Pig movements across eastern Indonesia and associated risk of classical swine fever transmission

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Apart from the assistance stated in the acknowledgments and references made in text, this thesis represents the original work of the author. The results from this study have not been submitted for any other degree or diploma at any other university.

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Abstract

Classical swine fever (CSF), a highly contagious Pestivirus, has caused substantial socioeconomic loss for pig farmers in Indonesia since its introduction to this country in the mid 1990s. Live pig movements are believed to have facilitated the introduction of CSF into Nusa Tenggara Timur (NTT) province, in eastern Indonesia. This province has the largest pig population, with approximately 85% of households owning at least one pig and the smallholder sector being the dominant industry. Pigs have high cultural and economic importance—being used as an income source, financial security and playing an important role in traditional and religious ceremonies. The number of reported CSF cases in NTT is still increasing, with newly infected islands as recent as 2011.

This study was conducted from 2009 to 2012 that investigated live pig movements and the role of markets and villages in CSF transmission across NTT province. The research aimed to identify areas where mitigation measures could be implemented to assist in the control of CSF to reduce its spread in NTT and reduce the potential risk to Australia. Six phases were incorporated into the study to produce findings that could inform decision making.

The first phase of the research was to investigate formal pig movements (farm to market) by conducting a market survey where interviews were conducted at nine live pig markets on West Timor, Flores and Sumba islands during September and November 2009, with 292 pig seller and 281 pig buyer respondents. Information was collected by questionnaire on pig movements, pig management, biosecurity, and knowledge on pig health and CSF. Grower and fattener pigs were most commonly sold at market with high annual demand periods identified from August to October. Understanding of CSF and biosecurity was limited, with 85% of sellers and 83% of buyers stating they had no prior knowledge of CSF.

Observations were also conducted at each market site which provided baseline information on live pig markets and confirmed an extreme lack of biosecurity with high risk practices having the potential to influence CSF transmission.

To investigate the potential role of informal movements of pigs (farm to farm) in CSF transmission, a survey of smallholder pig farmers was conducted from March to May 2010. Eighteen villages were selected across West Timor, Flores and Sumba, and 289 pig farmers were interviewed. Information was collected by questionnaire on pig movements, pig management, biosecurity, and knowledge on pig health and CSF. Most (73.0%) farmers
stated they purchased pigs in order to raise the animal on their farm. Over half of the respondents (65.0%) purchased pigs from another farmer and not through a market, and 35.6% reported purchasing at least one pig within the last year. Pigs were sold or left their herd most commonly during the months of January, August, September and October.

Information obtained from the market and farmer surveys enabled a social network analysis (SNA) to be conducted on formal and informal movements using information on trading practices, source and destination locations, and the number of pigs being moved. Both inter- and intra-island movements were found to occur, however inter-island movement was only observed between Flores and Sumba islands. West Timor and Sumba had highly connected networks where large numbers of villages were directly and indirectly linked through pig movement. Pig movements were identified from Kota Kupang to the border of East Timor in West Timor connecting all five districts. The pig-movement network on Sumba had a higher potential for pigs to move a greater number of sequential locations across the entire island. Flores was found to have a more fragmented network, with pig movements concentrated on its eastern or western regions, influenced by terrain. Markets were considered high-risk locations for the introduction and spread of disease, having over 20 contacts (based on in and out-degree values) with different villages on an operational day. Of the markets investigated, Detusoko and Mbay markets on Flores and Waikabubak Market on Sumba represented the highest-risk market locations for the potential to spread disease through the network. For informal movement among the villages investigated, Rindi Village in Sumba represented a high-risk location for CSF spread via informal movements with the greatest exiting pig volume (78 pigs) from 2009–2010. Nunbaun Delha Village in West Timor was a high-risk location for CSF introduction due to external contact with 13 other villages.

A quantitative risk assessment was conducted on formal and informal pig movements across NTT province to assess the likelihood of classical swine fever virus (CSFV) transmission along the market chain. This risk assessment sought to identify pathways in the live pig market chain with the greatest risk of CSFV transmission and to assess the effect of mitigation measures to reduce CSFV transmission. Two modular risk models were developed, one to assess formal pig movements and the other to assess informal pig movements, with only live pig to pig transmission considered. Data obtained from the market and farmer surveys, published literature and expert opinion were utilised. A Monte Carlo simulation was performed with @Risk (Palisade) with 10,000 iterations. Modules were divided based on market chain movement processes from village to market/village.
Outputs included the number of infected and clinical pigs at market/village and the probability a market/village was infected with CSFV. Mitigation strategies assessed were vaccination and pre-entry market or village inspection. The baseline model demonstrated that markets and villages in West Timor and Sumba had the highest number of infected pigs entering a premise. The process of inspection at the market or village needed to be strict for it to be effective and to reduce the probability that a market or village was infected. Increased vaccination coverage reduced the number of infected and clinical pigs arriving at a market or village. However, CSFV was not eliminated from the environment.

Due to the risk posed by eastern Indonesia for the introduction of CSF into northern Australia, a simulation model was used to investigate the most appropriate surveillance techniques to detect and delineate the extent of infection among wild pigs for use following a CSFV incursion in the Kimberley region, north-western Australia. Due to the complexity of wildlife population dynamics and herd behaviour, it was concluded that a targeted approach to surveillance needed to be implemented. The use of simple random sampling was suboptimal, although disease was detected. The detection and containment of an outbreak must be as early and rapid as possible. The best way to approach the selection of an appropriate surveillance strategy is to use a more situation-based surveillance approach that accounts for disease distribution and the time period over which an epidemic has occurred. Radial and leapfrog surveillance were demonstrated to improve the effectiveness of infection delineation at various stages of a disease outbreak.

These findings have provided baseline information on pig movements and the pig market chain, allowing further analyses to be conducted to assist in guiding decision making for the development of mitigation strategies to control CSF in NTT. The identification of higher-risk practices can now be addressed through farmer education, and the detection of higher-risk village and market locations has suggested potential sites for mitigation measures to be trialled. Moreover, the quantitative risk analysis has provided suggestions for potential control measures to reduce the risk of CSF transmission along the market chain, and the simulation model output has provided information on effective surveillance techniques for CSF detection and delineation in northern Australia.
Contributions to Chapters

The development and writing of all chapters presented in this thesis were my principal responsibility, working independently under the supervision of Dr Jenny-Ann Toribio (principal supervisor), Prof Michael Ward (associate supervisor) and Dr Maria Geong (associate supervisor). Dr Toribio provided comments on all chapters and Prof Ward provided comments on Chapters 4, 5, 6, 7, 8, 9.

Chapter 3 and 5
The development of the market and farmer questionnaires was conducted by myself with guidance from Dr Toribio. During the interview process in NTT, interview teams on West Timor, Flores and Sumba conducted all interviews. I attended each study site during the interview process to provide assistance if needed and to conduct an observational study. Each interview team underwent a training course (conducted by myself, Dr Maria Geong and Dr Muktasam Abdurrahman) to ensure their delivery of the interview was consistent and their knowledge of the questionnaire was adequate. One member from each team entered data into a database that I had developed in Epi Info™ Software and during this process translated responses into English. On completion of this process I then went through completed questionnaires to check that the data was entered correctly and that the translation was accurate. Where translation was incorrect or needed additional clarification, a member of the West Timor interview team fluent in Bahasa, Larry Toha, was consulted.

All analyses of this data were conducted by myself with comments provided at the draft stages of the chapters. Conclusions have been made based on the findings and I have written the contents of this chapter.

Chapter 4
I conducted observations for this study at all market sites during visits made in the interviewing phase of the market survey. Data were analysed by myself and comments were provided at the draft stage of the chapter. Conclusions have been made based on the findings and I have written the contents of this chapter.

Chapter 6
Guidance and assistance was given by Dr Rob Christley from the University of Liverpool, England. His expertise in social network analysis was sought to assist in developing an appropriate approach for analysing the available data obtained from the market and farmer
surveys. I performed all the analyses and obtained feedback from Dr Christley during the development of the chapter with comments provided on the generated results and in the draft stages of this chapter. Conclusions have been made based on the findings and I have written the contents of this chapter.

Chapter 7
The risk models presented in this chapter are a collaborative effort between myself and Dr Naomi Cogger from Massey University, New Zealand. I worked directly with Dr Cogger to develop both models. The initial structure of the models were developed through consultation with Dr Cogger combining her understanding of risk assessments and my knowledge of the pig market chain in NTT and utilising data obtained from the market and farmer surveys. Through further discussions with Dr Cogger, the model structures were altered accordingly to suit a modular risk approach. Dr Cogger developed the mathematical approach to take and applied this to the models, and I provided assistance where appropriate. Once the models were complete, I ran all the analyses for both models and obtained feedback during this process to ensure results were appropriate. Conclusions have been made based on the findings and I have written the contents of this chapter. Dr Cogger also provided comments on the draft thesis chapter.

Chapter 8
This chapter contains results that were generated by a model developed by Dr Graeme Garner and Dr Brendan Cowled. Using this model, I ran all simulations and conducted analyses on the output. Feedback was provided by Prof Ward and Dr Cowled during the development of the chapter. During the final stages, Dr Garner and Dr Toribio provided additional comments on the draft chapter prior to submission to the journal Transboundary and Emerging Diseases.
Publications and Conference Proceedings


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<tr>
<td>ACIAR</td>
<td>Australian Centre for International Agricultural Research</td>
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<td>AHW</td>
<td>Animal Health Worker</td>
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<td>AI</td>
<td>Avian Influenza</td>
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<tr>
<td>ASF</td>
<td>African Swine Fever</td>
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<tr>
<td>AusAid</td>
<td>Australian Agency for International Development</td>
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<tr>
<td>BDV</td>
<td>Border Disease Virus</td>
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<tr>
<td>BPS</td>
<td>Budan Pusat Statistik Office of Nusa Tenggara Timur Province, Indonesia</td>
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<tr>
<td>BVDV</td>
<td>Bovine Viral Diarrhoea Virus</td>
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<td>CSF</td>
<td>Classical Swine Fever</td>
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<tr>
<td>CSFV</td>
<td>Classical Swine Fever Virus</td>
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<tr>
<td>DGLAHS</td>
<td>Directorate General of Livestock and Animal Health Services</td>
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<tr>
<td>DIC</td>
<td>Disease Investigation Centre</td>
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<td>DLS</td>
<td>District Livestock Services</td>
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<td>East Timor</td>
<td>Democratic Republic of Timor-Leste</td>
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<tr>
<td>ELISA</td>
<td>Enzyme-linked Immunosorbent Assay</td>
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<td>FAO</td>
<td>Food and Agriculture Organization of the United Nations</td>
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<td>FEA</td>
<td>Field Extension Agent</td>
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<td>FMD</td>
<td>Foot-and-Mouth Disease</td>
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<tr>
<td>HPAI</td>
<td>Highly Pathogenic Avian Influenza</td>
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<tr>
<td>IAQA</td>
<td>Indonesian Agricultural Quarantine Agency</td>
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<tr>
<td>Km</td>
<td>Kilometre</td>
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<tr>
<td>Km²</td>
<td>Square Kilometre</td>
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<tr>
<td>Lao PDR</td>
<td>Lao People’s Democratic Republic</td>
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<tr>
<td>LWC</td>
<td>Large White/Landrace cross</td>
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<td>MDA</td>
<td>Maternally Derived Antibodies</td>
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<td>MPRM</td>
<td>Modular Process Risk Model</td>
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<td>NAQS</td>
<td>Northern Australia Quarantine Strategy</td>
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<td>NGO</td>
<td>Non-Government Organisation</td>
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<td>NTT</td>
<td>Nusa Tenggara Timur</td>
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<td>OIE</td>
<td>World Organisation for Animal Health</td>
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<td>PLS</td>
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Animal Health Worker: An AHW is an individual employed by the government in a kabupaten, who is generally a para-veterinarian or veterinary assistant providing basic animal health assistance to farmers.

Biosecurity: Measures put in place to reduce the introduction and spread of disease such as at the farm, village or market level implementation of cleaning, vaccination or isolation of new animals.

Biskayu: An open air truck used for public transportation, predominantly found in Flores. This type of vehicle carries many individuals and travels for long distances with animals and other agricultural products.

Boar: Male pig used for breeding.

Collector: An individual involved in collecting pigs from various sources, such as different farmers, and acting as a middleman selling these pigs on to other farmers or at market.

Clinical Pigs: Pigs displaying clinical signs.

Crossbred Pig: A cross-breed pig breed can be defined as a pig with a short nose, a straight back, a belly higher off the ground than local breeds with ears that are often long.

Desa: Village, divisional unit of a subdistrict (Kecamatan), self-governed and each with a Village Head (Kepala Desa).
District Livestock Services: Department of Agriculture and Livestock at the district level, Livestock and Animal Health Services.

Dinas: Government.

Dinas Peternakan Propinsi: Provincial Livestock and Animal Health Services (Provincial Livestock Services).

Fattener: Pigs older than 6 months of age not used for breeding.

Field Extension Agent (FEA): Animal health workers employed by the government to implement animal health programs.

Formal Movement: Movement of pigs between villages involving sale/purchase at a market and movement of pigs between islands entering and exiting via formal ports.

Grower: A pig ranging from 3–5 months of age.

Informal Movement: Movement of pigs between villages not involving sale/purchase at a market and movement of pigs between islands not entering and exiting via formal ports, includes sale/purchase of pigs for gifts.

Kabupaten: District within a province.

Kandang: A structure used to house pigs, often made of bamboo. It can contain one to several pigs either in a single pen area or divided into sections.

Kecamatan: Subdistrict, unit within a district.

Kelurahan: The equivalent of a village but in an urbanised area. It is governed by the Bupati or City Mayor rather than a Village Head (Kepala Desa).

Kepala Desa: Village Head, governs one village, equivalent to a Desa.

Leis: A pig owner finds a group of people (usually five to 10) who want to purchase pig meat. The pig owner then slaughters the pig and the meat is divided between these individuals. In some circumstances the meat is paid for using a barter system providing the pig owner with rice or other agricultural products. Alternatively monetary payment is accepted.
Local Pig Breed: A local or native pig breed can be defined as a pig that is often black in colour; however, this can vary. The back is curved with a belly low to the ground with small erect ears.

Ojek: Motorbike taxi service operating across Indonesia.

Permanent Market Sellers: An individual who remains at market selling pigs that have been purchased from sellers coming to that market location, effectively buying pigs and reselling them at the market in question.

Piglet: Young pig that has not stopped suckling (approximately < 2 months).

Poskeswan: Animal Health Post, one or more located in districts across the province to provide animal health assistance to farmers, assist veterinarians with treatments and report and provide disease case figures to District Livestock Services.

S’ei babi: Special barbecued pork dish from West Timor.

Sow: Female pig used for breeding.

Topology: The study of the arrangements of units of interest in a network such as farms and markets, to investigate properties including clustering, path length and small world.

Total herd size: Refers to pigs ≥ 2 months of age; marketable age for pigs including weaners, growers, fatteners, sows and boars.

Trader: An individual that buys pigs from collectors or directly from farmers and then sells them to consumers at the household level.

Weaner: Piglet that has just been separated from a sow or stopped suckling (age ≥ 2 and < 3 months).
Chapter 1: Introduction

Classical swine fever (CSF) is considered one of the most economically damaging pig diseases (Boklund et al., 2009). Outbreaks can result in substantial losses from both direct and indirect impacts. The current global distribution of CSF is throughout South-East Asia, Africa, Eastern Europe, and South and Central America (Durand et al., 2009). North America, most of the countries in the European Union, and Australia have eradicated the virus (Artois et al., 2002; Edwards et al., 2000). The highly contagious nature of this transboundary animal disease (TAD) has led to reports to the World Organisation for Animal Health (OIE) from more than 60 countries over the past 15 years (Donahue et al., 2011). During an outbreak in the Netherlands in 1997–98, over 429 infected farms were identified as a result of CSF entry from an infected truck (Elbers et al., 1999). By the end of the outbreak following an eradication response, 1.8 million pigs were slaughtered with a total cost of US$2.3 billion. In many developing countries across South-East Asia, Africa and South America, CSF is currently endemic (Edwards et al., 2000; Hutabarat & Santhia, 1999; Phengsavanh et al., 2011). For countries such as Vietnam, the Lao People’s Democratic Republic (Lao PDR) and Indonesia, where pig production is a vital component of the smallholder sector, CSF continues to affect farmers by threatening their livelihoods through loss of income, food availability and the important traditional and cultural uses of pigs (Hutabarat & Santhia, 1999; Huynh et al., 2007; Phengsavanh et al., 2011).

Livestock produced in smallholder farming systems are considered essential components of the agricultural economy in developing countries (McDermontt et al., 1999). The loss of livestock for smallholder farmers reduces opportunity for achieving sustainable agriculture and can negatively impact food security (Drucker et al., 2006). The multiple uses of livestock—as a source of income, financial security and savings, bartering tool and role in traditional ceremonies—are vital in many developing countries (Huynh et al., 2007; Millar & Photakoun, 2008; Nampanya et al., 2011). In South-East Asia, pigs represent an important sector for smallholder farmers (Huynh et al., 2007).

Pig farming in Indonesia is the third-largest producer of meat for human consumption, following poultry and ruminants (Liano & Siagian, 2002). Although the majority of the population in Indonesia are Muslim (90%), several provinces have religious views that coincide with the consumption of pork, such as Bali, Nusa Tenggara Timur (NTT), Sulawesi, and Papua (Brandenburg & Sukobagyo, 2002). The province of NTT, in eastern
Indonesia, has the largest pig population in the country with pigs having economic and cultural significance (Dinas Peternakan Propinsi, 2011). High live pig demand within the province drives pig movements across and between islands, increasing the risk of CSF spreading. The close proximity of these islands to Australia also presents a risk for the reintroduction of CSF to Australia.

This study, conducted from 2009 to 2012, investigated live pig movements and the role of markets and villages in CSF transmission across NTT province. The research aimed to identify areas where mitigation measures could be implemented to assist in the control of CSF to reduce its spread within NTT and to reduce potential risks to Australia.

Chapter 3 describes an epidemiological survey conducted in nine live pig markets with pig sellers and buyers to investigate live pig movements, pig management, biosecurity practices and knowledge on pig health and CSF. Interviews were conducted in 2009 across two interview rounds (representing high- and low-pig demand periods). In addition, Chapter 4 presents an observational study conducted at the live pig markets involved in the market survey, to obtain baseline information on live pig markets in this region, which have not previously been investigated.

Chapter 5 describes an epidemiological survey conducted with smallholder pig farmers in 18 villages across NTT province in 2010. This survey aimed to obtain information regarding live pig movements, pig management, biosecurity practices and knowledge on pig health and CSF from smallholder pig farmers. On-farm management and trading practices needed to be investigated to identify potential areas for the implementation of control strategies.

In Chapter 6 a social network analysis is presented. This analysis utilised information obtained from the market and farmer surveys in Chapters 3 and 5 which included location information and pig volumes being moved throughout the province network. This analysis was conducted to identify key locations along the pig market chain for pig distribution and risk of CSF spread.

Using survey results and combining other data sources, a quantitative risk assessment using a modular model outlined in Chapter 7 was developed to investigate the transmission risk of the CSF virus along the live pig market chain. This risk assessment enabled
mitigation measures to be evaluated to determine their effectiveness in this region. Moreover, the results would assist in guiding decision making for CSF control strategies.

