farming practices.
3. Identify strengths, weaknesses, opportunities and threats (SWOT) for the current disease reporting structures in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands and how they impacted their surveillance system components.
4. Improve disease surveillance through capacity building training, survey development and implement a brucellosis freedom survey in PNG, Vanuatu and the Solomon Islands and a prevalence survey in Fiji.
5. Document and analyse the surveillance system components (SSCs) in place for the detection of bovine brucellosis in Fiji, Papua New Guinea, Vanuatu and the Solomon Islands.

PRACTICAL FRAMEWORK APPLIED UNDER THIS STUDY

The research first sought to gain a better understanding of the status of Brucellosis in the Pacific Island Community and the region; the research also examined retrospective data to calculate the prevalence of the disease to determine its spread in Fiji since Fiji had an outbreak of the disease at that time (Chapter 2). The research sought to further enhance the understanding of the disease by examining which risk factors could have been associated with the outbreak of *B. abortus* on Dairy farms in the Tailevu province of Fiji (Chapter 3). After completing the research studies in Chapter 2 and Chapter 3 it was evident that there was a poor understanding of the disease and disease surveillance capacities were weak, so the research examined the reporting structures to identify gaps and areas that could be improved as well as on how policy support was impacting disease surveillance in the Pacific Island Community (Chapter 4). The next step was to build surveillance capacities for Fiji, PNG, Vanuatu and the Solomon Islands through the research activities as this was lacking, i.e. through the development of surveys to detect *B. abortus* in selected regions as funding was limited (Chapter 5). The final step was to improve disease surveillance and reporting through the examination of the SSC in place in Fiji, PNG, Vanuatu and the Solomon Islands to analyse the sensitivities to detect *B. abortus*. The models focussed on the documentation of the surveillance system components (SSCs) for Fiji, PNG, Vanuatu and the Solomon Islands enabling the analysis of its different components to identify where weaknesses were, thus allowing for recommendations for improvements to be made (Chapter 6).

The result of this research enabled a more detailed examination of the surveillance system components (SSCs) for Fiji, PNG, Vanuatu and the Solomon Islands. This utilised a regional approach which is a more proactive method of analysing surveillance and reporting systems for animal diseases in the Pacific Island community, i.e. it provided a deeper insight at the different SSC's and which ones need to be improved to improve overall surveillance and reporting as most PICTs could share lessons learnt and synergise surveillance activities.

A diagrammatic representation of the research process and related outputs are presented in Figure 7-1.

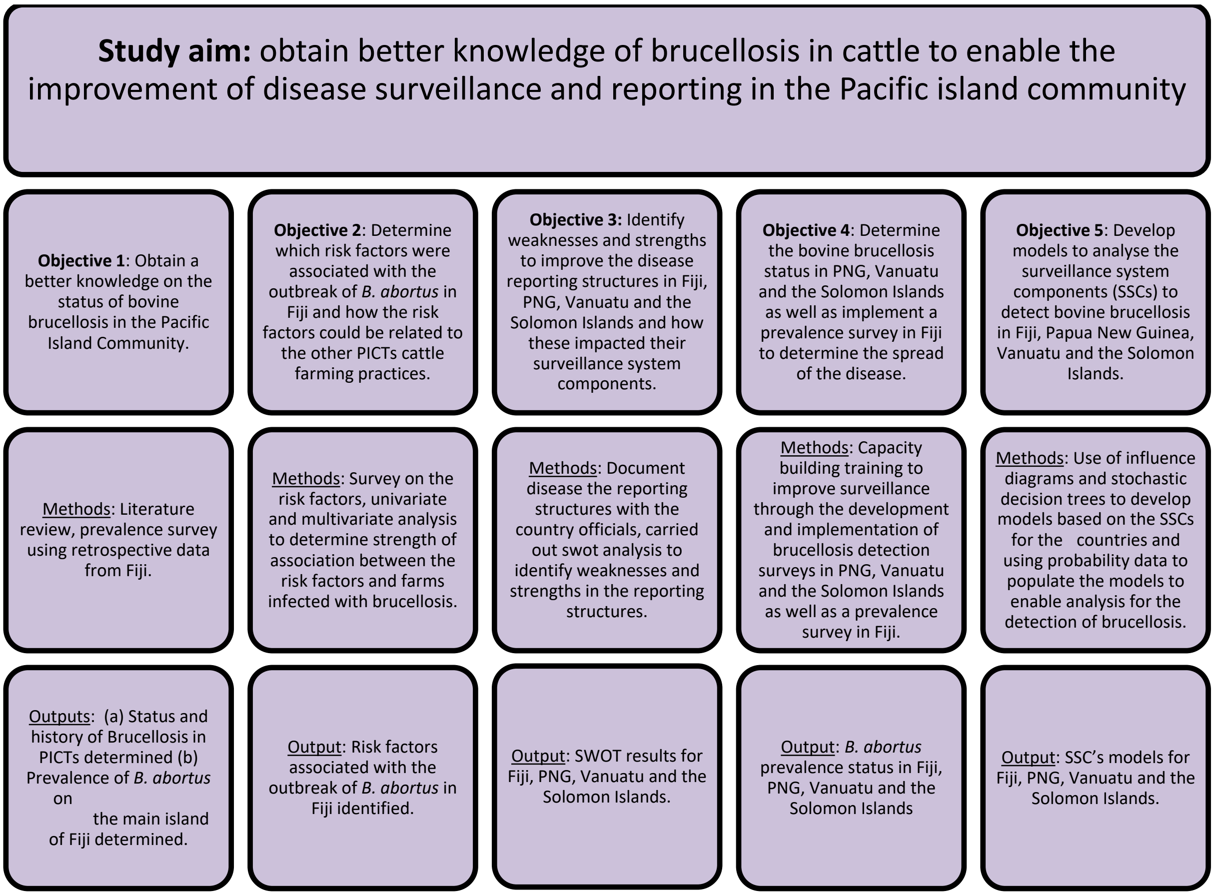

Figure 7-1: Diagrammatic representation of the research process with related outputs

SUMMARY OF STUDY KEY FINDINGS AND CONCLUSION

Key findings from the literature review on the history of brucellosis in the Pacific island community and the prevalence study of *B. abortus* in Fiji and conclusions (Chapter 2)

Examination of the literature indicated that brucellosis has been in the Pacific for many years, but may not be considered important. Studies have indicated that the disease has been identified in animals in the Pacific (PNG) as early as 1965 (Aldrick, 1968). One of the reasons why the disease may have not been considered important is that there has not been much awareness about the disease being carried out within the communities in the Pacific Island Countries and Territories (Tukana et al., 2015).