The final experimental chapter, described in Chapter 8, uses a simulation model to investigate the outcome of a CSF incursion in north-western Australia. The close proximity of NTT province to northern Australia presents a risk for the reintroduction of CSF to Australia. The aim of this chapter is to investigate different surveillance strategies that could be applied as a response to a CSF outbreak. The results demonstrate the effectiveness and efficiency of three different surveillance techniques implemented at different time points following an incursion to detect and delineate extent of infection.

An overall discussion, with recommendations and suggested mitigation strategies, is outlined in Chapter 9. The results of this study have provided baseline information on live pig markets in NTT and smallholder farming practices across the province. Moreover, the data gathered can be used to guide decision making on mitigation strategies to control CSF in NTT. In addition, information was obtained on appropriate surveillance techniques to be implemented in northern Australia as a response to a CSF incursion.

It also needs to be acknowledged that this thesis describes practices at markets and during transportation as they currently are in NTT following the cultural practices in this region. I do not condone the practices observed where pig welfare has been affected. Although these practices cannot be changed in the short term, further research and education will enable future improvements to develop pig welfare.
Chapter 2: Literature Review

2.1 Indonesia and Nusa Tenggara Timur Province

2.1.1 Location

Indonesia is made up of 33 provinces and shares land borders with Malaysia, Democratic Republic of Timor-Leste (referred to as East Timor in the remainder of the thesis) and Papua New Guinea (Figure 2.1). The province of Nusa Tenggara Timur (NTT) is located in eastern Indonesia within a collection of islands known as the Lesser Sunda Islands. This province is the closest to north-western Australia and poses a risk for animal disease introduction to Australia. Disease entry into a country can occur through various routes including animal movements, both domestic animals (Martinez-Lopez et al., 2008; Velthuis & Mourits, 2007) and wildlife (East et al., 2008; Rappole & Hubalek, 2006) or contaminated fomites such as transportation vehicles, people and infected animal products (Allepuz et al., 2007; Fritzemeier et al., 2000).

NTT is an archipelago comprising 566 islands that equates to an area of 47,349km², only 2.5% of Indonesia’s total (BPS Statistics, 2009; Roland-Holst & Frielink, 2009). Of these islands, it is estimated that only 42 are inhabited (Roland-Holst & Frielink, 2009). The capital of the province is Kota Kupang in West Timor, and it has the largest urban concentration in the province (Figure 2.2). The southernmost Indonesian island, Rote Ndao, is located within this province and lies only 110 km from the Territory of the Ashmore and Cartier Islands, Australia (Figure 2.2; Potemra et al., 2002; Crib and Ford, 2009).
Figure 2.1
Location of Nusa Tenggara Timur province in Indonesia, close neighbour to Australia (Santos, 2012).

Figure 2.2
2.1.2 Demographics of Nusa Tenggara Timur

2.1.2.1 Population and Poverty

The human population of NTT province in 2009 was 4,679,316 (BPS Statistics, 2009), only 2% of Indonesia’s total population (BPS Statistics, 2009). NTT is classified as the poorest province within Indonesia with 95% of individuals in rural communities living in poverty (Wang, 2007). There is a wide economic disparity between those living in more developed areas of western Indonesia with the Human Development Index (HDI) in NTT lower than the national average (Roland-Holst & Frielink, 2009; World Bank, 2006). Indonesia has seen some substantial changes over the last decade in response to the economic crisis that occurred in 1997–98, followed by decentralisation in 2001 (Levinsohn et al., 2003; Wollenberg et al., 2006). As a result of the economic crisis, agriculture was recognised as an important component of rural income and vital for poverty alleviation (Brandenburg & Sukobagyo, 2002).

2.1.2.2 The Agriculture Sector

Within NTT province, agriculture is the primary income source for the majority of households, with a focus placed on subsistence farming (Wang, 2007). Across Asia, the smallholder farming sector is often comprised of mixed farming systems with the integration of crops and livestock (Devendra & Thomas, 2002; Thorne & Tanner, 2002). A study conducted by Russell-Smith et al. (2007) supported these findings in NTT. Surveys on the islands of Sumba and Flores from villages in two districts found that the majority of households were reliant on mixed farming practices.

The main crops cultivated in the province are rice, maize, cassava and sweet potato (Roland-Holst & Frielink, 2009) with livestock such as chickens, pigs, cattle and goats kept by many households (Christie, 2007; Johns et al., 2009). A study by the World Bank (2006b) found that in Manggarai district in Flores, for example, almost 90% of the population was involved in primary production. Agriculture contributes approximately 40% of the NTT Gross Regional Domestic Product (GRDP) (Patunru et al., 2010).

A recent study by Johns et al. (2009) found that only 12% of households in NTT are involved in cattle production. Across Indonesia, cattle production is focused in the western regions with Java being the major cattle producing region holding around 45% of the cattle population. Sumatra and NTT produce 22% and 13% of cattle respectively (Sullivan & Diwyanto, 2007). Since the early 1990s a reduction in cattle production in this region was
seen due to an increase in human population which reduced the amount of available grazing land for cattle (Christie, 2007). As a result, the number of pigs kept by smallholder farmers increased due to their low input and low output management system (Christie, 2007). Pigs in NTT have high cultural value with approximately 85% of households owning at least one pig (Johns et al., 2009; Santhia et al., 2006). Pigs have the second-highest rate of production in terms of animal number following poultry in NTT (Dinas Peternakan Propinsi, 2011; Liano & Siagian, 2002).

2.1.2.3 Language
The national language for Indonesia is Bahasa Indonesia (Smith-Hefner, 2009). However there are a variety of local languages across NTT with more than 32 of 170 dialects across the country being indigenous to NTT province (Azhar et al., 2010). When conducting studies in areas with multiple local languages, this is an important consideration for study design and implementation. A study by Lee et al. (1999) investigated issues of questionnaire translation during a survey with pig farmers in the Philippines. Their study determined that the use of back-translation and pilot testing reduced sources of error. Moreover, it was recognised that the development of questions needed to be appropriate for the target audience. The selection of interviewers also needs to be considered as an important component of study design (Marschan-Piekkari & Reis, 2004).

2.1.2.4 Religion
Religious denominations across NTT province are quite diverse. The majority of the population is Roman Catholic (55%) and Protestant (32%). These religious views coincide with the consumption of pork and only 9% of the population adhere to Islam (Barlow & Gondowarsito, 2007). Sumba is unique in its religious practices. Although the majority of the population are Catholic or Protestant, the original local religion, Marapu, is still practised (Fowler, 2005; Mudita & Natonis, 2008).

Within NTT, the church plays an important social role. Collaborations have developed between local non-government organisations (NGOs) and churches to orchestrate distribution programs to assist in poverty alleviation. Products often include live animals and other food types (Barlow & Gondowarsito, 2007; Christie, 2007).

2.1.2.5 Climate and Seasonal Variations
NTT experiences a tropical climate with two different seasonal periods annually, a wet and a dry season (Corwin et al., 2005). The wet season spans from December through to
March, and the dry season from April to November (Asih et al., 2009). Rainfall varies across regions with districts in Flores often receiving higher rainfall in comparison to West Timor (Barlow & Gondowarsito, 2007). For example, rainfall varies between 500–2000mm per year in Kupang with up to 4000mm per year recorded in Manggarai District (Corwin et al., 2005).

The extreme changes in weather can often influence crop and livestock production. Droughts experienced during extended dry seasons can result in the death of livestock due to feed shortages. During the wet season, increased rainfall can often lead to destruction of crops (Barlow & Gondowarsito, 2007; Dalgliesh et al., 2008; Russell-Smith et al., 2007). Moreover, transportation is impeded during the wet season due to road degradation and rough seas, with ferry cancellations a common occurrence (Patunru et al., 2010; World Bank, 2006b).

2.1.3 Major Islands

NTT province is made up of a total of 21 Kabupatens (districts), 269 Kecamatans (subdistricts) and 2836 Desas (villages) (Table 2.1; BPS Statistics, 2011). The majority of the population reside on the islands of Timor, Flores, Alor and Sumba (Roland-Holst & Frielink, 2009). These islands are particularly important for agriculture with the majority of households being smallholder farmers (Bond et al., 2007).

Trade across the border between West Timor and East Timor has continued, despite prior conflicts. Manufacturing, agricultural and livestock products are currently imported by East Timor (UNDP, 2011). For example, a study by the United Nations Development Program (2011) found that chicken demand in East Timor is met through imports predominantly from Indonesia and Brazil. Limited data are available to quantify livestock movements across the border. However, it was reported by Do Karmo (pers comm, 2011), that pigs are traded across the border. Pigs are utilised for similar purposes in East Timor as in NTT including cultural and traditional events (Patrick et al., 1999).
Table 2.1
Demographic and pig population information for Nusa Tenggara Timur province, eastern Indonesia (BPS Statistics, 2009).

<table>
<thead>
<tr>
<th>Island</th>
<th>District</th>
<th>No. Sub-districts</th>
<th>No. Villages</th>
<th>Capital City</th>
<th>Year of Est²</th>
<th>Pig Population</th>
<th>Area (km²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Kota Kupang</td>
<td>4</td>
<td>49</td>
<td>Kupang</td>
<td>1958</td>
<td>23,350</td>
<td>160.34</td>
</tr>
<tr>
<td></td>
<td>Kab. Kupang</td>
<td>23</td>
<td>240</td>
<td></td>
<td>1958</td>
<td>1,111,854</td>
<td>5,898.26</td>
</tr>
<tr>
<td></td>
<td>TTU¹</td>
<td>22</td>
<td>240</td>
<td>Kefamenanu</td>
<td>1958</td>
<td>70,584</td>
<td>2,669.66</td>
</tr>
<tr>
<td></td>
<td>TTS²</td>
<td>24</td>
<td>174</td>
<td>Soe</td>
<td>1958</td>
<td>294,856</td>
<td>3,947.00</td>
</tr>
<tr>
<td></td>
<td>Belu</td>
<td>25</td>
<td>208</td>
<td>Atambua</td>
<td>1958</td>
<td>116,010</td>
<td>2,445.57</td>
</tr>
<tr>
<td>Flores</td>
<td>Flores Timur</td>
<td>18</td>
<td>226</td>
<td>Larantuka</td>
<td>1958</td>
<td>145,550</td>
<td>1,812.85</td>
</tr>
<tr>
<td></td>
<td>Ende</td>
<td>20</td>
<td>214</td>
<td>Ende</td>
<td>1958</td>
<td>759,821</td>
<td>2,046.62</td>
</tr>
<tr>
<td></td>
<td>Sikka</td>
<td>21</td>
<td>160</td>
<td>Maumere</td>
<td>1958</td>
<td>109,731</td>
<td>1,731.92</td>
</tr>
<tr>
<td></td>
<td>Ngada</td>
<td>9</td>
<td>94</td>
<td>Bujawa</td>
<td>1958</td>
<td>83,970</td>
<td>1,620.92</td>
</tr>
<tr>
<td></td>
<td>Nagekeo</td>
<td>7</td>
<td>100</td>
<td>Mbay</td>
<td>2007</td>
<td>84,247</td>
<td>1,416.96</td>
</tr>
<tr>
<td></td>
<td>Manggarai Timur</td>
<td>6</td>
<td>114</td>
<td>Borong</td>
<td>2007</td>
<td>51,571</td>
<td>2,502.24</td>
</tr>
<tr>
<td></td>
<td>Manggarai Barat</td>
<td>9</td>
<td>149</td>
<td>Ruteng</td>
<td>1958</td>
<td>58,382</td>
<td>1,686.66</td>
</tr>
<tr>
<td></td>
<td>Manggarai Barat</td>
<td>7</td>
<td>121</td>
<td>Labuan Bajo</td>
<td>2003</td>
<td>50,510</td>
<td>2,947.50</td>
</tr>
<tr>
<td>Sumba</td>
<td>Sumba Timur</td>
<td>22</td>
<td>156</td>
<td>Waingapu</td>
<td>1958</td>
<td>42,327</td>
<td>7,000.50</td>
</tr>
<tr>
<td></td>
<td>Sumba Barat</td>
<td>6</td>
<td>53</td>
<td>Waikabubak</td>
<td>1958</td>
<td>17,537</td>
<td>737.42</td>
</tr>
<tr>
<td></td>
<td>Sumba Tengah</td>
<td>4</td>
<td>43</td>
<td>Waibakul</td>
<td>2007</td>
<td>14,498</td>
<td>1,869.18</td>
</tr>
<tr>
<td></td>
<td>SBD³</td>
<td>8</td>
<td>96</td>
<td>Tambolaka</td>
<td>2007</td>
<td>29,338</td>
<td>1,445.32</td>
</tr>
<tr>
<td>Alor</td>
<td>Alor</td>
<td>17</td>
<td>175</td>
<td>Kalabahi</td>
<td>1958</td>
<td>77,617</td>
<td>2,864.60</td>
</tr>
<tr>
<td>Rote</td>
<td>Rote Ndao</td>
<td>8</td>
<td>80</td>
<td>Baa</td>
<td>2002</td>
<td>70,030</td>
<td>1,280.00</td>
</tr>
<tr>
<td>Lembata</td>
<td>Lembata</td>
<td>9</td>
<td>144</td>
<td>Lewoleba</td>
<td>1999</td>
<td>54,967</td>
<td>1,266.38</td>
</tr>
</tbody>
</table>

¹Timor Tengah Utara district; ²Timor Tengah Selatan; ³Sumba Barat Daya district; ⁴Kota Kupang is the capital city of West Timor; ⁵Year of establishment for district border lines.

2.1.4 Structure of the Directorate General of Livestock and Animal Health Services (DGLAHS), Provincial Livestock Services (PLS) and their Role in Animal Health

2.1.4.1 DGLAHS and PLS (Dinas Peternakan Propinsi)

The Directorate General of Livestock and Animal Health Services (DGLAHS) governed under the Ministry of Agriculture is the central government body responsible for animal health programs and services across Indonesia (Brandenburg & Sukobagyo, 2002; Wodowati & Hutabarat, 1999). This government branch is divided into five divisions: breeding, livestock production, animal health, cattle feeding, and veterinary public health and post harvest (BPS Statistics, 2009; Brandenburg & Sukobagyo, 2002). The DGLAHS
is the main directive body for the Provincial Livestock Services (PLS), also referred to as Dinas Peternakan Propinsi (Patrick et al., 1999). Following decentralisation in 2001, there have been changes in structure particularly at the provincial level (Brandenburg & Sukobagyo, 2002; Christie, 2007). Each district government is now in charge of allocating budgets and determining priorities, effectively acting autonomously (Christie, 2007). This has resulted in limitations for disease control programs, particularly when multiple districts are involved and cooperation is needed across borders (Christie, 2007).

In NTT, PLS is located in Kota Kupang and acts as the head of the animal health services for NTT province. At the district level, there is the Department of Agriculture and Livestock (District Livestock Services) which employs government veterinarians and animal health workers to implement programs down to the village level.

Across Indonesia animal health laboratories are categorised as type A, B or C. The type refers to the ability of the laboratory in reference to the extent of resources available and the diagnostic tests that can be performed. Type A laboratories [also referred to as Disease Investigation Centres (DIC)] are regional laboratories with the ability to perform comprehensive disease diagnosis, surveillance and investigations (Brandenburg & Sukobagyo, 2002; Wodowati & Hutabarat, 1999). Type B laboratories are generally located at the provincial level and conduct parasitic and bacterial diagnoses. In NTT province, there is only a type B laboratory present in Kota Kupang. For more extensive diagnostic services, the laboratory is required to send samples to the DIC in Denpasar, Bali (Geong M. pers comm, 2009). Type C laboratories have the capacity to conduct basic parasitic diagnosis (Brandenburg & Sukobagyo, 2002).

The DGLAHS have also implemented livestock distribution programs in collaboration with international organisations such as the World Bank and the Asian Development Bank (Christie, 2007; Wodowati & Hutabarat, 1999). The DGLAHS aims to address farmer welfare issues, promote sustainable agriculture through the use of local products and improve agricultural production (Ministry of Agriculture Indonesia, 2012).

In 2006 the Ministry of Agriculture passed Regulation 51 (Ministry of Agriculture, 2006) which is a guideline for the examination, observation and treatment of quarantinable diseases. The aim of this regulation was to provide strategies to prevent the entrance of diseases into the Republic of Indonesia and further inter island spread, in addition to restricting the release of TADs present in Indonesia to other countries. The regulation also
launched the Animal Health Management Information System to enable the collation of animal health information into a database. Animal Quarantine Technical Implementation Unit (UPT) and veterinary laboratories with the DIC and Agency for Agricultural Quarantine work collectively to pool information every three months regarding investigations, cases of disease, mapping disease spread and monitoring the status of animal diseases.

2.1.4.2 The Role of Veterinarians, Animal Health Workers and the Role of the Poskeswan (Animal Health Posts)

District Livestock Services (DLS) employ both veterinarians and animal health workers (AHWs) to implement various animal health programs (Brandenburg & Sukobagyo, 2002). AHWs are typically assigned a set of villages to work in, one of which they are expected to reside in (Robertson et al., 2010b). AHWs tend to be para-veterinarians who have undergone more basic animal health training that can be applied at the village level. They provide farmers with advice, assist veterinarians with treatments, report and provide disease case figures to DLS (Robertson et al., 2010b). In developing countries, access to veterinary services is often limited, accompanied by a limited number of trained personnel. An investigation by Catley et al. (2004) demonstrated that utilising para-veterinarians can increase the number of villages with access to animal health services, which can greatly improve smallholder animal production. However, in Indonesia, problems have been identified with the use of AHWs. Deveridge (2008) identified, from a study on Alor island, that AHWs are often limited by inadequate training, equipment and facilities, lack of transport and the failure of DLS to employ adequate numbers of veterinarians to cover different jurisdictions. Veterinarians working for Dinas at the district level are generally employed by the DLS with further approval through the PLS. Factors such as these are impacting on the ability of AHWs to perform their jobs effectively.

Animal health posts (Poskeswan) provide services down to village level and have veterinarians or para-veterinarians stationed at them who aim to assist animal production in their region. Staff working with the DLS provide animal health support to these local animal health posts in terms of animal health information, vaccinations and they respond to calls when assistance is needed (Brandenburg & Sukobagyo, 2002). Each district has at least one poskeswan where a veterinarian or para-veterinarian is located to provide support (Table 2.2). However, in Indonesia, there are many problems with the current set-up for poskeswans to deliver animal health services. Budget constraints for operational costs,
limited government support and inadequately trained staff are negatively impacting farmers (Brandenburg & Sukobagyo, 2002). It was recognised by Bragg (2007) that due to the structure of animal health services, lengthy delays can be experienced with information required to pass through each level of government before action can be taken. This deters farmers from reporting suspected cases of disease as they are uncertain whether action will result. In addition, a large number of animal health posts are located in urbanised areas. However, as 60% of Indonesia’s population lives in rural areas, this limits farmers’ ability to access animal health facilities (Liano & Siagian, 2002). Deveridge (2008) found that on Alor, farmers were reluctant to travel long distances to report disease or request assistance due to the travel costs incurred.

Table 2.2
Number of Animal Health Posts (Poskeswans) present in Nusa Tenggara Timur province, eastern Indonesia (BPS Statistics, 2009).

<table>
<thead>
<tr>
<th>Island</th>
<th>Poskeswan No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timor</td>
<td>44</td>
</tr>
<tr>
<td>Sumba</td>
<td>29</td>
</tr>
<tr>
<td>Flores and Lembata</td>
<td>48</td>
</tr>
<tr>
<td>Alor</td>
<td>8</td>
</tr>
<tr>
<td>Rote Ndao</td>
<td>8</td>
</tr>
<tr>
<td>Sabu Raijua</td>
<td>2</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>139</strong></td>
</tr>
</tbody>
</table>

2.2 Pig Industry in Nusa Tenggara Timur

2.2.1 Pig Population and Distribution

NTT province has the largest pig population in Indonesia (BPS Statistics, 2009). Pig raising is a major agricultural practice that continues to provide financial security to households and plays an important cultural role in traditional ceremonies and celebratory events (Johns et al., 2009). The current pig population per district can be viewed in Table 2.1.

2.2.2 Pig Introduction into Indonesia and Present Pig Breeds

Pigs have been present in Indonesia for more than 10,000 years (Larson et al., 2007). Due to the archipelagic nature of the country, there has been a dispersion of different pig breeds
identified across the islands. During the early Neolithic period, animals such as pigs had strong cultural significance across Asia. As a result, phylogenetic studies have been conducted throughout South-East Asia to identify pig dispersal patterns in the hope of reconstructing human dispersal patterns into Oceania (Larson et al., 2007). Larson et al. (2007) concluded that it was human movement that enabled the spread of pigs throughout this region. Furthermore, it is thought that the current indigenous pig breeds present in South-East Asian regions are most likely feral descendants of early domesticated pigs (Larson et al., 2007). Timor island currently represents two different clade types: the Pacific clade (constituting Sus scrofa); and the Sus celebensis clade, indigenous to Indonesia (Larson et al., 2005). Dobney et al. (2008) further supported Larson et al. (2007) by confirming the presence of the two major groups: the Sus scrofa distributed on the islands of Sumatra, the Riau-Lingga archipelago, Java and across Nusa Tenggara Timur, reaching the Komodo Islands; and the Sus celebensis currently distributed across Sulawesi and the islands of Timor, Roti Lendu, Flores and Simuleue.

An alternative study by Hayashi et al. (1984) identified the presence of additional subspecies. The native pig breeds that have been cultivated by the indigenous people in different areas of Indonesia are the short-eared type bred by the Batak people in North Sumatra in addition to the Toraja people in South Sulawesi. Moreover, there is a Hainun-like type breed on Bali island. Wild boars have also been reported across the country, including the species of Sus scrofa and S. verrucosus, while the presence of various subspecies have also been described including S. s. vittatus, S. s. milleri and S. s. floresianus (Hayashi et al., 1984).

2.2.3 Smallholder Pig Farming in Indonesia and other Developing Countries

Across Indonesia, the presence of both smallholder farmers and a commercial pig sector has been identified (Liano & Siagian, 2002). Pig farming in Indonesia is the third-largest producer of meat for human consumption, following poultry and ruminants (Liano & Siagian, 2002). Within Indonesia, pig production occurs in Java, Kalimantan and Sumatra and also across eastern Indonesia in Bali, Sulawesi, NTT and Papua (Brandenburg & Sukobagyo, 2002; Iyai et al., 2011; Liano & Siagian, 2002). Dinas Peternakan Propinsi in Kota Kupang (NTT) has developed a classification system to categorise pig herds where smallholder pig farmers are those with total herd sizes of ≤ 20 pigs (Table 2.3).
Livestock production is crucial to the livelihood of a large proportion of those living in poverty around the world (Roessler et al., 2008). It was recognised by Quartermain (2009) that priorities for improving the livelihood of farmers need to revolve around livestock improvement, particularly regarding animal health, nutrition, waste management and education.

Farmers across NTT are primarily smallholders, with animals such as pigs and chickens kept by many households (Christie, 2007; Johns et al., 2009). In Indonesia, pigs are viewed as reliable livestock, particularly if money is required urgently (Liano & Siagian, 2002). They are durable animals that can survive on a varying diet, typical of the pig diets provided by smallholders with changes to household income and differences in climate and geography between regions. Moreover, pigs grow to a fattener size in a shorter amount of time than animals such as cattle and provide an important protein source (Christie, 2007; Kruska et al., 2003; Liano & Siagian, 2002). Smallholder farmers in South-East Asia tend to have small herds of around 1–3 sows or less than 10 fatteners per household (Christie, 2007; Johns et al., 2009; Knips, 2004; Lemke et al., 2006).

For smallholder farmers in Vietnam, Lemke et al. (2006) identified that pig production only makes up a component of total household income with nine to 41% of a family’s total income derived from pig production. In the smallholder sector in developing countries, a variety of animals are used as forms of financial security, such as cattle in Cambodia (Nampanya et al., 2011) and pigs in eastern Indonesia (Christie, 2007).

### 2.2.3.1 On-farm Pig Management

Pig housing systems used by smallholder farmers are similar across NTT province, South-East Asia and Africa, with small pens, tethering and free roaming systems commonly utilised (FAO, 2010; Kagira et al., 2010). For farmers that pen their pigs, structures are
generally built using local materials, such as bamboo, straw and wood, providing containment for small numbers of pigs (Lemke et al., 2006; Robertson et al., 2010b).

Local agricultural products available to households are commonly used as a food source for pigs kept by smallholder farmers due to limited income and restricted availability of feed (Lemke et al., 2006). In NTT products such as cassava, taro, sweet potato, rice bran and water spinach are often used (Johns et al., 2009). Similar food products, which tend to vary according to season, are utilised across South-East Asia (Kumaresan et al., 2007; Lemke et al., 2006; Varney, 2006). An extensive study by Cargill et al. (2009) was conducted in Papua province, Indonesia to investigate the importance of sweet potato-pig production due to its role role as a primary food source for both humans and pigs. It was found that cooking sweet potato and providing feed regularly and in greater amounts (equivalent to approximately 10% of a pig’s body weight) led to substantially improved growth rates.

A study by Phengsavanh et al. (2010) in Lao PDR with smallholder pig farmers identified that foodstuffs provided to pigs are generally produced on-farm or collected from areas surrounding a village. Poor feed quality in many developing countries is a factor contributing to loss of productivity for pig production (Mutua et al., 2012; Varney, 2006). Diets tend to be high in energy but low in protein (Phengsavanh et al., 2010). Environment and feed management all impact on the nutritional status and accessibility of feed sources being provided to pigs (Kunavongkrit & Heard, 2000).

### 2.2.4 Commercial Pig Farming in NTT

With the ‘livestock revolution’ occurring across South-East Asia since the 1970s, rapid expansion of livestock production has occurred along with increases in the consumption of animal products (Delgado, 2006; Gerber et al., 2005). Since the 1990s, pig production in NTT has increased, resulting in the growth of the commercial sector (Brandenburg & Sukobagyo, 2002; Christie, 2007; Liano & Siagian, 2002).

It was identified by Johns et al. (2009), through an investigation into smallholder commercial farms in NTT, that there are presently only six commercial pig farms in Kupang district with more than 50 pigs per herd. In Flores, some NGOs and churches have larger small business farms (Table 2.3) from which they distribute pigs as part of their aid support (Christie, 2007; Kira I. pers comm, 2010). However, across Flores and in Sumba, no commercial farms have been identified (Johns et al., 2009).
2.2.5 Pig Diseases in NTT

Data on pig disease distribution and level in NTT is very limited with the province being classified ‘data poor’ in this respect (Johns et al., 2009; Wodowati & Hutabarat, 1999). However, it has been documented that several pig diseases, including CSF and porcine reproductive and respiratory syndrome (PRRS), have been introduced to NTT over the past 30 years and resulted in substantial negative impacts on pig production across the province (Brandenburg & Sukobagyo, 2002).

A 2008 survey conducted by the Australian Quarantine Inspection Service (AQIS), in collaboration with DGLAHS, confirmed the presence of CSF, Aujesky’s disease, PRRS and Japanese encephalitis in NTT province (apparent prevalence levels with 95% CI: 29.4 (21.4, 37.3), 7.1 (2.6, 11.6), 3.2 (0.1, 6.2) and 62.6 (53.8, 71.5) respectively). The AQIS survey was the first to confirm the presence of PRRS in NTT province. Other studies have supported these results, also confirming the presence of erysipelas and diarrhoea in piglets in NTT to be a problem impacting farmers (Liano & Siagian, 2002).

From previous surveys on Alor island in NTT, farmers have demonstrated the ability to recognise clinical signs of a sick pig (Deveridge, 2008; Robertson et al., 2010b). However, these clinical signs were not associated with any particular disease. Moreover, it should be mentioned that it is common for poorer pig farmers in developing countries to sell pigs with suspected disease to avoid loss of income, which represents a risk for dissemination of infectious diseases (FAO, 2010).

2.2.6 Societal Importance of Pigs

2.2.6.1 Women and Pig Farming

The important role that women play in the smallholder pig farming sector in NTT has been identified (Johns et al., 2009). This is a common finding also identified in other areas of South-East Asia and the developing world including Lao PDR (Phengsavanh & Stur, 2006), Vietnam (Lemke et al., 2008a) and Kenya (Kagira et al., 2010). Kristjanson et al. (2010) calculated that two thirds of the world’s 600 million poor livestock keepers are rural women. In Lao PDR for example, women will spend up to three hours per day collecting and cooking pig feed for their herd (Phengsavanh & Stur, 2006). Across households in NTT, women tend to be the primary caretakers for pigs with primary responsibility for providing feed and water to pigs that are generally kept in close vicinity to the house (Johns et al., 2009).
In poverty-stricken areas around the world, the extent of assets owned by a household is more critical than yearly income (Kristjanson et al., 2010). The more assets one owns the greater the ability to cope in an emergency situation when resources are scarce. Research in Bangladesh has looked at the impact of women with assets within the home. It was suggested that where women have a higher share of assets, particularly on entry to a marriage for example, there is often improvement in food security, child nutrition, education and improved wellbeing for women (Kristjanson et al., 2010; Quisumbing & Maluccio, 2003).

2.2.6.2 Pigs as a Source of Financial Security and Savings

Across South-East Asia, pigs are an important part of subsistence farming and are commonly utilised as a source of income or savings (Huynh et al., 2007). Pigs are often sold when money is needed for household necessities, educational costs or for emergencies (Huynh et al., 2007; Ratarasarn, 1980). A study conducted by Santhia et al. (2006) on Alor in NTT found the primary purpose for farmers keeping pigs was for child education funds and for use at festivals and ceremonies.

2.2.6.3 Cultural Use and Consumption

Pigs are held in high cultural regard across the islands of NTT. They are used in cultural events such as traditional ceremonies, weddings, funerals and other important celebrations (Christie, 2007; Johns et al., 2009). Similarly, in Papua New Guinea, pigs are used for ceremonial feasting and typically involved in traditional celebrations (Jones, 2002). For weddings and funerals in NTT, a minimum of five pigs are generally required to feed family members who arrive from all over the province (Kira & Kasman, 2011). This is in addition to dowry payments for the bride, which require large numbers of pigs—sometimes up to 40—to align with the status of the female (Geong M. pers comm, 2009). In other areas of Indonesia, the slaughter of livestock occurs at traditional ceremonies. For example, in South Sulawesi it is common for buffalo to be slaughtered in the belief that they are a ‘vehicle to reach heaven’ (Riethmuller, 1999). The importance of such traditions needs to be considered by the government and international organisations when working in rural development (FAO, 2010).

Preliminary evidence from Malo (2011) and personal communication with Dr Maria Geong from Dinas Peternakan Propinsi, has suggested that pigs are predominantly purchased live for slaughter across the province. The limited cold chain present in the
province is a factor hindering development of the meat trade industry (Salin & Nayga, 2002). Typically in NTT pork meat can only be purchased in urban centres. This is similar to the situation in Cambodia where the domestic meat trade centres on urbanised centres following slaughter at slaughterhouses (Knips, 2004).

In the past 3–5 years a new restaurant type referred to as ‘se’i babi’ has developed across West Timor (Geong M. pers comm, 2010; Kira I. pers comm, 2010). Johns et al. (2009) conducted a survey of these restaurants to investigate their characteristics. Se’i refers to a method of cooking in which pork is smoked on a barbeque. In general, consumers in NTT were found to prefer the taste of cross-bred pigs as they were classified as leaner and better tasting. In contrast, a study by Jabbar et al. (2010), found that consumers in Vietnam preferred the flavour of local pigs. Moreover it was found that in Vietnam, pork consumers reported that they preferred the taste of fresh meat from an animal that had been recently slaughtered as opposed to frozen meat (Lapar et al., 2009).

### 2.2.7 Backyard Slaughtering of Pigs and Slaughterhouse Usage

It is common among smallholder farmers in NTT to slaughter pigs at their residence (Johns et al., 2009). The use of slaughterhouse facilities can incur payments of approximately Rp 13,200 per head for the transportation and slaughter of pigs (Priyanti & Putu, 1999). Priyanti and Putu (1999) recognised that inspection by animal health workers (AHWs) may also result in the identification of disease, which deters farmers due to the potential for loss of product and income. As a result, with the majority of farmers in NTT living below the poverty line, households choose to slaughter pigs at their residence (Johns et al., 2009). Stakeholder estimates obtained by Johns et al. (2009) suggested that as many as 650,000 pigs per year are slaughtered using this process.

Backyard slaughter can lead to issues of swill feeding if appropriate disposal management is not adopted. This practice is the feeding of meat and meat products to pigs and is a common mode of disease transmission in pigs (Cameron, 1999; Mutua et al., 2012; Schembri et al., 2010). Diseases including CSF (Edwards, 2000), African swine fever (Sanchez-Vizcaíno et al., 2012), and parasitic infections including *Trichinella* (Pozio, 2001) and *Taenia solium* (Rajshekhar et al., 2003) can be spread from this practice, which poses risks for zoonotic infection (Ngowi et al., 2008). A farmer survey conducted in West Timor found that 91.3% (n = 237) of farmers fed household waste to their pigs which presents a risk if it contains uncooked pork meat (Malo, 2011). As recognised by FAO
(2010), this type of high-risk practice needs to be regulated to reduce the risk of transmission.

Currently in NTT province there are a total of 19 government and privately run livestock slaughterhouses (Table 2.4). A report from the FAO in 1999 stated the presence of only three cattle slaughterhouses in NTT, with no pig slaughterhouse facilities available (Priyanti & Putu, 1999). With developments in the pig industry and population increases, the number of slaughterhouses has since increased to meet demand (BPS Statistics, 2009).

Table 2.4
Number of livestock slaughterhouses and the number of pigs slaughtered at these premises (BPS Statistics, 2009).

<table>
<thead>
<tr>
<th>Location</th>
<th>Government</th>
<th>Private</th>
<th>TOTAL</th>
<th>No. of pigs slaughtered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kota Kupang</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1,953</td>
</tr>
<tr>
<td>Kupang</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>9,384</td>
</tr>
<tr>
<td>TTU</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5,946</td>
</tr>
<tr>
<td>TTS</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>24,750</td>
</tr>
<tr>
<td>Belu</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>9,658</td>
</tr>
<tr>
<td>Flores Timur</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>12,095</td>
</tr>
<tr>
<td>Ende</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6,388</td>
</tr>
<tr>
<td>Sikka</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9,172</td>
</tr>
<tr>
<td>Ngada</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>6,879</td>
</tr>
<tr>
<td>Nagekeo</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>7,111</td>
</tr>
<tr>
<td>Manggarai Barat</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4,218</td>
</tr>
<tr>
<td>Manggarai</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>9,140</td>
</tr>
<tr>
<td>Manggarai Timur</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>No data</td>
</tr>
<tr>
<td>Sumba Barat</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1,331</td>
</tr>
<tr>
<td>Sumba Timur</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>3,454</td>
</tr>
<tr>
<td>Sumba Barat Daya</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2,694</td>
</tr>
<tr>
<td>Sumba Tengah</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1,193</td>
</tr>
<tr>
<td>Alor</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>6,449</td>
</tr>
<tr>
<td>Lembata</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>4,570</td>
</tr>
<tr>
<td>Rote Ndao</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>5,843</td>
</tr>
<tr>
<td>TOTAL (2008)</td>
<td><strong>15</strong></td>
<td><strong>4</strong></td>
<td><strong>19</strong></td>
<td><strong>132,288</strong></td>
</tr>
</tbody>
</table>
2.3 Classical Swine Fever in Indonesia

2.3.1 CSF Entry and Spread across Indonesia

The route of CSF introduction into Indonesia is still under debate. Present literature suggests that pig movements from Malaysia into North Sumatra may have been the entry point (Christie, 2007; Hutabarat & Santhia, 1999). The first confirmed case was in North Sumatra in 1994 following the unexplained deaths of thousands of pigs (Hutabarat & Santhia, 1999). Referring to Figure 2.3, from 1994 through to 1998 CSF spread across a large number of provinces in Indonesia and reached as far as East Timor (then a province of Indonesia) (Christie, 2007; Hutabarat & Santhia, 1999; Santhia et al., 1997). A study by Santhia et al. (1997) investigating CSF occurrence in East Timor found that, by 1997, CSF was present across six districts with an average prevalence level of 34.75% based on reported cases. For NTT, the first suspected cases were reported on Flores and Sumba islands in 1997. However, not until 1998—when a suspected CSF case was tested in Kota Kupang and found to be positive—was it recognised that CSF had entered this province (Figure 2.4) (Christie, 2007; Hutabarat & Santhia, 1999; Santhia et al., 1999).

More recently, CSF infection was detected in Papua and West Papua provinces (Geong M. pers comm, 2011; Sri, 2009; Wulandari R. P. pers comm, 2012). In 2007, 105 cases were reported in Papua with an additional 12 cases in 2009 (Geong M. pers comm, 2011). Currently infected districts are thought to be Timika and Jayapura in Papua and Manokwari and Worong in West Papua (Wulandari R. P. pers comm, 2012). The last laboratory confirmed case was in 2010 with Dinas veterinarians aiming to conduct surveillance and community education (Wulandari R. P. pers comm, 2012). In March 2012 however, a suspected CSF outbreak was reported in the district of Intan Jaya in the Pauaposa local newspaper despite this area being reportedly CSF free.

Across Indonesia, from 1994 to 1998, 15 out of 27 provinces experienced reductions in pig population (BPS Statistics, 2009). Table 2.5 provides population data for those provinces that had confirmed CSF cases. Aligning with Figure 2.3 it can be seen that North Sumatra, for example, had a substantial reduction in pig population from 1994 to 1995. This is the time period in which CSF was first confirmed. This trend was not identified in all provinces. However, it does suggest that impacts on pig population were experienced during the time of CSF’s introduction.
The entry pathway of CSF into NTT province is still unknown. However, evidence suggests that there are two potential points of entry for this virus. Pig movements from East Timor may have brought the disease into West Timor, as suggested by the distribution across several districts of East Timor in 1997 (Santhia et al., 1997). Alternatively, there is still some speculation that the virus may have come across from Bali or other western areas of Indonesia (Geong M. pers comm, 2010). Livestock and product movement is common between Bali province and NTT, which provides evidence for this entry pathway (Christie, 2007; Patunru et al., 2010).

Once introduced Figure 2.4 illustrates the spread of CSF across NTT province, which by 2002 had pigs on all major islands infected with CSF. With the demand for pigs increasing and fewer pigs in affected districts, the movement of live pigs around the province most likely facilitated its spread. The introduction of CSF into NTT was seen to coincide with dramatic decreases in pig population following 1998 (BPS Statistics, 2009). Between 1999 and 2000 all districts within NTT province experienced a reduction in pig population, the most substantial being in Kupang, TTU and Sumba Barat districts. Brandenburg and Sukobagyo (2002) reported reductions in pig production across Indonesia from 1995, with the largest decline seen in 2000–2001; reportedly as a result of higher commercial feed costs. Referring to BPS Statistics (1995 to 2009), pig numbers in NTT prior to 1999 were increasing followed by a dramatic reduction of over 1.5 million pigs between 1999 to 2000 in NTT (Table 2.6). This reduction coincides with the introduction of CSF into the province and the 96,984 CSF cases reported to Dinas Peternakan during 1998, predominantly in Kupang (Dinas Peternakan Propinsi, 2011). Furthermore, the majority of farmers across the province were smallholders and did not utilise commercial feed (Christie, 2007).