There has also been very little literature published on *B. abortus* in the Pacific Island region over the last 20 years making it difficult to gauge the impact of the disease (Conclusion 1). 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 (Tukana et al., 2015).

The re-emergence of *B. abortus* in Fiji was most likely due to the lack of monitoring for the disease. Furthermore the disease could have been present in pockets of untested cattle and the practice of retaining older cows for milking gave rise to the potential of harbouring the *B. abortus* organism in the dairy cow herds in Fiji. There also has been a high level of unregulated cattle movement in Fiji possibly transferring the *B. abortus* organism to clean areas.

Disease surveillance is limited and poor in Papua New Guinea (PNG), Vanuatu and the Solomon Islands (Conclusion 2). Eventhough PNG, Vanuatu and the Solomon Islands declared freedom from *B. abortus* to OIE; the declaration was based mainly on past history. Thus there is a need to have continued disease surveillance for *B. abortus* as well as for other important cattle diseases as cattle is an important livelihood for those countries. In addition, as with the case in Fiji, i.e. once the disease had re-emerged, it has been difficult to eliminate, so this stresses the need to have active disease surveillance.

The risk of *B. abortus* crossing over borders in Fiji is high since surveillance is poor. According to the retrospective data analysed, the Naitasiri province had a much higher *B. abortus* prevalence compared to other provinces and since the province shared its border with the Tailevu province, it was concluded that the infection was likely to have spread through the unregulated movement of infected cattle from Tailevu to Naitasiri and this was corroborated by the authorities and farmers in those provinces (Tukana et al., 2015).

The findings from Chapter 2 were, (Conclusion 1) that there was very little literature published on *B. abortus* in the Pacific Islands over the last 20 years and this made it very difficult to gauge the impact of the disease and also difficult to implement surveillance programs, and (Conclusion 2) *B. abortus* surveillance is poor in the Pacific Islands thus increasing the risks of re-emergence and transmission of the disease. With the re-emergence of the disease in Fiji, it was decided to study which risk factors could have been associated with the disease.

Key findings from the cross-sectional study of the risk factors associated with the *B. abortus* outbreak on dairy cattle farms in Fiji and conclusions (Chapter 3)

The risks of *B. abortus* transmission within cattle on dairy farms in Fiji are high (Conclusion 3). It was evident from the survey that the type of farming systems practiced in Fiji had a high percentage of open and mixed herds, thus allowing different classes of cattle to mingle within and from outside farms. Having a high density of cattle also created opportunity for greater contact and for the spread of brucellosis (Baudracco et al., 2011). In addition, hygiene was poor on many of the farms surveyed, and this was evident in the milking sheds, creating an environment where infectious diseases could be maintained and spread, particularly during milking. Poor hygiene could also account for the high occurrence of mastitis reported on the farms surveyed, which were often left untreated.

The existence of other animal species on the dairy farms in Fiji may harbour the *B. abortus* organism). The existence of other animal species on the farm could also be important as they could have acted as potential carriers of *B. abortus* and Mycobacterium bovis, but these were only present in large numbers on a few farms, and the univariate and multivariate analysis failed to show any association with other animal species

Reporting of diseases by the farmers to the animal health authorities was poor (Conclusion 4). Reporting animal diseases to the relevant authorities (veterinary services) was very poor as less than half of the farmers interviewed indicated that they would only report diseases if they felt it would affect their livelihoods.

The risks of human infection were high with the farmers and their families (Conclusion 5). In Fiji, it is quite normal to see people working on farms with minimum or no personal protective equipment (PPE) at all. Using minimum or no PPE at all is due to not having the financial resources to procure PPE and because most farmers are not aware of the risks of exposure to zoonotic diseases. This is evident in the study which indicated that the use of PPE for routine work was very low and surprisingly even lower when dealing with high-risk situations, e.g. when delivering calves. Handling of cow afterbirth and aborted materials was another area of concern as more than one third of the farmers interviewed indicated that they did nothing in relation to disposing of those materials. The low levels of PPE use on the farms in Fiji increases the risk of exposure to zoonotic infectious diseases.

Farms having a history of reactor cattle to brucellosis and or tuberculosis were 30 times (OR= 30) more likely of being infected with the *B. abortus* organism (Conclusion 6). This could mean that some cattle may have been carriers of brucellosis for years, with signs going unnoticed until 2009 (Poester et al., 2013).

Farms that practised sharing of water sources for cattle within and with cattle from outside farms were 39 times (OR= 39) more likely of being infected with the *B. abortus* organism (Conclusion 7). The practice is normal in Fiji where rivers border farms, and cattle from different farms share the same water sources increasing the risks of brucellosis transmission. It is also normal that water sources are placed between fences so cattle from different paddocks could share the same water source.

The findings from Chapter 3 were, (Conclusion 3) the risks of disease transmission within cattle on the farms was high, (Conclusion 4) reporting of diseases by the farmers was poor, (Conclusion 5) the risks of human infection was high, (Conclusion 6) farms having a history of Brucellosis and or Tuberculosis had a high chance of being infected to *B. abortus*, and (Conclusion 7) farms that shared cattle water sources with other farms had a higher chance of being infected with *B. abortus*. After examining the risk factors associated with the *B. abortus* outbreak in Fiji, the reporting structures in the Pacific Islands were documented and analysed with the aim of identifying its strengths and weaknesses.

Key findings from the disease reporting structure analysis for Fiji, PNG, Vanuatu and the Solomon Islands and conclusions (Chapter 4)

Surveillance programs and reporting structures are impeded by the lack of policy to support them (Conclusion 8). Since there are little or no specific policies in PICTs to support disease reporting and surveillance, this could increase the chances of the spread of transboundary animal diseases as diseases are not detected and contained until they have been well established (Tukana et al., 2015). Furthermore, the lack of national policies to support animal disease surveillance and or animal disease reporting could be due to the perception that animal health is of minor importance compared to other diseases such as HIV and TB in the region. The limited priority placed on animal diseases by national governments leads to a lack of resource allocation from national government budgets (Rich et al., 2013).