A reduction in the pig population was also identified in the western districts of Flores including Ngada, Manggarai, Sikka and Ende (Table 2.6). This is interesting as three out of the four districts are still considered CSF free, with Sikka being a suspect district. Personal communication from Dr Maria Geong has suggested that this reduction may have been caused in part by problems with pneumonic pasteurellosis, a respiratory disease of pigs, present across Flores (Jackson & Cockcroft, 2007). The introduction of rabies into Flores during 1998 prompted the majority of animal health services to direct their efforts towards rabies control (Windiyananingsih et al., 2004). During this time farmers continued to report
clinical signs consistent with pneumonic pasteurellosis but had limited access to animal health services.

It needs to be noted that there have been modifications to district borders over time with changes occurring as recently as 2007. On Flores, Manggarai district was divided into three districts: Manggarai Timur (2007); Manggarai Barat (2003); and Manggarai. Nagekeo district was also formed in 2007, dividing Ngada district in two. Sumba was further divided from two districts into four, with the inclusion of Sumba Tengah and Sumba Barat Daya in 2007 (Table 2.1). As a result, the figures displayed in Table 2.6 represent total pig population values where available for district divisions present up to 2002.

The most recently infected island in NTT province is Lembata island, situated on the eastern end of Flores. Since the introduction of CSF into NTT, movement restrictions were established to stop pigs moving from infected to non-infected areas (Brandenburg & Sukobagyo, 2002; Hutabarat & Santhia, 1999). However, in 2011, four pig movement events were recorded from Kupang to Lembata with three classified as legal (with pig health documentation present) and one illegal movement. A total of 41 pigs were moved between January and July and the first confirmed case of CSF was identified in April (Diarmita, 2012). By December 2011, 1,628 cases of CSF had been recorded across six subdistricts (Geong M. pers comm, 2011).
Table 2.5

<table>
<thead>
<tr>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>North Sumatra</td>
<td>2,387,849</td>
<td>920,998</td>
<td>948,235</td>
<td>976,277</td>
<td>1,005,175</td>
</tr>
<tr>
<td>West Sumatra</td>
<td>32,640</td>
<td>46,283</td>
<td>46,733</td>
<td>46,953</td>
<td>47,179</td>
</tr>
<tr>
<td>Jakarta (North Java)</td>
<td>41,750</td>
<td>8,600</td>
<td>8,464</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Central Java</td>
<td>139,548</td>
<td>132,594</td>
<td>120,939</td>
<td>100,532</td>
<td>83,947</td>
</tr>
<tr>
<td>East Java</td>
<td>56,656</td>
<td>62,622</td>
<td>54,510</td>
<td>54,610</td>
<td>53,518</td>
</tr>
<tr>
<td>West Java</td>
<td>49,649</td>
<td>42,314</td>
<td>53,060</td>
<td>25,550</td>
<td>21,285</td>
</tr>
<tr>
<td>West Kalimantan</td>
<td>911,686</td>
<td>923,752</td>
<td>616,130</td>
<td>331,786</td>
<td>737,440</td>
</tr>
<tr>
<td>Bali</td>
<td>1,056,318</td>
<td>1,079,831</td>
<td>1,073,062</td>
<td>1,131,283</td>
<td>1,136,442</td>
</tr>
<tr>
<td>North Sulawesi</td>
<td>519,106</td>
<td>555,672</td>
<td>500,100</td>
<td>505,051</td>
<td>303,031</td>
</tr>
<tr>
<td>South Sulawesi</td>
<td>520,048</td>
<td>554,759</td>
<td>574,674</td>
<td>575,061</td>
<td>575,448</td>
</tr>
<tr>
<td>East Timor</td>
<td>308,385</td>
<td>343,169</td>
<td>377,898</td>
<td>375,866</td>
<td>383,382</td>
</tr>
<tr>
<td>Nusa Tenggara Timur</td>
<td>1,406,074</td>
<td>1,537,982</td>
<td>1,589,060</td>
<td>2,229,134</td>
<td>3,204,543</td>
</tr>
</tbody>
</table>
Table 2.6  

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumba</td>
<td>Sumba Barat</td>
<td>153,297</td>
<td>215,045</td>
<td>97,681</td>
<td>173,542</td>
<td>177,707</td>
<td>30,470</td>
<td>39,691</td>
<td>51,701</td>
</tr>
<tr>
<td>West Timor</td>
<td>Kupang</td>
<td>337,485</td>
<td>473,424</td>
<td>664,421</td>
<td>496,421</td>
<td>508,335</td>
<td>86,895</td>
<td>113,190</td>
<td>121,333</td>
</tr>
<tr>
<td>West Timor</td>
<td>Kota Kupang</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>No data</td>
<td>11,586</td>
<td>15,092</td>
<td>16,178</td>
</tr>
<tr>
<td>Sumba</td>
<td>Sumba Timur</td>
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<td>2,287,302</td>
<td>731,959</td>
<td>953,457</td>
<td>1,170,473</td>
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</tbody>
</table>

¹Highlighted grey areas are years where substantial reductions in pig population occurred across each district.
Figure 2.3
The spread of classical swine fever (CSF) across Indonesia following its introduction in 1994, adapted from information obtained from Hutabarat & Santhia (1999), Christie (2007), Geong, M (pers comm., 2009), Santhia et al. (2003), Santhia et al. (1997); 1: first confirmed case in Indonesia in North Sumatra, 1994, believed to have entered from Malaysia; 2: CSF reached Central and South Sumatra, late 1994; 3: first confirmed case on Java island, March, 1995; 4: confirmed case in Kalimantan in September 1995; 5: first case in Bali, October 1995; 6: North and South Sulawesi both had confirmed cases by the end of 1995, early 1996; 7: The capital city of Timor-Leste, Dili, reported its first CSF case in August 1997; 8: suspect cases were reported in NTT in mid-1997; however, laboratory confirmation was not until March 1998; 9: First cases in Papua in 2006 but not confirmed until 2007 (Geong M. pers comm, 2011; Sri, 2009).
Figure 2.4
The spread of classical swine fever across Nusa Tenggara Timur, eastern Indonesia; 1: first suspected cases in mid 1997 in Sumba Timur and Flores Timur districts; 2: first confirmed cases of CSF in NTT in March 1998 through laboratory testing; 3: cases identified in 1999; 4: first suspect case in 2000 in Sikka district from clinical reports from farmers; 5: first detected case on Alor Island in July 2002; 6: first confirmed case of CSF on Lembata Island in 2011; adapted from information obtained from Hutabarat & Santhia (1999); Christie (2007), Santhia et al. (2003), Geong, M (pers comm., 2011). Current classification of districts for classical swine fever as of 2011 shown by boxes; where infected is defined as: positive serology and reports of clinical signs from pig owners, red box; suspect; positive to serology but no clinical signs reported from farmers, yellow; not infected: no reported cases, green. As of May 2011, Lembata Island is classified as infected, seen highlighted in blue (Dinas Peternakan Propinsi, 2011).
2.3.2 CSF Prevalence and Current Distribution in NTT

After its introduction in the 1990s, CSF was listed as a national priority for control in Indonesia alongside rabies and bovine brucellosis (Hutabarat & Santhia, 1999). When CSF first entered NTT, districts across the region were classified as: infected, suspect or not infected. This classification system was adopted across all of Indonesia for CSF. The current divisions across NTT can be viewed in Figure 2.4. These classifications, based on passive surveillance and serological survey results, have dictated the distribution of limited CSF vaccines provided by the government (Brandenburg & Sukobagyo, 2002). Movement restrictions apply in accordance with these district classifications to stop pigs being moved from infected to non-infected areas (Dinas Peternakan Propinsi, 2011; Geong M. pers comm, 2011).

Through the use of passive surveillance, it has been recognised that the total number of CSF cases continues to increase with 1,087 cases reported in 2011 (Table 2.7). CSF cases have been reported every year in Sumba and West Timor since 1998. In Table 2.7 where it states ‘zero’ it should be noted that this is the number of reported cases to the Dinas Peternakan Propinsi. As shown by studies conducted by Robertson et al. (2010b) and Deveridge (2008), farmers across NTT are reluctant to report cases of diseases. Furthermore, Santhia et al. (2003) recognised that AHWs do not always report cases of disease. Hence these zero values do not necessarily reflect the absence of CSF cases in a district.

Across the past 12 years, several studies have been conducted in different areas of the province to investigate the prevalence and epidemiology of CSF. The majority of initial studies conducted following disease introduction were carried out by DIC Denpasar. The first published report for the Indonesian DGLAHS was in 1999 by Santhia et al. Prevalence levels as high as 30.9% and 10.8% were detected in Flores Timur district and Kupang district respectively, using a Creditest ELISA to detect antibody level in 120 pig sera samples (Flores Timur: 55 samples; Kupang: 65 samples).

Following the confirmation of CSF on Alor in July 2002, the DIC Denpasar was triggered to conduct another survey to determine the extent of disease spread across the island (Santhia et al., 2003). Interviews were conducted with farmers in eight villages to obtain information regarding the distribution of pigs with CSF. It was confirmed that by 2003, CSF had infected pigs in the eight villages where interviews had been conducted with the
majority of sick pigs between the ages of 2–5 months. Some inconsistencies have been detected between the number of CSF cases reported by Dinas Peternakan Propinsi (2011) and this study. Santhia et al. (2003) stated that a total of 2,859 pigs were sick with CSF. However, Dinas Peternakan reported only 1,250 recorded cases. It has been recognised that as a result of government decentralisation, communication between and within different government sectors is lacking, which may be causing data inconsistencies (Brandenburg & Sukobagyo, 2002). Moreover, Santhia et al. (2003) stated in their paper that farmers and AHWs on Alor were not reporting all cases of disease.

International organisations, including the Australian Centre for International Agricultural Research (ACIAR) and AQIS, have also been involved in studies across the region. In 2004, a project on Alor island was initiated by ACIAR as part of a five-year study to investigate the development of a surveillance system for CSF, avian influenza (AI) and foot-and-mouth disease (FMD) (Robertson et al., 2010b). Alor island was used as the study site for a CSF component and substantial baseline information was gathered regarding smallholder pig farming practices and CSF epidemiology on this island. Initially a cross-sectional study was conducted with 277 farmer interviews and 690 pig samples collected to obtain information on pig practices and CSF prevalence. A field-based vaccine trial was also conducted to determine the most effective vaccine (based on antibody response) in the field, comparing the locally distributed CSF vaccine (Hogsivet) with three international CSF vaccines. Moreover, during the duration of the project, pig movements to and from the island were banned. However, as reported by Bragg (2007), pig movements, although most likely reduced as a result of the restriction, did continue to take place with no recording or quarantine system in place for pigs on arrival. As a result of movement restrictions, and increased and sustained vaccination coverage combined with farmer education, the number of reported CSF cases was substantially reduced, with few cases reported from 2006–2007 followed by no reported cases for 2008 to 2011 (Table 2.7).

Across NTT, the most recent prevalence data suggest that the highest levels of CSFV are currently present in Sumba Timur on Sumba, and Belu district in West Timor (Appendix 10; ACIAR Project AH/2006/156, 2010). This study detected a true prevalence level of 26.1% (95% CI: 19.1–33) for Sumba Timur and 20.9% (16.5–25.3) for Belu district with 162 and 349 pigs tested respectively in each district. Positive pigs with vaccination history were not included in the analysis. Samples were tested using a commercial CSFV enzyme
linked immunosorbent assay (ELISA) kit (PrioCHECK® CSFV Antibody, Lleydstat, Netherlands) to detect antibodies. Positive and inconclusive results were re-tested with a second generation ELISA (PrioCHECK CSFV Ab 2.0). This ACIAR Project AH/2006/156 (2010) obtained data from seven different districts across the province with a total of 2039 samples tested. A survey conducted by AQIS in 2008 supported the high seroprevalence levels detected in West Timor and Sumba through a survey assessing the status of various diseases in NTT, including CSF. This study estimated a prevalence level of 51% for Belu district, and 54% for West Sumba (including Sumba Barat Daya and Sumba Barat districts) based on serum samples tested with a commercial PrioCHECK® CSFV Antibody ELISA without obtaining information on pig vaccination status. Given the ELISA tests used in these two surveys cannot distinguish between antibodies from vaccination and from natural infection, the AQIS survey results need more careful consideration due to: the lack of information on pig vaccination status, the much smaller sample size of 123 pig samples across six districts and the absence of a 2nd generation ELISA to rule out false positives that may have occurred due to cross reaction with antibodies in the sera of pigs infected with other pestiviruses.

The presence of CSF in the easternmost district of Flores, Flores Timur was previously confirmed by Santhia et al. (1999). The distribution of CSF on Flores in the remaining districts is still under investigation. Although Sikka district is currently classified as a suspect region with only one clinical case ever reported, diagnostic testing has confirmed the presence of CSF antibodies, from both the ACIAR AH/2006/156 (2010) and AQIS (2008) projects. The ACIAR Project AH/2006/156 (2010) provided an estimate of 2.7% (with removal of vaccinated pigs) whereas AQIS provided an estimate of 20%. Vaccination campaigns have been undertaken in Flores Timur and Sikka districts since 2006 (Dinas Peternakan Propinsi, 2011).

It was recommended by Hutabarat and Santhia (1999) that serological surveillance be conducted in areas considered free of CSF across Indonesia, to assist in disease control. Although this was suggested, no surveillance has been conducted by the Dinas Peternakan in NTT in central and western Flores due to the CSF free status. The first investigations into CSF prevalence in this region were done in the districts of Manggarai Barat and Manggarai by AQIS (2008) and ACIAR (2010). All samples collected in Manggarai Barat and Manggarai by AQIS (2008) were negative for CSF antibodies. A 5% prevalence estimate was detected for Ngada district, which is classified as a CSF-free area. The
ACIAR Project AH/2006/156 (2010) detected the presence of CSF antibodies in pigs in Manggarai Barat. An estimated prevalence of 10% was detected, taking into consideration that no farmers had reported vaccinating pigs in this region. There is still some question surrounding these results due to a lack of clinical reports by farmers. The potential for a cross-reaction with antibodies to other pestiviruses was addressed by performing a 2nd generation ELISA on all positive and inconclusive results, which is an issue that can impact results (Loeffen et al., 2009; Wieringa-Jelsma et al., 2006). The presence of ruminant pestiviruses including Bovine Viral Diarrhoea Virus (BVDV) and Border Disease Virus (BDV) can affect diagnosis of CSFV. Wieringa-Jelsma et al. (2006) found that the transmission of CSFV could be reduced in pigs infected with BVD. However, with pigs that had double infections, both BVD and CSF, a neutralisation peroxidase linked assay (NPLA) limited the ability to detect CSFV infection in animals that had BVD at the time of CSF infection. This suggests that diagnosis of CSF in herds where there is a high prevalence of BDV may be affected. Other species including goats and sheep can be infected with BVDV and BDV (Krametter-Froetscher et al., 2007; Mishra et al., 2009; Ridpath, 2010). Therefore, it is important to note that a substantial goat population and smaller sheep population are present in western Flores (12,366 goats and 28 sheep across Manggarai Barat and Manggarai collectively in 2009; BPS Statistics, 2009).
Table 2.7

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<td>1,957</td>
<td>560</td>
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</table>

¹Sikka district classified as suspected CSF infection; ²The districts of Manggarai Barat, Manggarai, Manggarai Tengah, Ngada and Nagekeo have been excluded as they are classified as CSF free and cases of CSF have not been reported.
2.3.3 Laboratory Testing

Clinical diagnosis is unreliable for CSF due to the absence of pathognomonic clinical signs and as such there is a need for laboratory confirmation (Osterhaus et al., 2009). A variety of diagnostic tests are available to confirm CSFV infection (Dewulf et al., 2004). The ‘gold-standard’ diagnostic tool for CSFV is virus isolation in cell culture. However, this method is time consuming and can take up to four days (Moennig, 2000; Risatti et al., 2003). Alternative diagnostic methods are available such as virus neutralisation tests (VNTs) and ELISAs for antibody detection with antibodies detectable at two–three weeks post infection (Greiser-Wilke et al., 2007; Koppel et al., 2007). Antibody ELISAs are often the test of choice as VNTs can be time consuming due to difficulties with mass analysis (Greiser-Wilke et al., 2007). Antigen-capture ELISAs are also available with CSFV detectable at 2–15 days post infection using blood tissue, plasma or serum samples (Greiser-Wilke et al., 2007).

Osterhaus et al. (2009) recommended that ELISA tests for antibodies and real time polymerase chain reaction (RT-PCR) are the most suitable diagnostic tools for CSFV. RT-PCR is effective due to its ability to detect virus DNA and thus indicate that an animal has been exposed to CSFV. In Indonesia, NTT province sends samples from CSF suspect cases to the DIC in Denpasar where appropriate facilities are available to test samples (Santhia et al., 2003). At this laboratory a VDPro® CSFV Antibody C-ELISA Kit is used for testing samples. This type of ELISA Kit is designed to detect the presence of anti-E2 antibody in swine serum.

2.3.4 Government Veterinary Assistance for CSF across NTT

2.3.4.1 CSF Vaccination across NTT

Vaccination campaigns for CSF have been implemented on Timor, Alor and Sumba islands since 2000, and in Flores Timur and Sikka districts on Flores from 2006 (Dinas Peternakan Propinsi, 2011). CSF vaccination is currently carried out by veterinarians and AHWs working with Dinas Peternakan. It is a public service that is freely available to smallholder farmers and at a subsidised cost to semi-intensive small business herds (Table 2.8) (Brandenburg and Sukobagyo, 2002). However, limited government budgets have restricted vaccine distribution. An approach used by Riise et al. (2005), from experiences in village poultry production across West Africa and Asia, was to give poultry farmers the first vaccination for Newcastle disease free of charge to demonstrate its effectiveness which encouraged farmers to maintain use of vaccinations. From the Alor project it was
demonstrated by Robertson et al. (2010b) that pigs were not getting vaccinated for several common reasons including the belief that vaccination was too dangerous, the farmer did not believe in vaccination and problems with AHWs providing the vaccination. This identified a need to educate farmers about the importance of vaccination to improve animal health.

In NTT province, vaccinations are only conducted in endemic areas with a target of 80% of the susceptible population to receive vaccinations. Focus is placed on regions with the highest pig densities and annual reports of clinical cases (Geong M. pers comm, 2010; Hutabarat & Santhia, 1999). Robertson et al. (2010b) determined that the cost of a CSF vaccine was Rp 4,600 (Hogsivet vaccine manufactured by PUSVETMA), with an additional Rp 6,000 for labour costs for vaccine administration.

Table 2.8
Regulations for CSF vaccine payments provided by the government in Nusa Tenggara Timur, eastern Indonesia (Dinas Peternakan Propinsi, 2011).

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<th>Pig herd size</th>
<th>Vaccination Payment Method</th>
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<td>1–20</td>
<td>Free</td>
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<tr>
<td>20–50</td>
<td>Farmers make a small contribution such as payment for labour</td>
</tr>
<tr>
<td>50–200</td>
<td>Vaccination must be paid for</td>
</tr>
</tbody>
</table>

The locally distributed vaccine in Indonesia is the Hogsivet vaccine. This vaccine is manufactured and registered for use in Indonesia by Pusat Veterinaria Farma (PUSVETMA), which is an organisation under the direction of the DGLAHS (Surabaya, East Java, Indonesia). As it is a live attenuated vaccine (Chinese strain), this limits the ability to distinguish between infected animals by serology with those within the vaccinated population (Graham et al., 2011).

Few investigations have been conducted on the Hogsivet vaccine. Robertson et al. (2010b) conducted the first field-based vaccine trial on Alor to compare the Hogsivet vaccine with three international vaccines. Although the manufacturers recommend a boost shot one month post primary vaccination, common practice on Alor (reported by AHWs), was to provide only one vaccine. As a result, the vaccine trial adopted this process. Literature suggests that a booster vaccination should be standard practice (Dewulf et al., 2001b; Greiser-Wilke & Moennig, 2004). The three international vaccines used for comparison included Kitasato from Japan, Pestiffa (Meria) and Pestvac (Fort Dodge) with 60 pigs in
each group. Results showed that the three internationally produced vaccines were significantly more effective (based on antibody response), than the locally manufactured Hogsivet vaccine. Furthermore, the three international vaccines did not significantly differ from each other.

In the field, environmental changes can lead to degradation of a vaccine through virus inactivation. Temperature and pH changes during storage, transportation, handling and vaccination procedures can lead to inactivation of the CSF vaccine (Barrera et al., 2009). Studies have identified this as a reason for insufficient vaccine dosage levels that can lead to a risk of incomplete protection among vaccinated pigs (Barrera et al., 2009). The limited cold chain and distances required to travel to many rural villages can impact vaccine efficacy in many developing countries (Peeling & Holden, 2004; Wirkas et al., 2007).

2.3.4.2 Farmer Education and Participation

Educational material on CSF for farmers in NTT has been developed by both Dinas Peternakan Propinsi in Kupang and the ACIAR Alor Project (Robertson et al., 2010b). Figure 2.5 provides examples of some educational material being distributed currently across NTT. Similarly, a study conducted in eastern Indonesia in Papua province by Cargill et al. (2009) developed educational material for the establishment of farmer-to-farmer training programs. The focus of this material was on modifying pig diets and production systems for improved pig health. It was found that selected project farmers who actively participated in the program improved their knowledge.

Catley and Leyland (2001) investigated community participation and the delivery of veterinary services in Africa. They outlined factors linked with successful animal health projects and concluded that community participation is a major aspect to consider in the design and implementation of a project. Involving local villages provides the community with a sense of ownership and a drive to continue the implementation of mitigation measures. An example of community education and participation can be seen in a paper by Ngowi et al. (2008). A health-education intervention was trialled in Tanzania for porcine cysticercosis. The intervention saw improved knowledge in disease transmission and a reduction in infected pork consumption, which resulted in a decrease in the incidence rate at the village level. Moreover, it has been recognised by Barham and Chitemi (2009) and Kefasi (2010), through studies in Africa, that engagement with smallholder farmers and
appropriate stakeholders is a priority when wanting to improve agricultural development with the aim of poverty alleviation.

Figure 2.5
Educational material for farmers on classical swine fever, i: Hog Cholera information book developed by Dinas Peternakan Propinsi, Nusa Tenggara Timur; ii: book developed for pig farmers during the ACIAR Alor project with information on Hog Cholera.

2.4 Epidemiology of Classical Swine Fever

2.4.1 Introduction

Classical swine fever virus is from the Pestivirus genus of the Flaviviridae family of viruses (Moennig et al., 2003). This pig virus causes one of the most economically damaging pig diseases and is on the World Organisation for Animal Health (OIE) list of notifiable diseases (Boklund et al., 2009). It results in high mortality rates and with both direct and indirect transmission routes, this highly contagious virus is of great concern to
pig industries worldwide (Deng et al., 2005; Greiser-Wilke et al., 2000). Severity varies with strain type. However, the animal’s age, breed and additional environmental factors all contribute to the course of the disease (Weesendorp et al., 2009a). Economic losses in the event of an outbreak are often very extensive. They can be experienced due to pig deaths, reduced reproductive and growth performance as well as implemented control strategies where compulsory slaughter and movement restriction further increase costs (Schnyder et al., 2002). For example, the total cost of the Netherlands epidemic in 1997/1998, was estimated to be US$2.3 billion (Artois et al., 2002).

Classical swine fever’s current global distribution is throughout South-East Asia, Africa, Eastern Europe and Southern and Central America (Durand et al., 2009). North America, most of the European Union and Australia have eradicated the virus (Artois et al., 2002; Edwards et al., 2000). It was first diagnosed in 1833 in North America in domestic pigs and first confirmed in wild boar in Germany during 1896 (Kaden et al., 2005).

Due to difficulties in confirming CSF through clinical signs, other potential infections need to be considered during diagnosis (Osterhaus et al., 2009). CSF has clinical signs similar to other diseases including African swine fever (ASF), erysipelas and PRRS. These diseases should be considered during differential diagnosis of pigs in infected areas (Moennig et al., 2003). Moreover, the earlier detection occurs, the greater the likelihood of minimising the size of an outbreak and subsequent economic impacts (Durand et al., 2009). Everett et al. (2010) acknowledged that in some circumstances following virus introduction, it can take up to two months for CSF to be identified as the disease agent. Diagnosis can be hindered by a lack of specific clinical signs in addition to lower virulent strains often having delayed onset of clinical signs. This can be seen from the Netherlands outbreak in 1997–1998 where Elbers et al. (1999) reported a six-week lag period between the time of disease introduction and diagnosis of the primary outbreak.

It is described by Elbers et al. (2002) that across Germany and the Netherlands, 75% or more of CSF cases in the past several years were identified through detection of clinical signs observed by farmers and those working for veterinary authorities. This type of collaborative effort is important to facilitate effective detection and response. However, interviews with pig farmers in the ACIAR Alor Project identified that farmers were unaware of animal health services, did not have access to AHWs that they could report to and were unaware of clinical signs of CSF. In Indonesia, the current mistrust by farmers of the government and a lack of government resources is resulting in underreporting,
misdiagnosis and the limited ability of farmers to identify CSF; all of which hinder detection (Deveridge, 2008; Robertson et al., 2010b).

2.4.2 Forms of CSF
There are several different forms of CSF that affect pigs: acute, chronic and mild forms (Dahle & Liess, 1992).

2.4.2.1 Peracute and Acute Form
For the peracute form, high morbidity and mortality generally occurs between 4–10 days post infection (Dahle & Liess, 1992). There is generally an absence of typical clinical signs followed by sudden death. For the acute form, death usually occurs between 10 and 20 days post infection (Dahle & Liess, 1992). Similar to most pestiviruses, during the acute phase of infection, the virus results in immunosuppression (Moennig, 2000). Clinical signs include fever, anorexia, conjunctivitis, weakness and purple cyanotic discoloration on the abdomen, inner thighs, ears and tail. The acute form is most commonly seen in pigs up to 12 weeks of age and has a high mortality rate, up to 90% (Artois et al., 2002; Moennig et al., 2003; Paton & Greiser-Wilke, 2003). The acute form is associated with the presence of highly virulent strains of CSF but can result from infection with moderate and low virulent strains (Table 2.9) (Durand et al., 2009). Virus is shed in saliva, nasal secretions, urine and faeces and this can begin before onset of clinical signs and continues until death (Iowa State University, 2008; Weesendorp et al., 2009b).

2.4.2.2 Subacute Form
Subacute and chronic forms of CSF are often more prevalent with more recently identified CSF isolates tending to be of lower virulence; classified as moderate or low virulent strains (Animal Health Australia, 2009; Floegel-Niesmann et al., 2003; Mittelholzer et al., 2000). For the subacute form, animals display clinical signs such as lethargy, reduced appetite, stiff walking and constipation (Weesendorp et al., 2009b). Floegel-Niesmann et al. (2003) found that breathing and skin showed no changes until later stages of infection, at 17 days post infection. When pigs experienced fever, the maximum temperature was 40.4°C, not reaching as high as pigs suffering from acute infection (Weesendorp et al., 2009b). Death usually occurs in older pigs between 20 and 29 days post infection (Dahle & Liess, 1992). Recovery is typically only seen with the subacute form (Floegel-Niesmann et al., 2003; Weesendorp et al., 2009a) and recovered pigs can be protected from CSF for up to six months or develop lifelong immunity (Artois et al., 2002). However, pigs that recover can
become carriers, continuing to shed virus. Referring to Table 2.10, it can be seen that for pigs with subacute infection, the highest levels of excretion were detected in nasal fluid (Table 2.10). Levels of excretion however, were lower than pigs with acute and chronic infection. Table 2.9 displays results found by Floegel-Niesmann et al. (2003) following an investigation into the clinical course of different CSFV isolated. Subacute infection occurred in only one pig following infection with a moderately virulent strain. Weesendorp et al. (2009b) conducted an additional study investigating differences between high, moderate and low virulent forms of CSFV. For five pigs inoculated with the 2.1 Paderborn moderately virulent strain, three pigs experienced subacute infection and recovered while the remaining two pigs experienced chronic infection.

Table 2.9
Results obtained from Floegel-Niesmann et al. (2003) providing a summary of the different clinical courses of CSF following infection with different classical swine fever virus isolates.

<table>
<thead>
<tr>
<th>Virus Strain</th>
<th>2.1 (CSF0277)</th>
<th>2.2 (CSF0537)</th>
<th>2.3 (German isolate CSF0634)</th>
<th>2.3 (Spain isolate CSF0123)</th>
<th>1.1 (CSF0902)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of pigs</td>
<td>9</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Acute form</td>
<td>7</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Subacute form</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chronic form</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mortality at end of experiment (%)</td>
<td>100</td>
<td>50</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 2.10
The total amount of infectious virus, quantified by virus titration, excreted during the entire infectious period, with the amount of secretion/excretion standardised to 1g/day or 1 ml/day (urine), table of results taken from Weesendorp et al. (2009b).

<table>
<thead>
<tr>
<th>Virus Strain</th>
<th>Mean total excretion (TCID$_{50}$ standardised to 1g or ml/day) analysed by virus titration</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Oropharyngeal fluid</td>
</tr>
<tr>
<td>Bresica (1.2)</td>
<td>6.54$_{a,b}^{,2}$</td>
</tr>
<tr>
<td>Paderborn (chronic, 2.1)</td>
<td>8.50$_{a,b}^{,1}$</td>
</tr>
<tr>
<td>Paderborn (recovered, 2.1)</td>
<td>4.65$_{a}^{,3}$</td>
</tr>
<tr>
<td>Zoelen (2.2)</td>
<td>2.92$_{a}^{,4}$</td>
</tr>
</tbody>
</table>

SD: standard deviation; \( ^{1-4} \) Means within columns with no common superscript differ significantly (\( P < 0.05 \)); \( ^{a-d} \) Means within rows with no common superscript differ significantly (\( P < 0.05 \)).
2.4.2.3 Chronic Form

The chronic form of CSF has also been associated with virus strains of lower virulence (Floegel-Niesmann et al., 2003; Paton & Greiser-Wilke, 2003). Variations in the literature are seen regarding the course of infection for this form. The majority, however, agree that survival is generally greater than 30 days, potentially up to 100 days (Artois et al., 2002; Dahle & Liess, 1992; Moennig et al., 2003; Weesendorp et al., 2010b). However, infection with this form is usually fatal (Dahle & Liess, 1992; Moennig et al., 2003; Weesendorp et al., 2010b). In a study conducted by Floegel-Niesmann et al. (2003), two pigs suffering with chronic infection died at 39 and 49 days post infection whereas those with acute infection all died within 28 days post infection.

It was reported by Mengeling and Packer (1969) that the course of chronic infection occurs in three phases. The first phase of infection was clinically similar to acute infection although less severe, marked by an increase and then a decrease in the amount of virus in serum. The second phase saw partial recovery of pigs with low or absent virus titres and minimal presentation of clinical signs. Moennig et al. (2003) also suggested this transition to an ongoing or intermittent stage of non-specific clinical signs such as wasting and fever. The final phase saw an enhancement of clinical signs with increasing virus levels throughout the body followed by death. In contrast, Weesendorp et al. (2009b) found that for pigs suffering with chronic infection only mild clinical signs were observed in the first 3–5 weeks such as depression, anorexia and growth retardation. Both pigs experienced fever for an extended duration detected at five days post infection. For one pig, fever lasted 20 days and the second pig experienced intermittent fever up to day 41 post infection. During the terminal phase (6–10 days before death), there was a noticeable change in clinical signs with a staggering gait, hind leg weakness and petechia on the skin observed with both pigs euthanized at 34 and 44 days post infection respectively. Virus can be shed from pigs before onset of clinical signs and continuing until death (Weesendorp et al., 2009b). For pigs with chronic infection, virus can be shed continuously or intermittently for months (Iowa State University, 2008). Weesendorp et al. (2010b) found that pigs with chronic infection pose a very significant risk of spreading disease. In a study comparing high-, moderate- and low-virulent strains, overall, these infected pigs were shown to excrete up to 40,000 times more virus than pigs with acute infection and those that had recovered from the virus. This was taking into account higher titre values from excretions and a longer infectious period.
2.4.2.4 ‘Carrier Sow Syndrome’

‘Carrier sow syndrome’ is generally the result of an adult sow exposed to a low or moderately virulent form of CSF leading to subclinical infection and the potential to produce chronically infected piglets (De Smit et al., 2000; Terpstra, 1987; Van Oirschot, 1979). Sows can shed virus for months before death and can often go unnoticed while infected due to the limited presence of clinical signs (Terpstra, 1987). If present, clinical signs often include fever and decreased feed intake with reproductive loss the most common sign. Depending on the stage of gestation when infection occurs, abortions, mummifications and birth of weak piglets with delayed growth are often seen (Dahle & Liess, 1992; De Smit et al., 2000; Meyer et al., 1981; Van Oirschot, 1979). As CSF is immunosuppressive, death can result due to the virus itself or secondary bacterial infections (Dahle & Liess, 1992; Moennig, 2000).

Persistently infected piglets display constant viraemia with continuous virus excretion (De Smit et al., 2000). Variations can be seen in clinical signs with the majority born in a weakened state (Dahle & Liess, 1992; Van Oirschot, 1979). Van Oirschot (1979) detected only two out of 23 piglets had haemorrhages of the skin, in addition to retardation of growth. Death of piglets generally occurs between two to 11 months after birth (Dahle & Liess, 1992; De Smit et al., 2000). Van Oirschot and Terpstra (1977) found a delayed onset of clinical signs (following retarded growth) in pigs and an average survival time greater than six months making them a risk for potential disease transmission.

2.4.3 CSF Strains and Virulence – The Case of Indonesia

It has been recognised in the literature that there are three different genotypic groups of the CSF virus (Durand et al., 2009; Floegel-Niesmann et al., 2003; Paton et al., 2000). Currently it is understood that those isolated from genotype group 1 are more historical isolates, generally highly virulent (Floegel-Niesmann et al., 2003; Paton et al., 2000). Group 2 is considered to contain isolates that are more recent. Subgroup 2.1 for example was introduced into Europe during the 1990s and was responsible for the 1997–1998 CSF outbreaks in the Netherlands where 429 outbreaks were recorded (Paton & Greiser-Wilke, 2003; Paton et al., 2000). Genotype 3 has only recently been identified, with isolates of this genotype presently confirmed in Asia. There is evidence to suggest that subgroup 3.3 evolved locally in Thailand (Everett et al., 2010). The CSF virus is believed to mutate relatively slowly (Paton & Greiser-Wilke, 2003).
An association between the virulence of a CSF strain and the presence and severity of clinical signs was recognised by Durand et al. (2009). Everett et al. (2010) determined that for low virulent strains, mild disease or asymptomatic infection is most commonly seen, which has the potential to delay disease detection. For highly virulent strains, clinical signs are much more severe and often produce lethal infections (Dahle & Liess, 1992).

Across Asia, all genotypic groups have been identified. Regarding Indonesia, current evidence suggests the presence of groups 1 and 2 (Paton & Greiser-Wilke, 2003; Paton et al., 2000). No genotyping has been conducted on the CSF virus in eastern Indonesia and statements regarding genotypic group present in the literature are based on knowledge of pig movements and clinical courses of disease. It is believed that CSF was introduced to Indonesia from Malaysia (Hutabarat & Santhia, 1999). The subgroups currently identified from Malaysia include 1.1, 1.2 and 2.1 (Frias-Lepoureau & Greiser-Wilke, 2002; Lowings et al., 1996; Paton & Greiser-Wilke, 2003; Paton et al., 2000). Group 2 is a moderately virulent strain and has been confirmed in Thailand, Lao PDR and Malaysia (Dortmans et al., 2008; Lowings et al., 1996; Paton & Greiser-Wilke, 2003). In addition the Timor Animal Health Project (Patrick et al., 1999) stated that based on the field reports of high case fatality rates of CSF in East Timor, a highly virulent strain was suspected.

### 2.4.3.1 Disease Processes of High and Moderately Virulent Strains

Durand et al. (2009) found that the acute course of CSF experienced shorter latent periods of ≤ four days. With a moderately virulent strain, the latent period was found to be six to eight days. Clinical signs for moderately virulent strains have been found to be similar across different studies. Weesendorp et al. (2008a) found that pigs infected with Paderborn strain (2.1) generally developed fever, haemorrhages of the skin, unsteady gait and diarrhoea. In contrast, it was also found that pigs infected with a low-virulent strain did not display fever or clinical signs (Weesendorp et al., 2008a). Floegel-Niesmann et al. (2003) described the differences between pathological and clinical signs when pigs were infected with genotype group 2 of CSF (including subgroups 2.1, 2.2 and 2.3 with an additional highly virulent form of 1.1 for comparison). Only minor differences in the clinical and pathological signs were found between each different virus subgroup for genotype 2. It was genotype 2.2 that displayed the most variable pattern of disease.

Moreover, Mittelholzer et al. (2000) described differences between low-, moderate- and high-virulent strains that support the current literature. Pigs infected with a highly virulent strain experienced severe clinical signs. Pigs infected with moderate- and low-virulent
strains had less severe clinical signs; with no distinct clinical signs detected for the low-virulent strain.

2.4.4 Virus Shedding and Infection

Pigs are generally infected oronasally with the virus multiplying in the epithelial cells of the tonsils (Moennig, 2000; Paton & Greiser-Wilke, 2003; Susa et al., 1992). The virus results in immunosuppression and leukopenia with gross pathological lesions in the form of haemorrhages often on ears and hind legs, with post-mortem examination often revealing pathological changes to the spleen, kidneys and lymph nodes (Moennig et al., 2003; Paton & Greiser-Wilke, 2003; Sanchez-Cordon et al., 2005).

Weesendorp et al. (2010a) identified that the average infectious period for pigs infected with a moderately virulent strain (Paderborn) with high levels of virus excretion (defined as high virus titres for a minimum of 4 days >5.5 TCID\textsubscript{50}) was 32.5 (range: 21.2—51.8) days. For pigs with low levels of virus excretion (defined as low virus titres for a maximum of 3 days >5.5 TCID\textsubscript{50}), the average infectious period was 14.7 (range: 13.2—16.3) days. In acute and subacute infections, the virus is often only shed for a short period of time due to a shorter course of clinical disease. However, for pigs with the chronic form of CSF, the virus is shed intermittently or continually until death (Moennig et al., 2003).