Reporting structures are affected by the vacant positions and shortage of veterinarians (Conclusion 9). Vacant positions and the lack of veterinarians and high officer turnover mean that most frontline animal health officials are inexperienced and not able to recognise disease signs so are not able to make disease reports.

Reporting structures are too long, hierarchical in nature and have multiple reporting branches which are not functioning well (Conclusion 10). The multiple reporting branches in the reporting structures for the countries studied are not functioning properly so are contributing to reducing the efficiency of reporting diseases in Fiji, PNG, Vanuatu and the Solomon Islands. The upward hierarchical nature of the reporting systems is also affecting the efficiency of reporting as the normal practice in the countries studied is that officers in a branch cannot bypass immediate superior officers thus lengthening the reporting period.

The key findings from Chapter 4 were, (Conclusion 8) surveillance programs and reporting structures in the Pacific Islands are impeded by the lack of policies to support them, (Conclusion 9) reporting structure are affected by vacant positions and the shortage of veterinarians, (Conclusion 10) reporting structures are too long, hierarchical in nature and have multiple branches which are not functioning well. After analysing the reporting structures, detection surveys were developed and implemented in the Pacific Islands to see if *B. abortus* was present.

The key findings from the disease surveillance training and the implementation of the *B. abortus* detection surveys in PNG, Vanuatu, the Solomon Islands and the prevalence survey in Fiji (Chapter 5)

Lack of funds impacted surveillance programs in Pacific Island Countries Territories (Conclusion11). The revealed that lack of funds impeded the development of active animal disease surveillance programs in these countries and this was common across the countries studied. In comparison to developed countries, developing countries are at a disadvantage because of limited skilled financial and human resources and cannot adequately respond to zoonosis outbreaks (Jakob et al., 2007).

Lack of technical expertise reduced disease surveillance capacities in PICTs (Conclusion12). The lack of technical capacity 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 is 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).

Outdated data on cattle population impeded the development of surveys for disease surveillance in PICTs (Conclusion 13). 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, and 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, 2016).

PNG, Vanuatu and the Solomon Islands all tested negative to *B. abortus* based on the survey sample sizes for selected regions (Conclusion 14). The results from the indirect ELISA tests on all the samples performed at Kila Kila (PNG) and Koronivia (Fiji) have yielded negative to *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).

The key findings from Chapter 5 were, (Conclusion 11) lack of funding support impeded the development of active disease surveillance programs in the Pacific Islands, (Conclusion 12) lack of technical capacities reduced surveillance capacities, (Conclusion

13) outdated data impeded the development of surveys for disease surveillance and (Conclusion 14) the negative results for *B. abortus* in the countries surveyed were based on the sample sizes in selected regions and does not necessarily mean disease freedom on a national basis. After analysing the prevalence of *B. abortus* through capacity building training and active disease surveillance, the actual surveillance system components in the Pacific Islands were documented and analysed to identify weaknesses and suggest areas that could be improved.

The key findings from the analysis of surveillance system components and their influence on animal disease reporting in Fiji, Papua New, Vanuatu and the Solomon Islands using *Brucella abortus* as a model (Chapter 6)

The proportion of reports being made for Brucellosis and other diseases was low (Conclusion 15). Possible reasons for this was that farmer capacity to recognise signs of brucellosis were low and also some farmers would only report diseases if there was mortality observed in their cattle (Tukana and Gummow, 2017).

The proportion of disease investigations being carried out by the animal health authorities was low (Conclusion 16). This could have resulted from the fact that the authorities were just not following up on reports that were made by the farmers; this may have also resulted from low staff numbers or vacant positions in the surveillance system components for the countries studied.

The survivability of samples collected, processed and sent to the reference laboratories were low (Conclusion 17). This most likely resulted from inexperience as well as reduced capacities of the frontline officers to properly collect and process samples for the indirect ELISA test.

Data for certain nodes in the country SSC's were limited affecting the determination of the country sensitivities to detect Brucellosis (Conclusion 18). Most of the information collected was from survey questionnaires and information collected was based on opinions which could have caused bias for certain nodes in the SSC's. Thus there is a need for further investigation should funding be available.

The findings from Chapter 6 were, (Conclusion 15) the proportion of reports being made by farmers was low, (Conclusion 16) the proportion of disease investigations made by the authorities was low, (Conclusion 17) the survivability of the samples collected from the field were low, (Conclusion18) data for certain nodes in the country SSC's were limited.

Table 7-1 Summary of conclusions from the research

METHODS	CONCLUSIONS
Chapter 2 Literature Review and *B. abortus* retrospective study for Fiji.	**Conclusion 1**: There has been very little literature published on *B. abortus* in the Pacific Island region over the last 20 years making it difficult to gauge the impact of the disease. Even though Bovine brucellosis has been present in PICTs for many years it may not be considered important as there is little information available and a lack of awareness on the disease.
	Conclusion 2: Disease surveillance is limited and poor in PNG, Vanuatu and the Solomon Islands. Poor surveillance and monitoring may have contributed to the re-emergence of *B. abortus* in Fiji.
Chapter 3 Cross-sectional study of *the* risk factors associated with the *B. abortus* outbreak on dairy cattle farms in Fiji	**Conclusion 3**: The risks of brucellosis transmission within cattle on dairy farms in Fiji are high.
	Conclusion 4: Reporting of diseases to the animal health authorities was poor with the farmers.
	Conclusion 5: Risks of human infection was high with the farmers.
	Conclusion 6: Farms having a history of reactor cattle to brucellosis and or tuberculosis were 30 times (OR= 30) more likely of being infected with the *B. abortus* organism.
	Conclusion 7: Farms that practised sharing of water sources for cattle within and with cattle from outside farms were 39 times (OR= 39) more likely of being infected with the *B. abortus* organism.
Chapter 4 Disease reporting structure analysis in Fiji, PNG, Vanuatu and the Solomon Islands	**Conclusion 8**: Surveillance programs and reporting structures are impeded by the lack of policy to support them.
	Conclusion 9: Reporting structures are affected by the vacant positions and shortage of veterinarians (lack of technical expertise).
	Conclusion 10: Reporting structures are too long, hierarchical in nature and have multiple reporting branches which are not functioning well.