Uttenthal et al. (2003) found that through testing with the Paderborn (2.1) virus strain, virus excretion was initiated with the onset of viraemia. Blacksell et al. (2006) determined viraemia to occur between 3–5 days for the LWC and between 4–10 days for the indigenous Moo Laat pig. In terms of the relationship between clinical signs and virus excretion, the incubation period has been shown to vary between 7–10 days in domestic pigs (Animal Health Australia, 2009; De Vos et al., 2006; Dewulf et al., 2002b). Moreover, the latent period for CSF is 2–8 days (Durand et al., 2009; Laevens et al., 1999), depending on the virus strain.

2.4.5 Age and Breed Associated Factors

In addition to virulence, the age of a pig when CSF infection occurs can impact on the clinical outcome of the disease (Artois et al., 2002; Moennig et al., 2003). Younger pigs tend to have the highest mortality rates, more frequently suffering the peracute and acute forms of the disease (Artois et al., 2002). As pigs age, clinical signs become less specific (Moennig et al., 2003). It has been found that for older pigs with CSF infection, often only
mild clinical and pathological signs will appear, with reproductive failure commonly seen in sows (Colling et al., 2010; Maes et al., 2008).

Breed differences that impact on the course of the disease have been identified in several studies. Depner et al. (1997) found no difference in the susceptibility of German Landrace and Pietrain x German Landrace when inoculated using the German Vibe/Han95 isolate, genetic type 2.3 (Floegel et al., 2000). All purebred pigs experienced the acute form of the disease with a higher average body temperature. Artois et al. (2002) reported that only the acute course of CSF has been described in wild pigs in Germany. The presence of bristles on wild boar can also hinder the identification of clinical signs such as skin haemorrhages. Blacksell et al. (2006) compared the susceptibility of indigenous pig breeds from Lao PDR and a Large White/Landrace cross-breed to CSF infection. This study reported shorter survival periods for exotic cross-breed and a delayed onset of clinical signs for indigenous pig breeds. This study utilised only virus subgroup 2.2 in both breeds. More recently, Everett et al. (2011) investigated CSF susceptibility and transmission in two local African pig breeds to estimate the impact on disease spread within wild populations using a genotype 2.1 CSFV isolate. Both the South African bush pig (Potamochoerus larvatus) and the common warthog (Phacochoerus africanus) were successfully infected under experimental conditions and could transmit disease to in-contact animals of the same species. South African bush pigs developed clinical signs similar to domestic pigs whereas the common warthog remained clinically normal throughout the study, apart from two pigs (one dying from causes thought to be unrelated to CSFV). Studies are yet to be conducted on local pig breeds in Indonesia.

2.4.6 Modes of Classical Swine Fever Transmission

The transmission of CSF is influenced by multiple factors with a variety of potential transmission routes (Ribbens et al., 2004).

2.4.6.1 Horizontal Transmission: Pig-to-Pig Contact

Direct pig-to-pig contact represents the most efficient route for CSF transmission between infected and susceptible pigs (Ribbens et al., 2004). One of the major causes for primary CSF outbreaks in Germany during the 1990s was direct contact between wild boars and domestic herds (Fritzemeier et al., 2000). In countries where CSF is endemic in wild pig populations, wild pigs create a permanent reservoir of disease (De Vos et al., 2006). Young
wild boar are classified as higher risk as they tend to have a wider home range (Paton & Greiser-Wilke, 2003).

2.4.6.2 Vertical Transmission and Congenital Infection

The potential for vertical transmission with CSF has been known for several decades (Van Oirschot & Terpstra, 1977). An early study conducted by Van Oirschot and Terpstra (1977) regarding congenital CSF infection identified that CSFV can result in piglets that persistently shed virus once born. Infection during early stages of gestation generally leads to reproductive losses such as abortion (Dewulf et al., 2001b). A study by Dewulf et al. (2001b) found that mummification and stillborn piglets resulted from sows infected with CSF between days 42 and 67 of gestation. Moreover, Meyer et al. (1981) conducted a study that found sows infected with CSFV between days 68–88 of gestation resulted in the birth of piglets with viraemia. Studies have suggested that persistently infected piglets are more likely to be born when a sow becomes infected during the second trimester (Dewulf et al., 2001b; Ribbens et al., 2004; Van Oirschot, 1979). A pig foetus generally becomes immunocompetent around day 80 of gestation (Salmon, 1984). Consequently, De Smit et al. (2000) suggested a reduction in the potential for persistent congenital infections when sows become infected in the third semester. A study by Van Oirschot (1979) also supported this finding stating that the later a sow becomes infected, the greater the number of uninfected piglets are born. This study investigated congenital infection from eight sows infected with low-virulent CSF at day 40, 65 and 90 days of gestation. Three sows produced litters that were all infected whereas for the remaining five sows, not all piglets were infected. The study found that prenatal mortality was most frequent for sows infected at 40 days of gestation and postnatal death most frequent for sows infected at 65 days of gestation.

2.4.6.3 CSF Virus Survival in Excretory Waste, Soil and Slurry

The CSFV is considered a moderately fragile virus that can have a variable survival time in the environment dependent on environmental factors such as temperature and pH (Barrera et al., 2009; Edwards, 2000). The most recent study, conducted by Weesendorp et al. (2008b), found variations in virus survival in faeces and urine relating to both temperature and virus strain. In faeces, virus survival was found to be longer for highly virulent strains and up to 20 days at an environmental temperature of 20ºC. The higher the temperature, the lower the survival time (Table 2.11). Seasonal influences have also been suggested,
where under winter conditions, longer survival times have been recorded in pens (Harkness, 1985).

The decay rate of CSFV in soil has undergone limited investigation. Estimates for decay rates in soil have been provided by Gale (2004) based on estimates from slurry determined by Haas et al. (1995). Haas et al. (1995) looked at the inactivation of viruses in liquid manure, finding that CSFV could survive for two weeks at 20°C and up to six weeks at 5°C in slurry. Botner & Belsham (2011) found that 14 days were required for the inactivation of CSFV at 20°C. Slurry has been identified as a source of infection for an outbreak of CSF in Catalonia, Spain in 2001–2002 (Allepuz et al., 2007). Allepuz et al. (2007) attributed 5% of outbreak cases to slurry. The source was believed to have been either a contaminated truck used to transport slurry, or land adjacent to a pig farm that was sprayed with slurry.

Table 2.11
Survival of CSFV at different temperatures in faeces and urine derived from pigs infected with the Brescia and Paderborn strain (table results taken from Weesendorp et al., 2008c).

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Virus Strain</th>
<th>Estimated Mean Survival in Faeces (days) ± 95% CI</th>
<th>Estimated Mean Survival in Urine (days) ± 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>Brescia (1.1)</td>
<td>4.8 (1.2–20)</td>
<td>1.8 (0.15–22)</td>
</tr>
<tr>
<td></td>
<td>Paderborn (2.1)</td>
<td>3.5 (0.84–14)</td>
<td>2.1 (0.17–25)</td>
</tr>
<tr>
<td>30</td>
<td>Brescia (1.1)</td>
<td>0.85 (0.20–3.5)</td>
<td>1.4 (0.12–17)</td>
</tr>
<tr>
<td></td>
<td>Paderborn (2.1)</td>
<td>0.61 (0.15–2.5)</td>
<td>1.6 (0.13–20)</td>
</tr>
</tbody>
</table>

1Estimates of the duration of survival of CSFV in faeces during maximum virus excretion (based on Weesendorp et al., 2008c); 2Estimates of the duration of survival of CSFV in urine during maximum virus excretion (based on Weesendorp et al., 2008c).

2.4.6.4 Contaminated Transportation Vehicles

Literature has suggested that contaminated animal transportation trucks are the second most important factor to consider for CSF transmission, following direct pig contact (Stegeman et al., 2002; Terpstra & De Smit, 2000). Detergents and disinfectants based on chlorine and aldehydes can inactivate the virus (Depner et al., 1992; Edwards, 2000). However, if appropriate biosecurity measures are not followed, trucks that have not been disinfected pose a risk for transmission (Dewulf et al., 2000; Stegeman et al., 2002). For disinfectants to work effectively, vehicles need to be cleaned first. Stegeman et al. (2002) estimated transmission rates as high as 0.011 per contact by pig transportation trucks.
2.4.6.5 Virus Survival in Meat and Swill Feeding

Swill feeding has been confirmed as a source of CSF infection for pigs (Edwards, 2000; Fritzemeier et al., 2000). The feeding of untreated swill to pigs is considered a high-risk practice for disease spread and is illegal in many countries including Australia, US, across Europe and New Zealand (Schembri et al., 2010; Valarcher et al., 2008). Swill feeding is of international concern as it can result in the transmission of other diseases including FMD (Schembri et al., 2010). For CSF outbreaks in Germany during the 1990s, it was found that 23% of primary outbreaks resulted from the illegal feeding of swill to domestic pigs (Fritzemeier et al., 2000).

Quick temperature changes have been found to be detrimental to the survival of CSFV (Ribbens et al., 2004). However, the virus is most stable in frozen meat, with recorded survival times of up to four years (Edwards, 2000). Studies have demonstrated that through cooking at temperatures > 65°C, the virus can be inactivated (Edwards, 2000). However, this is dependent on the length of cooking time. Due to the issues of regulating the treatment of swill, it is recommended by Moennig et al. (2003) and Edwards (2000) that a swill feeding ban is the preferred measure for control.

2.4.6.6 Breeding and Artificial Insemination

De Smit et al. (1999) conducted the first study that confirmed that CSFV could be transmitted to sows through artificial insemination. Moreover, it was recognised by Plumiers et al. (1999) during CSF outbreaks between 1997–1998 in the Netherlands that the distribution of semen from two artificial insemination centres resulted in the infection of 36 herds.

Within the smallholder pig sector it is not uncommon for farmers to share breeding boars within a village. This is seen across South-East Asia (Huynh et al., 2007; Lemke et al., 2006) and Africa (Wabacha et al., 2004) and risks transmitting CSF.

2.4.7 Control and Eradication of Classical Swine Fever

Approaches used to control CSF vary between countries with contingency plans and legislation often in place to try to ensure the most appropriate measures for control and eradication (Edwards et al., 2000). For effective selection of appropriate control measures, knowledge of disease incidence and prevalence in the population is important (Moennig, 2000).
For countries that are CSF free, a non-vaccination policy with stamping out is often adopted for eradication in the event of an outbreak in order to eliminate the disease and recommence export markets as quickly as possible given trade losses associated with the use of vaccination (Moennig, 2000). The OIE Terrestrial Code (2012) states that a country is classified free if no vaccination for CSF has been carried out in the previous 12 months and no clinical cases occurred during the vaccination free period. Serological surveillance is often adopted and undertaken in domestic and wild pig herds with a focus placed on regions with high pig density to provide evidence of disease freedom (Edwards et al., 2000; Moennig, 2000). In the Netherlands, the 1997 outbreak took 14 months to eradicate (Terpstra & De Smit, 2000). This outbreak demonstrated the need to follow strict biosecurity protocols during a non-vaccination eradication program. Terpstra and De Smit (2000) observed that movement restrictions between zoned areas of infection resulted in the transmission of CSF to an additional 36 farms from contaminated transportation trucks that neglected basic hygiene.

For countries where CSF is endemic, such as Indonesia and other countries in South-East Asia, control is based on the use of vaccination to avoid serious losses (Edwards et al., 2000; Moennig, 2000). The control measures selected for use by the Indonesian government have focused on pig and pig product movement restrictions and vaccination. The division of the country into infected, suspect, and non-infected areas was established to enable the government to distribute the limited resources available and focus vaccination campaigns on areas with endemic infection (Hutabarat & Santhia, 1999).

The immune response of pigs following vaccination varies depending on vaccine type. Van Oirschot et al. (2003), Blome et al. (2006) and Graham et al. (2012) suggested that the live-attenuated vaccine based on the Chinese strain induces effective immunity between 4–7 days post administration and can result in lifelong immunity. De Smit et al. (2001b) found that protection from clinical infection and a reduction in virus transmission can be achieved at 1–2 weeks after vaccination using a live recombinant vaccine. It is suggested that the earlier vaccination can occur prior to virus exposure, the more effective it can be in protection against infection (Uttenthal et al., 2001). However, even at one day post vaccination, pigs can begin to show partial protection (Graham et al., 2012). Immune response to vaccination has also been found to vary with pig age and sow immunity (De Smit et al., 2001a; Klinkenberg et al., 2002b; Precausta et al., 1983). Studies have been conducted on the impact of vaccinating sows and the corresponding protection in
vaccinated piglets from immune sows. Precausta et al. (1983) found that when using the CSF Chinese strain vaccine, piglets could be vaccinated as early as seven days old, if born from non-vaccinated sows. Due to the influence of maternally derived antibodies (MDAs), protection in piglets can extend beyond two months depending on the time a sow is vaccinated prior to gestation (Klinkenberg et al., 2002b; Precausta et al., 1983). It was found that piglets born from sows vaccinated ten months prior to farrowing, vaccination could occur as early as five weeks without significantly affecting antibody titres. Klinkenberg et al. (2002b) determined that for piglets born from vaccinated sows and vaccinated with the E2 marker vaccine at two weeks of age, maternal immunity in piglets reduced vaccination-induced antibody levels at both three and six months of age. Moreover, it was suggested that this led to less effective protection against virus transmission after six months. Vaccine trial studies have been conducted with weaners (Uttenthal et al., 2001) and sows (Depner et al., 2001) using marker vaccines. Both age groups experienced increased protection from clinical disease and virus shedding, but this was not complete.

Recent vaccine developments have seen the use of marker vaccines with companion diagnostic tests to assist in distinguishing between vaccinated and infected pigs (Uttenthal et al., 2001). The use of live attenuated vaccines produces antibodies that do not allow differentiation between infected and vaccinated animals (Beer et al., 2007; Koenig et al., 2007a). Thus the development of novel marker vaccines has greatly assisted CSF diagnosis and their implementation in CSF outbreaks can reduce pre-emptive large scale culling and the associated ethical, economic and welfare related concerns (Beer et al., 2007). In a challenge with weaner pigs, Uttenthal et al. (2001) found that marker vaccine efficacy was best when used three weeks before virus challenge, reducing the severity of clinical signs such as fever. Additional studies have investigated the use of marker vaccines in sows (Ahrens et al., 2000; Depner et al., 2001; Dewulf et al., 2002a). Ahrens et al. (2000) found that the Porcilis® Pesti vaccine, a subunit marker vaccine, resulted in protection of 90% of litters from CSF infection when sows were challenged with a low virulent strain during mid-gestation. In contrast, Dewulf et al. (2002a) concluded that a double dose of vaccine Porcilis® Pesti only protected pregnant gilts from the clinical course of CSF and did not prevent horizontal or vertical spread of CSFV. This study challenged the animals with a moderately virulent strain of CSF. Additional studies have also been conducted examining the use of oral bait marker vaccines in wild boar populations due to the risks they pose as a CSF reservoir (Koenig et al., 2007b).
In order to eradicate CSF from a pig population, transmission of the virus needs to be reduced to an extent where it can no longer survive and be maintained within the population (Schnyder et al., 2002; Weesendorp et al., 2010a). For eradication programs to be effective they need to incorporate several components. Animal movement management and quarantine periods are important to aid in the containment of an epidemic, allowing the disease to be concentrated in specific areas (Edwards et al., 2000; Moennig, 2000). A simulation model developed by Velthuis and Mourits (2007), was used to investigate the effectiveness of movement-prevention regulations to reduce FMD spread among cattle in the Netherlands. A reduction in epidemic size was simulated; however, it was recognised that the use of movement regulations is more effective in sparsely populated areas due to the impact of localised spread in densely populated areas.

As part of stamping out, culling and pre-emptive slaughter can be used for both infected herds and those suspected of being infected, often utilising a trace back and trace forward method (Edwards et al., 2000; Moennig, 2000). Control zones should be established around infected properties (3km radius) followed by an additional surveillance zone at 10km (Edwards et al., 2000). For countries that elect to implement vaccination, it was found (Backer et al., 2009) that implementing a vaccination ring of 2km around an infected source was just as effective as ring culling within a 1km radius. Moreover, the use of vaccination is often more acceptable to the general public with ethical issues arising from large-scale culling (Klinkenberg et al., 2003). Regulation of swill feeding is also important during outbreak response and then subsequently to prevent re-introduction (Edwards et al., 2000).

The use of biosecurity is imperative in disease prevention and control (Pinto & Urcelay, 2003; Roman et al., 2006). The Food and Agricultural Organization (FAO) defines biosecurity as ‘the implementation of measures that reduce the risk of the introduction and spread of disease agents; it requires the adoption of a set of attitudes and behaviours by people to reduce risk in all activities involving domestic, captive/exotic and wild animals and their products’. Although biosecurity has been readily accepted in many countries in the pig sector, there are still limiting factors hindering the adoption of these measures in South-East Asia (Windsor, 2011). For developing countries, three key parameters - access to resources, affordability and acceptability - have been identified as imperative when trying to implement animal health interventions (Heffernan et al., 2008). Limited access to resources and the need for farmer education in adopting these practices have been
recognised in the literature (Nampanya et al., 2011; Windsor, 2011). Measures such as not trading sick animals, avoiding swill feeding, cleaning and disinfecting, and proper carcass and waste disposal are key components that should be implemented in educational programs (FAO, 2010).

### 2.5 Animal Movement and Disease Spread

#### 2.5.1 Introduction

With rapid urbanisation, population growth and the intensification of livestock production, trade in live animals has become a greater contributor to global human and animal health issues (Zinsstag et al., 2011). A study by Noremark et al. (2011) found that a key component for the transmission of contagious animal diseases between farms is live animal movement. Between-farm linkages vary greatly with regard to farm/production type, farm size and herd size. To enable disease transmission there must be a direct or indirect contact that can transfer viable pathogens (Brennan et al., 2008). Farms in close proximity to one another have a greater likelihood of being connected through parameters such as direct farm-to-farm movement or sharing equipment (Brennan et al., 2008). In Vietnam, receiving pigs from an external source was found to be a risk factor associated with the occurrence of porcine high fever disease (PHFD) (Le et al., 2012). Mangen et al. (2002) recognised that a reduction in off-farm transport contacts resulted in the reduced spread of CSF infection in high pig density areas in the Netherlands.

Many countries have chosen to regulate animal movements in order to lessen the transmission potential for animal disease, making it a requirement for all animals to be registered and individually identified. This has allowed for, in some cases, lifetime traceability from farm to slaughter (Caja et al., 2005; Noremark et al., 2011). The identification of pigs going for sale or slaughter is crucial to ensure traceability that will permit on-farm control action in the event of identification of a public health risk related to pork products or an exotic disease incursion (McKean, 2001; Stark et al., 1998). Farrow-to-finish pig operations, for example, have been considered to present the lowest risk of disease spread as the only movement of these pigs is from the farm to the slaughterhouse. Additionally, the use of identification such as ear notching, ear tagging, tattooing and electronic devices, is often sufficient to trace pigs from the slaughterhouse back to the farm (Madec et al., 2001). Moving pigs between multiple premises at different stages of production can present a greater risk for disease spread (Madec et al., 2001). In Australia,
for example, the current system requires batch identification of pigs from farm to slaughter to facilitate a traceback scheme. The Pig Pass National Vendor Declaration (NVD) form is required for all pig movements and involves both the government and Australian Pork Limited (Taylor & Evers, 2009).

2.5.2 Movement Pathways and Transportation in NTT

Little is currently known about pig movement patterns across NTT province. Basic understanding suggests that there are both formal and informal movement pathways: formal defined as movements through a registered live animal market, and informal defined as movements directly between farms (Geong M. pers comm, 2011; Johns et al., 2009). Similar types of systems have been identified in other smallholder farming sectors in developing countries. In Tanzania livestock are traded either officially, through markets where sellers are taxed, or through livestock traders visiting farmers’ households directly (Kivaria, 2003). A study by Madin (2011) found that price can be used as a predictor for animal movements in the Greater Mekong Subregion.

Informal animal trade is known to be a risk factor for disease spread as animals are not necessarily subject to veterinary checks (Fevre et al., 2006). In Somalia up to 850,000 goats are informally moved annually to the Middle East, accounting for >95% of goat exports from Africa (Fevre et al., 2006). Economic forces are driving the informal trade of animals and animal products leading to widespread movement over often large distances (Van Kerkhove et al., 2009). A study by Cocks et al. (2009) found that informal movement of livestock still dominates cross-border movement throughout the Greater Mekong Subregion. Trading animals informally allows tax payments that would be incurred during transportation and market entry to be avoided (FAO, 2010; Roland-Holst & Frielink, 2009). It is not uncommon for farmers to trade pigs as soon as disease is suspected to avoid income loss (FAO, 2010). Bragg (2007) identified that animal trade to Alor island was unregulated and unrecorded with animals brought to Alor by private boat; bypassing quarantine inspection. Movement restrictions have been put in place by the Indonesian government, which include a ban on moving pigs from infected to non-infected CSF areas. However, movement regulations are rarely enforced and extremely difficult to control (Brandenburg & Sukobagyo, 2002; Geong M. pers comm, 2011). It is the responsibility of PLS to control intra-provincial livestock movements with the assistance of the quarantine services in NTT (Brandenburg & Sukobagyo, 2002). Moreover, when pigs are moved, farmers need to obtain quarantine and health certificates for movements between districts.
and islands, which require Dinas Peternakan approval (Geong M. pers comm, 2011). Due to such costs, farmers are driven to move pigs informally without proper authorisation (Geong M. pers comm, 2011; Roland-Holst & Frielink, 2009).

Quarantine in NTT is governed by the Indonesian Agricultural Quarantine Agency (IAQA), a branch of the Ministry of Agriculture that works in collaboration with the PLS. The main focus of the IAQA is on both animal and plant pests and diseases. Subdivisions, including the centre for animal quarantine and animal biosafety, animal product quarantine division and animal biosafety division, assist in the development of policy and work in conjunction with a functional group to allow implementation and monitoring in the field (IAQA, 2012). Due to the hierarchical structure of this branch, information primarily flows from the IAQA to the PLS, further allowing communication between the DLS with the PLS to ensure all necessary parties are informed of developments in policy and activities in the field. It is the responsibility of the DLS to ensure communication with farmers to inform them on any policy that may affect them. In regards to pig movement regulations, the restrictions on pig movement between infected and non-infected areas is known down to the level of the DLS (Geong M. pers comm, 2011). Communication between villages and government agencies has been a long standing issue in this area of Indonesia, particularly in more remote areas (Robertson et al., 2010a). A survey by Roberston et al. (2010a) on Alor reported some farmers being unaware of any movement regulations for live pigs.

### 2.5.2.1 Known Formal Movement Pathways

Across the province both road and ferry transportation are utilised to transport people, animals and goods (Patunru et al., 2010). In many regions across Indonesia, poor road infrastructure affects villages (World Bank, 2006b). In Kabupaten Manggarai, for example, due to the high rainfall, road degradation due to erosion is commonly experienced (World Bank, 2006b).

Ferry movements are an important transportation method for NTT (Patunru et al., 2010). They facilitate the movement of live animals and products around islands both within and outside the province. The formal ferry ports identified across the province can be seen in Figure 2.6. Smaller informal ports also exist across the province; however, their locations have yet to be documented (Geong M. pers comm, 2011).
2.5.3 Role of Livestock Markets in Disease Spread

The ability to trade animals is vital to the livelihood of livestock producers and live animal markets play an important role in this trade (Brennan et al., 2008; FAO, 2010). Live animal markets have been recognised as mixing points along a market chain representing a source for disease spread (FAO, 2010). In a market environment, the transmission of CSF due to the accumulation of pigs from a variety of sources in a single location has long been recognised as a dangerous practice (Beals et al., 1970). Traditional live animal markets in NTT are an important trade route along the live pig market chain and are crucial to meet consumer demand (Johns et al., 2009). Ortiz-Pelaez et al. (2006) investigated animal movement networks and determined that for an outbreak of FMD to be contained, market premises are primary locations to focus on. Further, the aggregation of livestock owners at live animal markets means they are useful locations to disseminate information to local farmers (FAO, 2010).

2.5.3.1 Market Locations in NTT

Appendix 1 provides a list of markets across West Timor, Flores and Sumba that trade live pigs. These are the only available data for markets on these islands and were collated from data collected from DLS across the province. Table 2.12 provides a summary of the number of markets recorded for each district. It should be noted that no market list was available at the initiation of this research project and its development required contact with
each DLS office to obtain this information. Moreover, it is likely that this list is not complete with several districts having few to no markets recorded.

Table 2.12
The number of markets on West Timor, Flores and Sumba that trade live pigs, Nusa Tenggara Timur, eastern Indonesia, information obtained from District Livestock Services (2011) (Further details in Appendix 1).

<table>
<thead>
<tr>
<th>Location</th>
<th>District</th>
<th>Number of Markets Trading Live Pigs</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Kab. Kupang</td>
<td>3</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>TTS</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTU</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Belu</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Flores</td>
<td>Flores Timur</td>
<td>0</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Sikka</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ende</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Nagekeo</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ngada</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manggarai Timur</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manggarai</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manggarai Barat</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sumba</td>
<td>Sumba Timur</td>
<td>1</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>Sumba Tengah</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sumba Barat</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sumba Barat Daya</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

2.5.4 Social Network Analysis and Disease Spread

Social network theory suggests that individuals are incorporated into a web of social relations and interactions (Borgatti et al., 2009). By investigating networks, an understanding can be developed regarding the contacts within these networks and potential movement pathways for individuals or animals (Borgatti et al., 2009; Dubé et al., 2009).

By the 1980s the use of social network analysis (SNA) had become an established field in the social sciences (Borgatti et al., 2009). Its ability to be applied in a variety of contexts led to its use in an animal health investigating live animal movements in association with disease spread (Borgatti et al., 2009; Dubé et al., 2009; Kiss et al., 2006; Webb, 2005). By
determining contact patterns and identifying central locations for animals mixing along a market chain, it is possible to estimate the extent of an outbreak (for example in terms of the number of affected farms) and to identify locations where implementation of surveillance and mitigation measures would be most effective (Christley et al., 2005; Natale et al., 2009).

A network is generally composed of nodes (units of interest such as a location or individual) that are connected by ties representing the relationship between a pair of nodes (Dubé et al., 2009). Nodes can have attributes such as location type, species and geographical features (Dubé et al., 2009). The ties connecting pairs of nodes are referred to as edges (if undirected) and arcs (if directed). When ties are undirected, movement can occur in both directions (Martínez-López et al., 2009b). Directed movement provides a greater level of understanding about the relationships and flow between nodes (Christley et al., 2005; Dubé et al., 2009). Figure 2.7 is an example of a network incorporating livestock markets and cattle farms in the United Kingdom (UK) (Shirley & Rushton, 2005a). It is demonstrated that market locations tend to have a larger number of contacts within a network in comparison to individual farms. Moreover, ties within this network are directed, demonstrating the potential flow of disease through the network. Within this network, all markets are connected through other nodes. Sections of a network that are isolated and not connected to the entire network are referred to as components (Dubé et al., 2009).
Figure 2.7
Network of the 2011 foot-and-mouth disease epidemic in the UK. Nodes consist of livestock markets (labelled) and farms (remaining nodes without labels); arrows indicate route of infection; image taken from Shirley & Rushton (2005a).

The use of SNA also allows the calculation of parameters that can provide further information on the contact structure and topology within a network.

**Network centrality**: aims to identify ‘important’ nodes, investigating their position within the network (Christley et al., 2005; Martínez-López et al., 2009b). A measure of centrality is made up of several different measures including:

1) Degree centrality: this measures the sum of contacts made by a node. An in-degree calculation is the number of contacts a node received. An out-degree value is the number of contacts leaving a node (Christley et al., 2005; Dubé et al., 2009). In the network displayed in Figure 2.8 a star type network is used as an example where Market 1 has an in-degree value of three and an out-degree of four.
2) Betweenness centrality: this is a measure that provides an estimate of the probability that the shortest path between any pair of nodes within a network passes through a particular node (Martínez-López et al., 2009b).

3) Closeness centrality: this is a measure that estimates how closely connected nodes are to other nodes within a network, taking into account ingoing and outgoing arcs (Martínez-López et al., 2009b).

4) Cut-points: are nodes within a network that if removed will result in an increase in the number of components within a network. This measure is obtained through observation of a network rather than by making calculations. These are important to consider when assessing pathways for disease transmission and locations for mitigation measures (Dubé et al., 2009).

Network size measurements: These measurements provide information on the overall network structure.

1) Number of nodes.

2) Number of directed links: this is a measure that identifies the total number of connections between nodes (Aznar et al., 2005).

3) Size: this is a measure of the total number of nodes and contacts constituting the network (Martínez-López et al., 2009b). It is calculated by the number of nodes $i$ multiplied by $i$ minus 1.

4) Diameter: this measure is defined as the longest distance between two nodes. In the network displayed in Figure 2.9 the diameter is equal to four as connections are present from node A to node D consecutively.
Figure 2.9
Artificial network to illustrate diameter network calculations.

**Measures of Cohesion**

These measurements describe:

1) Network density: this measures the extent of contacts between pairs of nodes within a network (Martínez-López *et al.*, 2009b). It is calculated based on the proportion of all contacts that could be present that actually are (Aznar *et al.*, 2005).

2) Geodesic distance: is the shortest path length between two nodes (Christley *et al.*, 2010; Dubé *et al.*, 2009).

3) Geodesic distribution: is the distribution of frequencies of geodesic distances (Christley *et al.*, 2010).

In animal health, SNA investigations of live animal movements and of individuals involved in their movement are used to identify high-risk locations for disease spread or individuals involved in the movement of potentially infected animals (Christley *et al.*, 2005). The ability to weight the edges that connect nodes is an important feature to consider in these investigations (Borgatti *et al.*, 2009). Weightings such as volume of live animals and frequency of movements provide essential information on the risk associated with different movement pathways. For example, in Figure 2.10, Village A within a network has only one connection to a live animal market, Market 1. However, in comparison to villages B and C, which bring animals to Market 1 and Market 2, Village A is bringing a larger number of pigs to the marketplace. Therefore, Village A should also be considered as a risk for disease dispersal even though it does not have as many market contacts.
Following the introduction of the Single European Act (1987) in the European Union (EU), live animals including cattle, pigs, sheep and goats, could move freely between EU member countries (McGrann & Wiseman, 2001). Outbreaks of FMD, CSF and bovine spongiform encephalopathy (BSE) during the 1990s demonstrated the potential harm of livestock movements to neighbouring member states and instigated the development of national databases to record animal movements (Dubé et al., 2009; Noremark et al., 2011). This has enabled investigations into contact networks and has supported the development of effective surveillance and strategic planning in emergency animal disease preparedness for outbreak control (Noremark et al., 2011). This technique has also enabled the tracing of animals to assist in outbreak control (Dubé et al., 2009; Kao et al., 2007). However, in many developing countries, data on live animal movements is minimal and often not recorded (Fevre et al., 2006; Van Kerkhove et al., 2009).

A study conducted by Van Kerkhove et al. (2009) investigated live poultry movements in Cambodia in relation to avian influenza surveillance and control. With limited data available and minimal understanding of the poultry market chain, a cross-sectional study surveyed individuals moving poultry. These consisted of rural villagers (715 individuals), market sellers (123 individuals) and middlemen (139 individuals). A total of 20 villages per province were represented from six selected provinces (out of 24). This type of approach could be applied to areas that are data poor. However, limitations of this approach need to be considered such as by not including all markets across the country, only a partial network was analysed. This can lead to a bias towards those areas that were selected for inclusion in the study with source and destination locations only being reported in association with selected locations. Moreover, some middlemen were interviewed more than once, which may have influenced the frequency with which locations were reported. These limitations need to be kept in mind when interpreting
results. However, in countries where animal movement knowledge is minimal, these types of studies can provide a basic understanding to inform and guide decision making for control strategies.

An additional SNA study by Stevenson (2008) was conducted on poultry movement in Bali. However, this study was limited to movement data from only one live bird market. By incorporating as many markets within a network as possible, better understanding about the distances live animals travel and potential locations for disease spread can be obtained.

### 2.6 Risk Assessment Methodologies

#### 2.6.1 Risk Analysis Introduction

Risk analysis is the process of estimating the probability and impact of a particular risk, such as pathogen transmission, to allow approaches to risk reduction to be evaluated (Murray et al., 2004). An internationally accepted process to conduct an import risk analysis for animal disease has been developed by the OIE (Murray et al., 2004). It consists of four stages: hazard identification, risk assessment, risk management, and risk communication (Figure 2.11).

![Figure 2.11](image_url)

**Figure 2.11**
Stages of the OIE risk analysis process (OIE Handbook, 2004).

Hazard identification is the necessary first phase of a risk analysis to identify the hazards with the potential to induce adverse effects. The next phase, a risk assessment, is composed of four different stages (Figure 2.12). The first stage is a release assessment that identifies pathways through which a particular hazard may enter an environment, and assess the likelihood of this occurring. An exposure assessment focuses on an evaluation of the pathways by which an animal or human may become exposed to a hazard, and the
likelihood of that happening. The consequence assessment describes the likelihood of a potential outbreak scenario to occur and the direct and indirect consequences of the outbreak scenario resulting from pathogen exposure. Direct consequences include mortality and morbidity while indirect consequences are factors such as the environment and the economy. The final stage is risk estimation where release, exposure and consequence estimations are integrated to produce an overall measure of risk associated with the hazard (OIE Handbook, 2004).

The OIE developed and documented the import risk analysis process to provide countries with an objective method to enable the risk of disease to be evaluated in association with ‘importation of live animals, animal products, animal genetic material, feedstuffs, biological products and pathological material’ (OIE Handbook, 2004). Due to its structure and ability to be applied to a range of hazards, it has a wide application to assist in the field of animal health.

The use of qualitative and quantitative risk assessments can be applied under different circumstances depending on the availability of data and knowledge of the hazards and potential pathways for introduction. Defined by the OIE, a qualitative risk assessment is ‘where the outputs on the likelihood of the outcome or the magnitude of the consequences are expressed in qualitative terms such as high, medium, low or negligible’. In contrast, a quantitative risk assessment is where the outputs are expressed numerically (OIE Handbook, 2004).

### 2.6.2 The Application and Use of Quantitative Risk Assessment

A risk assessment is a tool that enables statistical and scientific data to be used to extrapolate values that provide an estimate of the risk associated with a particular activity or event (Thrusfield, 2007). The results can guide decision making to improve surveillance and control strategies while also assessing impacts of preventative measures on disease spread (De Vos et al., 2006; Weiland et al., 2011).

An example can be seen in a study by Martinez-Lopez et al. (2008) who conducted a quantitative risk assessment to investigate the introduction of FMD into Spain via live animal imports. This study estimated that the probability of FMD virus being introduced into Spain was more likely to occur from the importation of live pigs as opposed to cattle, sheep and goats. The study further demonstrated that by using a quarantine period for all live pigs prior to entry into Spain, the probability of FMD virus introduction was reduced
to 50%. Studies such as these demonstrate the important role that risk assessment can have in guiding and assisting decision making on mitigation strategies to control a variety of animal diseases.

### 2.6.3 Modular Process Risk Modelling

#### 2.6.3.1 Methodology

A modular process risk model (MPRM) is based on a quantitative microbial risk assessment (QMRA) and is a tool for a quantitative exposure assessment that can also support evaluation of risk mitigation strategies (Nauta, 2001). It has a unique modular structure that enables a pathway or market chain to be divided into processing steps. Due to this structural feature and ability to adapt the model to a pathway, this method was selected to conduct the exposure assessment presented in this thesis. This method has predominantly been used in the food processing industry, with studies investigating the risk of products becoming contaminated through processing stages. Products such as milk (Clough et al., 2009), ground beef (Cassin et al., 1998), and broiler meat (Nauta et al., 2007), have utilised this method. This type of model evaluates the transmission of a hazard along a pathway by focusing on changes in prevalence and concentration of the hazard and product at each step of the pathway (Figure 2.12; Nauta, 2008). It provides a structured approach that can be applied in a variety of contexts to quantitative food chain risk assessments (Nauta, 2008). Clough et al. (2009) recognised that this approach is appropriate where a pathway divides naturally into a series of modules.

![Figure 2.12](image.png)

**Figure 2.12**
The modules in a modular process risk model demonstrating the changes in prevalence ($P$) and proportion of microorganisms per unit ($N$) in a process step, image from Nauta (2008).

The steps for a MRPM are described by Nauta (2008) and summarised below:

1. The first step involves the identification of both the product, such as a live animal or food, and the hazard presenting risk such as a pathogen or residue.
2. A pathway should be divided into processing steps termed modules. For each module there is an input–output relationship for the amount of product ($N$) and the prevalence of the hazard (what proportion of the product is contaminated) ($P$). $N$ is considered as an integer with whole numbers used in order to represent a living organism rather than fractions of a unit of product. This allows $N$ to change size (for example grouping together units of product into a single consignment) or to become infected. The model quantifies the risk of contamination at each module along the pathway by producing two outcomes from each module, $N_{\text{out}}$ and $P_{\text{out}}$, which are then used consecutively along the pathway to provide a final risk estimate for the amount of contaminated product and the prevalence of the hazard (Figure 2.12).

3. Risk mitigation identification
This type of model approach allows mitigation measures to be evaluated. The mitigation strategies can either be incorporated into a module or introduced into a model as a separate module. This then allows baseline information to be generated from the model with the exclusion of mitigation measures. Following this stage, mitigation measures can then be included to assess their impact on output parameters. For example, Nauta (2001) suggested the incorporation of a removal module to allow an inspection process to be simulated, which involved the removal of units considered to be contaminated. Figure 2.13 illustrates the process of inspection being added to a model. It can be used, for example, when fruit is blemished and needs to be removed (Nauta, 2001) or when infected animals are displaying clinical signs (Roche et al., 2011).

![Figure 2.13](image.png)

The removal process in a modular process risk model, contaminated units (marked ‘c’) are removed with a higher probability than units not contaminated. This process is generally based on visual contamination of a product such as inspection to remove animals with clinical signs or fruit with blemishes, Image from Nauta (2008).

4. According to the model structure, all relevant input data needs to be obtained. It is at this stage that input parameters can be assigned probability distributions to account for
variability. This can be done using a Monte Carlo simulation approach suggested by Nauta (2008).

5. Select data for appropriate scenarios to run in the model. A modular approach allows different scenarios to be run enabling comparisons between baseline results and the impact of mitigation measures (Nauta, 2001; Nauta et al., 2007).

### 2.6.3.2 Application and Use in Animal Health and Biosecurity

To our knowledge, only one study has applied this technique to an animal market chain. This study assessed the risk of highly pathogenic avian influenza H5N1 spread along the live bird market (LBM) chain in Bali, Indonesia (Roche et al., 2011). This approach was used because the market chain was easily divided into modules where inputs were added at each module level to quantify the level of risk at stages along the pathway. Figure 2.14 illustrates the modules that the pathway was divided into. The use of inspection was found to reduce the level of contamination at LBMs with a reduction in the number of infected birds entering a market.