Chapter 5 Disease surveillance training and *B. abortus* detection surveys implementation	**Conclusion 11**: Lack of funds impacted surveillance programs in PICTs.
	Conclusion 12: Lack of technical expertise reduced disease surveillance capacities in PICTs.
	Conclusion 13: Outdated data on cattle population impeded the development of surveys for disease surveillance in PICTs.
	Conclusion 14: PNG, Vanuatu and the Solomon Islands all tested negative to *B. abortus* based on the survey sample sizes for selected regions.
Chapter 6 Analysis of surveillance system components and their influence on animal disease reporting in Fiji, Papua New, Vanuatu and the Solomon Islands using *Brucella abortus* as a model	**Conclusion 15**: The proportion of reports being made for Brucellosis and other diseases are low.
	Conclusion: 16: The proportions of disease investigations being carried out by the animal health authorities are low.
	Conclusion 17: The survivability of samples collected, processed and sent to reference laboratories is low.
	Conclusion 18: Data for certain nodes in the country SSC's were limited affecting the determination of the country sensitivities to detect *B. abortus.*

THE SIGNIFICANCE OF THESE KEY FINDINGS AND CONCLUSIONS

In relation to the *B. abortus* re-emergence in Fiji and poor disease surveillance and reporting of animal diseases in Papua New Guinea (PNG), Vanuatu and the Solomon Islands, it surprising that most Pacific Island Countries and Territories claim freedom from *B. abortus* and other transboundary animal diseases.

According to the literature, *B. abortus* has been present in PICTs for a long time, yet may not be considered important. There also has been very little literature published on the disease over the last 20 years making it difficult to gauge the impact of the disease. This has implications on priority setting i.e. national governments and donor agencies may have other priorities such as HIV and TB ahead of *B. abortus* and other animal diseases even though many animal diseases impact human health as well as food security and livelihoods of the people in the Pacific Island community.

The farming practices on the cattle farms in Fiji was poor thus was favourable for the spread of *B. abortus* within the cattle on the farms as well as cattle from other farms. On-farm biosecurity and hygiene was particularly poor and this contributed to not only the spread of *B. abortus* but for other animal diseases as well. Awareness on the risks of Brucellosis infection and the use of PPE was low in the farming communities in Fiji and this increased risk of human infection for the farmers and their families.

The findings indicated that disease surveillance and reporting was poor in PNG, Vanuatu and the Solomon Islands. Since PNG, Vanuatu and the Solomon Islands as well as most other PICTs have farming practices and cultures similar to Fiji, they could also have re-emergence of diseases thus it is imperative that they improve their disease surveillance to protect their livestock sectors and livelihoods.

Disease surveillance and reporting structures in Fiji, PNG, Vanuatu and the Solomon Islands are affected by the lack of policy support, vacant staff positions in the reporting structures as well as a chronic shortage of veterinarians reducing capacity of those reporting structures. Furthermore, reporting structures are too long, hierarchical in nature and have multiple branches which are not functioning well. This reduces the efficiency of reporting diseases, affecting the ability of PICTs to monitor, contain and eradicate *B. abortus* and other animal diseases.

Lack of funds, lack of capacity (technical expertise) due to high staff turn-over as well as outdated livestock population data affects the development and implementation of disease surveillance and reporting programs in Fiji, PNG, Vanuatu and the Solomon Islands. Furthermore, the declaration of freedom for *B. abortus* from PNG, Vanuatu and the Solomon Islands are based on selected regions and past history. Since there currently is no active disease surveillance programs being implemented in this countries and most other PICTs there is a great risk of the re-emergence of *B. abortus* as well as other transboundary animal diseases.

Farmer capacity to recognise signs of brucellosis were low and also some farmers would only report diseases if there was high mortality observed in their cattle, this reduced the proportion of reports being made for Brucellosis and other diseases.

The authorities were just not following up on reports that were made by the farmers; this may have also resulted from low staff numbers or vacant positions in the surveillance system components for the countries studied, this reduced the proportion of disease investigations being carried out by the animal health authorities.

Inexperience as well as reduced capacities of the frontline officers to properly collect and process samples for the indirect ELISA test reduced the survivability of samples that were sent to reference laboratories for *B. abortus* analysis.

The information collected for the country surveillance system components (SSC's) was limited as the information was from questionnaires and was based on opinions which could have caused bias for certain nodes in the SSC's. This caused limitation in the scope of analysis for the sensitivity to detect Brucellosis.

Significance of the regional approach method applied

This research was unique in the sense that it used a regional approach where the disease studied was Brucellosis (*B. abortus*) and the unit of interest was cattle. The literature analysed the history and status of Brucellosis and covered twenty-two Pacific Island countries in the region and some other developed countries such as Australia and New Zealand. This gave an in-depth insight on the history and status of the disease in the region (findings and conclusions indicated above).

The Food Animal Biosecurity Network (FABN) project formed a regional approach where the countries studied were Fiji, Papua New Guinea, Vanuatu and the Solomon Islands, who are all Melanesian countries which to an extent have similar cattle on-farm biosecurity practices and cultures. The finding from the analysis of the re-emergence from the *B. abortus* organism in Fiji is important for PNG, Vanuatu and the Solomon Islands, e.g. there was a lapse of monitoring for the disease in Fiji and the disease was not picked up until it was well established in the dairy farms in the Tailevu province. PNG, Vanuatu and the Solomon Islands currently do not implement active surveillance for *B. abortus,* yet cattle are an important commodity for their food and livelihoods source. Thus it is important that they develop and implement surveillance programs not only to monitor *B. abortus* but for other transboundary animal diseases as well.

Working on a regional basis was relevant as there was a lot of advantages to be obtained compared to working with just one country. Using a regional approach enhanced different countries in the region to develop networks and use those networks to improve disease surveillance, e.g. Fiji and PNG both being subregional laboratories that test for *B. abortus* shared their end samples during the study to ensure that both laboratories were getting the same results thus improving capacities for serological analysis in the laboratory. Furthermore, this enabled the sharing of resources between the countries when carrying out the quality control tests for the *B. abortus* samples using the indirect ELISA tests in both laboratories.

The development of the Food Animal Biosecurity Network by the AusAID project enables the improvement of disease surveillance regionally and this network should be exercised, e.g. if Fiji is the leading sub-regional laboratory for the analysis of *B. abortus* samples, then other countries should use this opportunity to monitor the disease in their countries by having their samples tested in Fiji, as it can be cheaper. This however will be impacted by funds to support this as well as agreements to have samples enter Fiji for *B. abortus* testing.

The regional approach used when conducting surveillance capacity building training under the FABN project also ensured that the participants strengthened their networks, helped them better communicate their disease issues and status, thus become more transparent for trade purposes, e.g. the Solomon Islands requested Fiji for breeding cattle, however Fiji informed them that they currently have *B. abortus* infection.

Furthermore, surveillance capacity building trainings carried out by the FABN project in the countries stopped at the stage where the random sampling frames were develop and the countries were supposed to take ownership of the surveillance activities where they implemented the surveys for *B. abortus* during their routine surveillance animal health and production work thus sharing resources with the FABN project.

The findings from research could be translated to improve surveillance and reporting in the Pacific Island community, e.g. since there is a chronic shortage of veterinarians, the paravet program that used to be implemented by the Pacific Community (SPC) needs to be pursued further with funding support to build surveillance capacities in PICTs.

During the study on the reporting structures the findings indicated that some of the weaknesses were the same for the four countries analysed, this is helpful to understand when developing regional surveillance programs, e.g. most of the reporting structures in the PICTs were developed during the colonial days, hierarchical in nature and have long and multiple branches that were not functioning well. Thus there is an important need to review PICT reporting structures to make them shorter, remove duplication and make them efficient.

CHAPTER 8

RECOMMENDATIONS

The results from this study can be used to formulate recommendations to improve disease surveillance and reporting to reduce the impacts of zoonoses and protect the livelihoods of livestock farmers within the Pacific Island community.

PRACTICAL FRAMEWORK TO INTEGRATE THE APPROACHES APPLIED UNDER THIS STUDY

The novel aspects of the work conducted under this study was that a regional approach was used while studying the surveillance system components (SSC's) for the Fiji, Papua New Guinea (PNG), Vanuatu and the Solomon Islands. This enabled the detailed examination of the different surveillance system components which enabled recommendations to be made for the improvement of disease surveillance and reporting in the Pacific Island community. This regional approach has been lacking in the past when trying to improve disease surveillance and reporting and is very important due to the close ties between these countries. Fiji, PNG, Vanuatu and the Solomon Islands are all Melanesian countries where farming practices and cultures can be similar to some extent and lessons learnt can be applied in the region and thus have a wider impact from the study. For example, the fact that Fiji had an outbreak of *B. abortus* in 2009 and is currently controlling the disease has given rise to valuable lessons as it is a real time disease situation and other countries in the region can learn from.

Recommendation 1:

Raise awareness with the Pacific Island community on the importance of Brucellosis and launch further studies in PICTs to collect information on *B. abortus*

The findings from the study indicated that the *B. abortus* organism has been present in the Pacific Island community for many years. However the disease may not be considered important in many countries in the Pacific Island community as the impacts of the *B. abortus* is not well known and there may be other disease priorities ahead of *B. abortus*, e.g. HIV and TB (Tukana et al., 2018). In light of this, there is an important need to raise awareness with national governments on the impacts of *B. abortus* as well as for other transboundary animal diseases as these can have negative impacts on public health and the livelihoods of livestock farmers in the Pacific Island community. There has been very little literature published on Brucellosis and *B. abortus* in the Pacific Island community over the last 20 years thus it has been difficult to gauge the impact of the disease. Thus there is an important need to launch further studies to collect information on *B. abortus* and other livestock diseases to help decision makers develop strategies for surveillance and monitoring for diseases.

Recommendation 2:

Develop further surveillance programs to monitor B. abortus in Fiji, PNG, Vanuatu and the Solomon Islands

The lessons learnt from the cattle sector in Fiji was that there was a lapse of monitoring for *B. abortus* and the disease was not picked up until it was well established and re-emergence occurred in Fiji in 2009. Once the disease had re-emerged it has been difficult to control in Fiji (Tukana and Gummow, 2016). Thus there is an important need for PNG, Vanuatu and the Solomon Islands to develop surveillance programs to monitor for *B. abortus* and other livestock diseases for cattle. This is because cattle are an important commodity in PNG, Vanuatu and the Solomon Islands and if *B. abortus* were to re-emerge in their countries, it would devastate their cattle sector and impact the livelihoods of the farmers who depend on it.

Recommendation 3:

Regulate cattle movement and border security

The findings indicated that unregulated movement of cattle in Fiji was likely causing the spread of *B. abortus* to clean areas as well as the re-infection of areas that had been tested and were declared free from the disease. Thus there is a need to support the regulation of cattle movement, particularly from infected farms as well as zones that have infected farms. This support should be in relation to providing the financial resources for cattle movement regulation, i.e. setting up and manning of checkpoints as well as inspection of cattle trucks and abattoirs.

Recommendation 4:

Improve reporting and communication channels for farmers

The findings indicated that reports coming in from farmers were low. This was affected by the lack of communication between farmers and the frontline animal health officers as well as channels. There is a need to increase awareness with farmers on the importance of reporting cattle as well improve channels for farmer reports to go within the animal health authorities. This should ensure that *B. abortus* can be detected earlier and controlled before it spreads to other localities in Fiji.

Recommendation 5:

Improve usage of PPE on the farms in Fiji

The findings indicated that the use of PPE with the farmers in Fiji was low. Thus there is an important need to raise awareness on the use of PPE with farmers when doing routine farm work as well as when handling high risk situations, i.e. handling of cow after birth materials. This should reduce the risks of *B. abortus* infecting the farmers and their families. Funding is limited with most farmers in the rural areas and even basic PPE such as gumboots are not used at all. With increased awareness the farmer mindset should be changed and at least they should use basic the basic PPE when doing their farm work.

Recommendation 6:

Monitoring of farms that have history of *B. abortus* and or Tuberculosis reactors

Findings indicated that farms which had a history of *B. abortus* and Tuberculosis reactor cattle were strongly associated with *B. abortus* infection. Thus there is a need continue to monitor these farms for *B. abortus*. This should ensure that the disease will be picked earlier and controlled if it re-emerges.

Recommendation 7:

Regulate water sharing sources of cattle

Findings indicated that the farms that practiced sharing of water sources with cattle on the farm and with cattle from outside farms had a higher chance of being infected with *B. abortus*. Thus there is an important need to regulate water sources to ensure that older cattle and younger cattle are separated, more importantly sick cattle should be separated and sharing of water sources with cattle from other farms should be avoided. This should ensure the reduction of the risks of transmission of *B. abortus* within cattle on the farm as well as with cattle from outside farms.

Recommendation 8:

Develop policies to support disease surveillance

Findings indicated that lack of policies impede disease surveillance programs in PICTs. Thus there is an important need to develop policies to support disease surveillance programs. There should be collaboration with donor agencies such as ACIAR and FAO as well as with national governments and academic institutions to develop projects that focus on policies to support disease surveillance in PICTs.

Recommendation 9:

Develop programs to retain veterinarians

The findings indicated that the absence of veterinarians and vacant positions affected the reporting structures for Fiji, PNG, Vanuatu and the Solomon Islands. Thus there is a need for national governments to develop programs to retain veterinarians and ensure vacant positions are filled. This should be supported by creating reasonable work conditions and remuneration packages. The program should support young graduates to study veterinary sciences overseas in universities that have good track records. Scholarships and career pathways should be created for graduates when they return from studies. There also needs to be collaboration with other developed countries to engage retired veterinarians to support surveillance and disease reporting work in the short term when there currently is a shortage of veterinarians in PICTs. The veterinary registration criteria in PICTs could also be re-evaluated to accommodate veterinarians with qualifications from countries that have competent veterinary institutions.

Recommendation 10:

Restructure reporting structures

The findings indicated that reporting structures are too long, hierarchical in nature and have multiple reporting branches which are not functioning well. The reporting structures need to be restructured to remove duplication and shorten the reporting chains. This should ensure that reports reach decision makers in a short time thus enabling action to be taken on the investigation and containment of livestock diseases.

Recommendation 11:

Lobby national governments to increase funding for surveillance

The findings indicated that lack of funds impacted surveillance programs in the Pacific Island Communities. Thus there is a need to lobby with national governments to increase spending to support disease surveillance. Networking with academic institutions as well with donors such as ACIAR and FAO to develop projects for disease surveillance is a likely way to go as funds are always limited in the Pacific Island community.

Recommendation 12:

Training to develop disease surveillance capacity

The findings indicated that Lack of technical expertise reduced disease surveillance capacities in the Pacific Island community. This lack of technical capacities are most likely due to high staff turnover, inexperience as well as staff that have not being trained well before joining the animal health services in their respective countries. Thus there is a need to continue to support capacity building training in the Pacific Community to develop capacity on disease surveillance. This should ensure that diseases can be detected early and contained.

Recommendation 13:

Support national governments to develop databases

Findings indicated that data on cattle population was outdated and this impeded the development of surveys for disease surveillance in PICTs. Thus there is a need to develop databases to record cattle farms locations and cattle population. Data bases could just be simple excel spreadsheets that store locations of supervised cattle farms as well as the cattle population numbers. This should be updated from time to time to ensure the database is up to date.

Recommendation 14:

Develop target surveillance programs in PNG, Vanuatu and the Solomon Islands

The findings indicated that PNG, Vanuatu and the Solomon Islands all tested negative to *B. abortus* based on the survey sample sizes for selected regions. Thus there is a need to develop targeted surveillance in untested cattle farming areas to monitor for *B. abortus.* This will be cheaper than carrying out blanket disease surveillance in all sectors of those countries. Target surveillance should ensure that *B. abortus* is monitored and this should safeguard the cattle sectors and farmer livelihoods in PNG, Vanuatu and the Solomon Islands.

Recommendation 15:

Develop mobile phone syndromic surveillance reporting system

The findings indicated that the proportion of reports being made for Brucellosis and other diseases are low. Thus there is a need to develop surveillance reporting systems that promote farmers to make timely reports to the animal health reports. One such system is the use of mobile phone based systems to speed up animal disease reporting, not only for disease occurrence but for general animal health. This should increase the number of reports coming in from the farmers and also indicate to the decision makers if there is suspected disease occurrence.

Recommendation 16:

Develop protocols to follow through with investigations

The findings indicated that the proportions of disease investigations being carried out by the animal health authorities are low. Thus there is a need to develop protocols to assist with following up with investigation after receiving reports of disease occurrence from farmers, e.g. following up with a phone call to get the history of the disease and whether it warrants a physical investigation. This should ensure that the necessary investigation is carried when it is required.

Recommendation 17:

Capacity building to improve sample collection and laboratory capacities

The findings indicated that the survivability of samples collected, processed and sent to reference laboratories is low. Thus there needs to be training carried out to build the capacities of frontline animal health officers to properly collect and process those samples to be sent to reference laboratories. In addition to this, capacity must also be built to have some capacity to process samples, e.g. having a centrifuge and cool storage and some basic laboratory items to enable the collection and processing of samples to be sent to for analysis. Packing and shipping has also become an issue especially when sending biological samples overseas, so there also is a need to have some basic capacity building to improve knowledge on the International Air Travel Arrangement (IATA) for sending samples overseas for analysis.

Recommendation 18:

Further studies to collect information for SSC's nodes

The findings indicated that data for certain nodes in the country SSC's were limited affecting the determination of the country sensitivities to detect *B. abortus*. These in particular were the herd status, Rose Bengal Test and the indirect ELISA test nodes. Thus there is an important need to carry out further studies to collect information on those nodes. This will enable the collection of updated information on the prevalence of *B. abortus*, likelihood of cattle being positive with the disease from the Rose Bengal Test and from the indirect ELISA test. This should ensure that all the nodes in the surveillance system components are populated with data thus enable the calculation of the sensitivities for each country to detect a positive and negative *Brucella* cow.

The research process with related outputs and expected outcomes based on recommendations are presented below in Figure 8-1.

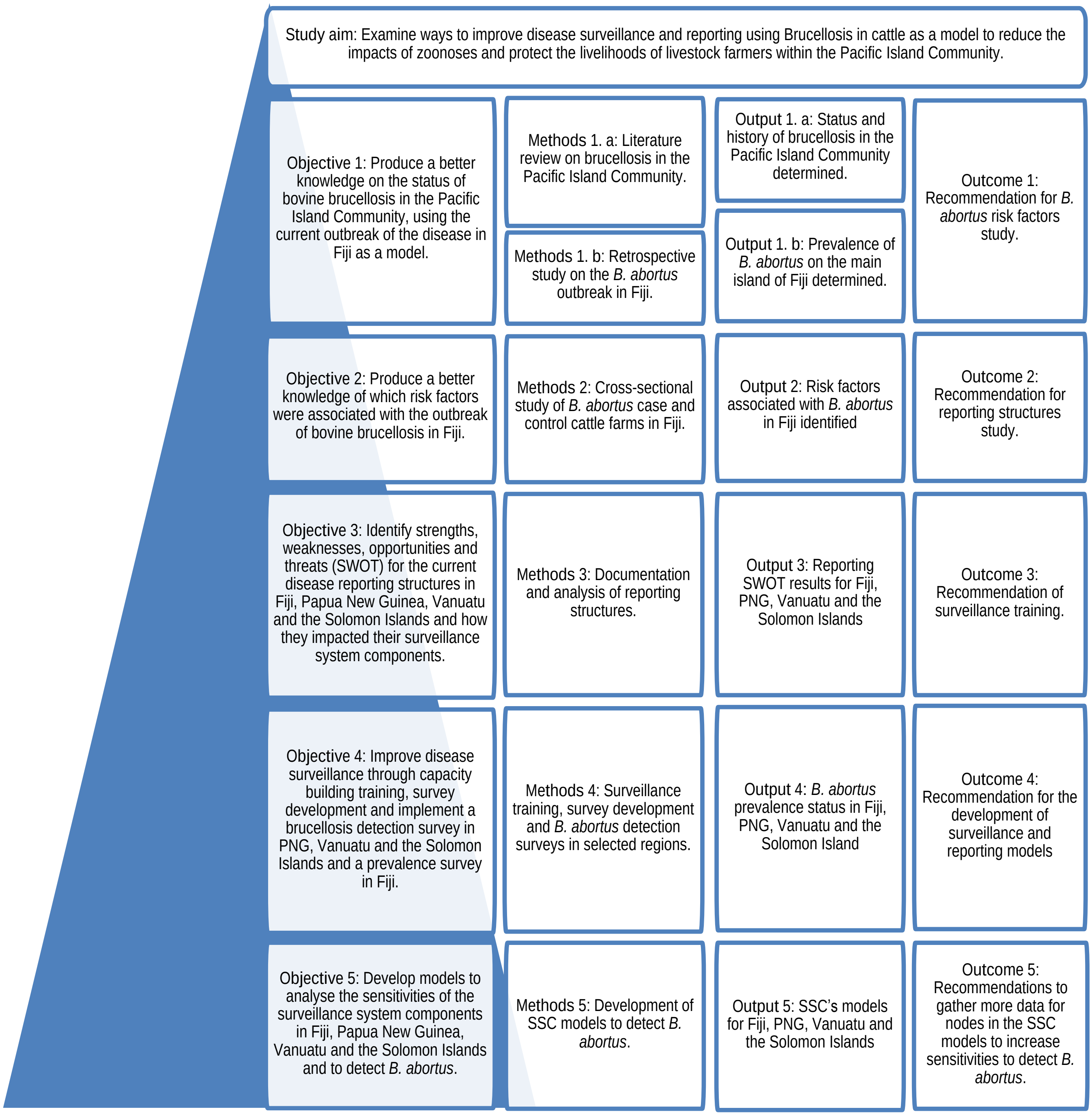

Figure 8-1: Diagrammatic representation of the research process with related outputs and expected outcomes based on research recommendations.

Table 8-1: Recommendations cross-referenced to the conclusions of the research and targets for implementation

METHODS	CONCLUSIONS	RECOMMENDATIONS	TARGETS
Chapter 2 Literature Review and *B. abortus* retrospective study for Fiji	**Conclusion 1**: There has been very little literature published on *B. abortus* in the Pacific Island region over the last 20 years making it difficult to gauge the impact of the disease. Even though Bovine brucellosis has been present in PICTs for many years it may not be considered important as there is little information available and a lack of awareness on the disease.	**Recommendation 1:** Raise awareness with the Pacific Island community on the importance of Brucellosis and launch further studies in PICTs to collect information on *B. abortus*	**Target 1**: The cattle sector and farmers in PICTs and academic institutions.
	Conclusion 2: Disease surveillance is limited and poor in PNG, Vanuatu and the Solomon Islands. Poor surveillance and monitoring may have contributed to the re-emergence of *B. abortus* in Fiji.	**Recommendation 2**: Develop further surveillance programs to monitor *B. abortus* in Fiji, PNG, Vanuatu and the Solomon Islands	**Target 2**: Cattle sectors in Fiji, PNG, Vanuatu and the Solomon Islands, Animal Health and Production Division.

Chapter 3 Cross-sectional study of *the* risk factors associated with the *B. abortus* outbreak on dairy cattle farms in Fiji.	**Conclusion 3**: The risks of brucellosis transmission within cattle on dairy farms in Fiji are high.	**Recommendation 3**: Regulate cattle movement and border security	**Target 3**: Farmers and frontline animal health officers in Fiji.
	Conclusion 4: Reporting of diseases to the animal health authorities was poor with the farmers in Fiji.	**Recommendation 4:** Improve reporting and communication channels for farmers through capacity building training	**Target 4:** Frontline animal health officers and farmers in the dairy farming communities in Fiji.
	Conclusion 5: Risks of human infection was high with the farmers in the dairy farms studied in Fiji.	**Recommendation 5:** Awareness programs and PPE training need to be developed with the Ministry of Health of Fiji to improve the use of PPE.	**Target 5:** Frontline animal health officers and farmers in the dairy farming communities in Fiji.
	Conclusion 6: Farms having a history of reactor cattle to brucellosis and or tuberculosis were 30 times (OR= 30) more likely of being infected with the *B. abortus* organism.	**Recommendation 6:** Monitoring for *B. abortus* on those farms are needed through active disease surveillance	**Target 6:** Frontline animal health officers and farmers in the dairy farming communities in Fiji.

	Conclusion 7: Farms that practised sharing of water sources for cattle within and with cattle from outside farms were 39 times (OR= 39) more likely of being infected with the *B. abortus* organism.	**Recommendation 7:** Regulate shared water sources to reduce the spread of *B. abortus* via water sources.	**Target 7:** Frontline animal health officers and farmers in the dairy farming communities in Fiji.
Chapter 4 Disease reporting structure analysis in Fiji, PNG, Vanuatu and the Solomon Islands	**Conclusion 8**: Surveillance programs and reporting structures are impeded by the lack of policy to support them.	**Recommendation 8**: Collaboration with FAO, ACIAR, OIE, academic institutions and national governments to develop policies that support work on surveillance to improve disease reporting in PICTs.	**Target 8**: National governments in PICTs.
	Conclusion 9: Reporting structures are affected by the vacant positions and shortage of veterinarians (lack of technical expertise).	**Recommendation 9:** Lobby national governments to create better policies to retain veterinarians in the animal health services.	**Target 9:** National governments in PICTs.
	Conclusion 10: Reporting structures are too long, hierarchical in nature and have multiple reporting branches which are not functioning well.	**Recommendation 10:** The reporting structures need to be restructured to remove duplication and shorten the chain of reporting.	**Target 10:** National governments in PICTs.

Chapter 5 Disease surveillance training and *B. abortus* detection surveys implementation	**Conclusion 11**: Lack of funds impacted surveillance programs in PICTs.	**Recommendation 11**: Lobbying with national governments to increase spending to support disease surveillance and networking with academic institutions as well with donors such as ACIAR to develop projects to develop projects for disease surveillance.	**Target 11**: National governments in PICTs.
	Conclusion 12: Lack of technical expertise reduced disease surveillance capacities in PICTs.	**Recommendation 12**: Develop capacities for disease surveillance through training.	**Target 12**: Frontline animal health officers as well laboratory officers in PICTs.
	Conclusion 13: Outdated data on cattle population impeded the development of surveys for disease surveillance in PICTs.	**Recommendation 13**: Develop databases to record cattle farms locations and cattle population.	**Target 13**: Frontline animal health officers and the cattle sector in PICTs.
	Conclusion 14: PNG, Vanuatu and the Solomon Islands all tested negative to *B. abortus* based on the survey sample sizes for selected regions.	**Recommendation 14**: Develop programs to carry out surveillance to monitor for *B. abortus* in other untested and tested areas.	**Target 14**: Frontline animal health officers and the cattle sector in PICTs.

Chapter 6 An analysis of surveillance components and their influence on animal disease reporting in Fiji, Papua New, Vanuatu and the Solomon Islands using *Brucella abortus* as a model	**Conclusion 15**: The proportion of reports being made for Brucellosis and other diseases are low.	**Recommendation 15**: Develop mobile phone based syndromic surveillance reporting systems.	**Target 15**: Farmers in the cattle sector as well as communities in rural farming areas in PICTs.
	Conclusion: 16: The proportions of disease investigations being carried out by the animal health authorities are low.	**Recommendation 16:** Develop protocols to follow through with investigations after reports are received.	**Target 16:** Policy makers and decision makers within the country reporting structures.
	Conclusion 17: The survivability of samples collected, processed and sent to reference laboratories is low.	**Recommendation 17:** There needs to be capacity building to improve field and laboratory capacities to improve sample survivability.	**Target 17:** Field officers and laboratory officers in PICTs
	Conclusion 18: Data for certain nodes in the country SSC's were limited affecting the determination of the country sensitivities to detect *B. abortus.*	**Recommendation 18:** Further investigation need to be conducted to enable the collection of data to populate all the nodes of the country SSC's.	**Target 18:** Cattle sector in PICTs.

CONCLUSIONS

The results of this research provided a better understanding of Brucellosis and in particular *Brucella abortus* in the Pacific Island community which enables the improvement of disease surveillance and reporting in the Pacific Island community. Since a regional approach was used, it makes the results more applicable as it can be easily applied to other countries in the Pacific Island community. By analysing Fiji's re-emergence of *B. abortus*, valuable insights were also obtained in relation to which risk factors were associated with the outbreak of the disease in Fiji and which strategies (recommendations) could be applied in the other countries in the Pacific Island community. As farming practices are similar it imperative that other PICTs continue to improve their surveillance and reporting systems to protect their cattle sector.

Furthermore, disease surveillance and reporting has been identified as being weak in most countries and this increases the risks of the re-emergence of not only *B. abortus* but other transboundary animal diseases in the Pacific Island community, so there is an important need to continue building capacity for the frontline animal health officers in light of the high staff turnover, inexperience, vacant positions as well as the chronic shortage of veterinarians in the Pacific Island community.

The development of surveillance system components (SSC's) for Fiji, Papua New Guinea, Vanuatu and the Solomon Islands provides a practical regional approach that can be replicated in the other countries of the Pacific Island community to improve disease surveillance and reporting. The development of the SSC's allowed for the detailed examination of each component in the SSC's thus identifying components that were weak thus enabling recommendations to be made for improvement.

Through increased globalisation there will also be increased risks of the spread of transboundary animal diseases, having implications on human, animal health and trade, thus there is an important need to have concerted efforts from the different sectors such as the World Health Organisation (WHO), the Food and Agricultural Organisation (FAO), Office of International Epizooties (OIE), academic institutions and national governments using a "One Health Approach" to develop scientific projects to improve disease surveillance and reporting in the Pacific Island community.

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APPENDICES

APPENDIX 1

Animal Ethics Committee

APPROVAL FOR ANIMAL BASED RESEARCH OR TEACHING (A17400)

Animal Ethics Approval:

This administrative form has been removed

APPENDIX 2

Human Research Ethics Committee

APPROVAL FOR RESEARCH OR TEACHING INVOLVING HUMAN SUBJECTS (H4414)

Human Ethics Approval:

This administrative form
has been removed