Limitations can be encountered when applying results from these types of models. Mitigation measures such as inspection and vaccination can be evaluated for their effectiveness in a scenario-based approach. However, when implemented in the field, in places such as Indonesia, inspection in a market environment is challenging and vaccination resources are minimal (Brandenburg & Sukobagyo, 2002). Therefore, other issues aside from model results need to be considered when looking at the application of mitigation strategies.

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**Figure 2.14**

Live bird market chain used in a modular risk model, adapted from Roche et al. (2011).
2.6.4 Monte Carlo Simulation

Monte Carlo simulation is an approach that allows probability distributions to be placed around input parameters to account for uncertainty and data variability. The use of probabilistic techniques such as Monte Carlo analysis have greatly improved the quality of risk assessments (Nieuwenhuijsen et al., 2006). Monte Carlo simulation involves the random sampling of a probability distribution to produce thousands of different scenarios in accordance with the shape of a distribution (Vose, 2008). Uncertainty can be defined as a lack of perfect knowledge of a parameter value (Vose, 2008). This can be improved by increasing sampling measurements and can be accounted for by using a probability distribution to provide a range in which the most likely value should fall. Variability is defined by Nauta (2001) as the ‘true heterogeneity of a population that is a consequence of the physical system’. It cannot be reduced by additional measurements (Vose, 2008).

Monte Carlo simulations can be done through the use of programs such as @Risk Software (Palisade Corporation, USA) and PopTools (Hood, 2011). @Risk is a software add-on to Microsoft Excel (Microsoft Corporation, Redmond, WA, USA), which makes it a useful tool (Nauta, 2001). Its application to a modular model allows the model structure to be developed in Microsoft Excel and probability distributions to be applied to appropriate input values. There are many different types of probability distribution to suit the characteristics of different parameters, the quality of fit of data to a distribution and the process being modelled (Nauta, 2001). It is necessary to select the most suitable distribution type for each parameter to generate appropriate output.

There are limitations that need to be considered when running simulation models. Both variability and uncertainty of input parameters and model assumptions can impact on the model’s output (Clifford et al., 2011; Harvey et al., 2007). If a model is developed without considering all potential pathway movements or environmental factors that impact input parameters, this can lead to results that are not applicable to real-world situations. Clifford et al. (2011) suggested that focus should be placed on the trends observed within the results to give an indication of baseline levels and the effectiveness of mitigation measures.
2.7 Animal Disease Surveillance and Wild Pigs in Northern Australia

2.7.1 Wild Pigs and their Role in Disease Spread

Wild pigs are an invasive pest species in Australia, which have a detrimental impact on agriculture production, ecosystem integrity and public health (Cowled et al., 2009; Spencer et al., 2005). Literature supports the role that wild pigs may play as disease reservoirs or maintenance hosts for animal diseases such as ASF, PRRS, CSF, brucellosis, FMD and pseudorabies (Costard et al., 2009b; Twigg et al., 2005; Wyckoff et al., 2009). The contact within wild pig herds and between wild and domestic livestock is of concern due to the potential for introduction or reintroduction of exotic, emerging and endemic diseases. Wild pig contact is of particular concern for domestic pig herds due to the species-specific nature of infectious diseases such as ASF, CSF and PRRS. Recent studies by Wyckoff et al. (2009) and Pearson (2012) suggest that contact between wild and domestic pig herds in the United States (US) and Australia is possible, with pigs coming within 100m of piggeries. It is important to understand dispersal patterns and social interactions of wild pigs to inform and guide decision making for disease control.

A study by Twigg et al. (2005) investigated wild pig populations in north-western Australia. They found that common gathering locations such as water sources and grazing land posed risks for disease spread between cattle and wild pigs. Moreover, they recommended wild pig population reductions of > 70% to > 90% are necessary for the effective control of exotic diseases.

The spread of CSF through wild pig populations has been documented (Fritzemeier et al., 2000; Rossi et al., 2005). Fritzemeier et al. (2000) demonstrated that during CSF outbreaks in Germany during the 1990s direct and indirect contact of wild boars with domestic herds was the primary route of transmission. Research has been conducted on wild pig populations within Australia to improve our understanding of their distribution, abundance and genetics, and to help inform decision making in the event of a disease incursion (Cowled et al., 2008; Cowled & Garner, 2008; Cowled et al., 2012; Cowled et al., 2009; Spencer, 2006; Spencer et al., 2005). The risk of disease spread is both between wild pig herds and between wild pigs and domesticated animals where contact can result in disease transmission.
2.7.2 Wild Pig Distribution in Australia and Risk from Indonesia

The close proximity of eastern Indonesia to Australia presents a risk for CSF introduction. The vast northern Australia coastline is vulnerable to potential introduction of exotic diseases and pests through the presence of multiple entry pathways. These include contaminated fomites such as transportation vehicles and people, and via live pigs and contaminated pork products with informal boat movements (East et al., 2008; Fevre et al., 2006). Australia eradicated CSF in 1961 following outbreaks in 1902, 1917, 1927 and 1942 (Animal Health Australia, 2009). Entry points considered dangerous were sea ports and the city of Sydney (Edgar, 1946). Australia has since established and implemented biosecurity policies through investments in pre-border, border and post-border strategies. Pre-border disease control strategies have been developed including the Northern Australia Quarantine Strategy (NAQS) (AQIS, 2005), a component of AQIS, research through ACIAR, and AusAID work in rural development to strengthen veterinary services. Post-border strategies, including regulations on swill feeding and compulsory batch level pig identification, are further minimising the potential for disease spread. Furthermore, continued research into wild pig herds in Australia, utilising methods such as simulation models (Cowled et al., 2012) and risk assessments, can help guide decision making for the development of appropriate mitigation strategies. As an important component of preparedness, Animal Health Australia (AHA) has developed the Australian Veterinary Emergency Plan for classical swine fever (Animal Health Australia, 2009) to provide contingency plans in the event of an outbreak. This document outlines control and eradication policies and recommends movement control and quarantine options.

Wild pigs are distributed predominately across northern Australia with concentrated populations in north-eastern and north-western Australia (Figure 2.15). A study conducted by Cowled et al. (2009) aimed to predict future distributions of wild pig populations with the understanding that this knowledge could assist biosecurity planning and inform control efforts. It was recognised that due to the presence of a sea port in Broome receiving international shipping traffic, there would be an increased risk for disease introduction if wild pig populations established themselves around Broome.

Surveys are conducted by NAQS to investigate high-risk animal and plant diseases and plant pest species across coastal areas of northern Australia, from Cairns to Broome, and in the islands of neighbouring countries that surround Australia, including Papua New Guinea, East Timor and eastern Indonesia (Waterhouse, 2003; Weinert et al., 2004).
recent years focus has been placed on East Timor due to an increase in civilian and military traffic to Australia posing a risk for disease or pest introduction (Weinert et al., 2004). Tourism and mining are additional factors that have increased in recent years that have the potential to influence disease spread to northern Australia. Other independent studies have investigated risks for H5N1 introduction into Australia due to migratory bird movements from South-East Asia (East et al., 2008). A study by East et al. (2008) identified Cape York and Cairns as the greatest risk areas for introduction of HPAI H5N1 from nomadic waterfowl movement. Studies need to be conducted on pig movements in eastern Indonesia to provide information regarding the potential risk for CSF reintroduction into Australia.

Figure 2.15
Wild pig distributions across Australia, image taken from West (2008).

2.7.3 Surveillance Methods for Disease Detection

The OIE defines surveillance as ‘a systematic ongoing collection, collation, and analysis of information related to animal health and the timely dissemination of information to those who need to know so that action can be taken’. It was recognised by Thompson et al. (2003) that for surveillance of exotic diseases to be effective it needed to involve activities
on a regional level with collaboration among neighbouring countries for appropriate protection of both trade and animal and public health. The ability of surveillance programs to act as early warning systems can allow resources to be allocated appropriately for effective control (East et al., 2008). Knowledge of diseases in wildlife populations is limited by a lack of information on species abundance, limited access to populations at risk and challenges in observing susceptible populations (Thulke et al., 2009). This in turn limits the adaptation of livestock surveillance programs to wildlife populations. These findings are supported by Nusser et al. (2008) and Thulke et al. (2009): in the case of wildlife disease, a more situation-based approach is needed for wildlife populations as using standard surveillance activities designed for livestock can lead to suboptimal outcomes due to implementation of inappropriate sampling techniques, and wasted resources and time. The ability to detect and delineate infection following a disease incursion is vital to control and eradicate it in livestock and wildlife populations.

Passive and active forms of disease surveillance are presently used to monitor a variety of human and livestock diseases (Hadorn & Stark, 2008). Passive surveillance programs are commonly used as they can be cost-effective and economically feasible to sustain. However, limitations due to underreporting or biased reports (such as voluntary submission) can require additional active surveillance to improve the sensitivity of surveillance programs (Hadorn & Stark, 2008).

Vengust et al. (2006) described the establishment of a surveillance program between Slovenia, Austria and Germany to control CSF in wild boar populations. Due to the highly contagious nature of CSF, there was a risk of CSF crossing country borders through wild pig populations (Fritzemeier et al., 2000). In Slovenia, surveillance activities were based around wild boar population density levels across different regions. Samples were obtained from hunted wild boar using a convenience sampling method. The program anticipated 700 samples a year however, only 40%–60% were obtained during 2003 and 2004 due to the problem of hunters providing contaminated samples. This sampling method poses some limitations in regards to sample size and bias of samples provided for analysis. A study by Nusser et al. (2008) investigated a convenience sampling method with samples taken from road kill. This study considered that animals with diseases including clinical signs such as weakened physical condition were twice as likely to be hit by vehicles in comparison to healthy animals. Similarly, samples from hunted animals may overly represent diseased animals and lead to an overestimate of disease prevalence if this bias is not considered.
Moreover, the presence of contaminated samples supports the need for improved hunter education, as suggested by Vengust et al. (2006).

2.7.4 Modelling for Disease Spread
Disease spread simulation modelling has become a useful tool in the field of epidemiology to assist in policy development and decision making (Garner et al., 2007; Harvey et al., 2007). It was suggested by Garner et al. (2007) that models are most useful prior to an outbreak to allow for contingency and resource planning, risk assessment and appropriate training for application during the event of a disease incursion. This understanding has led to the use of a simulation model, presented in this thesis, to determine the most appropriate surveillance techniques to detect and delineate infection during the event of a CSF incursion in north-western Australia.

Models have been developed to assess spatial distribution of outbreaks for diseases such as FMD (Doran & Laffan, 2005) and CSF (Cowled et al., 2012). Artois et al. (2002) suggested that models addressing the spatial structure of disease spread tend to provide a better understanding of factors influencing areas infected with disease. The effectiveness and efficiency of different mitigation strategies have also been assessed using such models including vaccination, culling (Backer et al., 2009; Cowled et al., 2012) and movement restrictions (Green et al., 2006).

For CSF, modelling has been used to identify factors that may modify the course of infection (Artois et al., 2002). Moreover, this has allowed the exploration of various epidemiological and demographic parameters and their influences on infection (Artois et al., 2002). One of the most recent models developed to investigate CSF spread was by Cowled et al. (2012). This study concluded that control and surveillance programs needed to account for the population and the spatial structure of wild pigs, as these are different to domestic herds. The features of the model that were considered of primary importance for CSF spread were population density, spatial structure, and parameters such as daily movement distances and transmission between and within wild pig herds.

2.8 Evaluation and Justification for Current Research
Over the past decade there has been increased focus on the role of animal movements in disease spread, the importance of biosecurity, and the role that disease surveillance can play in disease detection and prevention. Across South-East Asia, unregulated trade in
livestock poses substantial risks for transboundary disease epidemics (Cocks et al., 2009; Kerr et al., 2010; Van Kerkhove et al., 2009; Windsor, 2011).

The research presented in this thesis was a response to a lack of literature on pig movements across eastern Indonesia. To our knowledge no studies have previously been conducted in live pig markets in NTT and a greater understanding of the pig market chain across the province was needed following preliminary work done by Johns et al. (2009). CSF is considered a priority disease in Indonesia and the government is interested in developing mitigation strategies to control CSF in NTT province. The current impact of CSF across NTT province demonstrates that this disease is still a challenging issue faced by smallholder farmers. The aim was to assess live pig movements across eastern Indonesia and identify associated factors influencing the transmission of CSF. The results were then used to develop recommendations for CSF control to guide policy decision making. In addition, as recognised by AQIS, the islands in close proximity to northern Australia present risks for disease introduction. As a result, there was also a need for an assessment of disease surveillance methods that would be most appropriate for implementation in northern Australia in the event of a CSF outbreak.

This research utilised a variety of quantitative analytical methods to accomplish these aims. There were six stages of the study: pig seller and buyer interviews at live pig markets, an observational study at live pig markets, a smallholder farmer survey, a social network analysis, a quantitative risk assessment, and simulation modelling to investigate surveillance techniques for detection and delineation of CSF following an incursion into north-western Australia.
Chapter 3: Survey at Live Pig Markets across Nusa Tenggara Timur Province

3.1 Introduction

The trade of livestock is a vital part of the economy for many developing countries (Perry et al., 2005). Animals provide a major source of protein, income and assets for poor rural families (Johns et al., 2009; Perry et al., 2005; Windsor, 2011). Within NTT, the demand for live pigs remains high across the province for various celebratory events including weddings, communions and traditional ceremonies (Johns et al., 2009; Robertson et al., 2010b). The ability of livestock markets to maintain a supply of live pigs for purchase is vital within the province (Johns et al., 2009).

The management practices employed at livestock markets have the potential to influence disease spread (FAO, 2010). The introduction of animals from different source locations, the mixing and direct contact between animals with an unknown health status, in combination with minimal effective biosecurity, presents a significant risk (Boklund et al., 2008; FAO, 2010; Natale et al., 2009). Studies have confirmed that the use of biosecurity methods, particularly at markets (due to their high throughput of livestock), can greatly assist in minimising disease spread (Donaldson, 2008; Kiss et al., 2006; Roman et al., 2006). Kiss et al. (2006) stated that disinfecting a marketplace each day before the intake of livestock can assist in minimising disease transmission between animals.

Market premises tend to act as hubs within a movement network, bringing animals from different disease prevalence regions into one location, thus facilitating disease transmission (Robinson & Christley, 2007). Pig breeds in NTT have been shown to comprise predominantly local and cross-bred pigs, with local perceptions on pork taste varying between islands (Johns et al., 2009). Studies have suggested that there are differences between local and exotic pig breeds regarding the process of classical swine fever (CSF) infection. Blacksell et al. (2006) studied the comparative susceptibility of indigenous and exotic pig breeds in Lao PDR to CSF. It was determined that exotic breeds had a shorter survival period and there was a delayed onset of clinical signs for native pig breeds.

CSF, also referred to as hog cholera, is a Pestivirus that has been affecting pig farmers in Indonesia since its introduction in the 1990s (Hutabarat & Santhia, 1999). It is a highly
contagious virus that results in substantial socioeconomic loss (Blome et al., 2010). It is believed that CSF entered Indonesia in 1994 through pig movements from Malaysia, with the first confirmed case in Sumatra (Christie, 2007). Movements into NTT province are believed to have resulted from pig movements from other areas of Indonesia and from East Timor (Christie, 2007). Since its introduction in NTT, over 100,000 cases have been reported (Dinas Peternakan Propinsi, 2011). The high demand for pigs across the province still drives the movement of pigs and newly infected islands have been reported as recently as 2011 (Dinas Peternakan Propinsi, 2011).

The objective of this study was to describe the practices of pig sellers and pig buyers at selected market sites in relation to live pig movement, pig management, biosecurity practices and knowledge of pig health and CSF. This aims to provide information on high-risk practices for CSF transmission and what areas can be targeted for mitigation strategies that will be the most effective in controlling CSF.

3.2 Methodology

3.2.1 Market Study

A survey was conducted in the eastern Indonesian province of Nusa Tenggara Timur on the islands of West Timor, Flores and Sumba. Nine live animal markets were selected across the province (three on each island) where face-to-face interviews were conducted with pig sellers and pig buyers across two interview rounds: September 2009 and November 2009 (University of Sydney Human Ethics Approval No: 08-2009/11866).

3.2.2 Questionnaire

Two questionnaires were developed for seller and buyer respondent types focusing on obtaining information regarding live pig movement, pig management, biosecurity practices and knowledge of pig health and CSF (Appendix 2 and Appendix 8). The questionnaires were initially developed in English and then translated into Bahasa Indonesia by a native speaker of local origin (Dr Maria Geong, Dinas Peternakan Propinsi). Each questionnaire was pilot tested and interview teams involved in the study underwent training incorporating the developed questionnaires. The pilot testing occurred in two stages. The first involved Dinas Peternakan staff conducting eight questionnaires in Camplong market, Kab. Kupang, West Timor, (four sellers and four buyers). Changes were made to questions, following discussion, to improve respondents’ understanding. Consequently, a
further review of questionnaires was completed during interview team training (refer to section 3.2.3). The questionnaires comprised both open- and closed-ended questions with the majority of questions being checklist and short answer type responses. For checklist questions, multiple answers were allowed. The interview duration for sellers was approximately 20 minutes, and for buyers approximately 15 minutes. Throughout the questionnaire, CSF was referred to as hog cholera. In the results presented, the term CSF is used.

3.2.3 Interview Teams

Three interview teams of four people each were recruited (one from each island). These included Nusa Cendana University from West Timor and two local non-government organisations (NGOs), Yaspem Maumere from Flores and Yayasan Cendana Mekar from Sumba. A four-day training workshop was held for each team during August 2009. The training consisted of two days in the classroom so that all questions could be reviewed in detail to ensure everyone had a full understanding. The remaining two days were allocated to pilot testing of the questionnaire in selected markets where each interviewer conducted one seller and one buyer interview (totalling 24 interviews across the three teams). The West Timor team conducted interviews at Camplong Market, the Flores team used Detusoko Market, and the Sumba team used Melolo Market. This was followed by reflection sessions where any problems were resolved by clarification of terms and question refinement as required. Each team elected a leader who underwent further training on questionnaire data entry into the two purpose-designed databases.

3.2.4 Selection of Market Sites

Purposive selection was used to select market sites on the three main islands of NTT with substantial pig trade likely to reflect practices for most pig trade through markets in the province. A total of nine markets with three per island were determined by budget and logistic constraints. Location and market information can be seen in Figure 3.1 and Table 3.1. Market selection was based on the following criteria:

- Large numbers of pigs being moved through the market (>20 on a selling day).
- Markets located in Flores, Sumba or West Timor.
- From local knowledge classified as an important and well known market for pigs (information from local and government veterinarians, Dinas Peternakan staff, NGOs involved in the study and Dr Maria Geong).
- Accessible by vehicle.
Table 3.1
Market locations selected for pig movement study in West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009.

<table>
<thead>
<tr>
<th>Location</th>
<th>Market</th>
<th>District</th>
<th>Subdistrict</th>
<th>Village</th>
<th>Market Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Camplong</td>
<td>Kupang</td>
<td>Fatuleu</td>
<td>Camplong</td>
<td>Fri-Sat</td>
</tr>
<tr>
<td></td>
<td>Niki Niki</td>
<td>TTS</td>
<td>Amanuban Tengah</td>
<td>Niki Niki</td>
<td>Wed</td>
</tr>
<tr>
<td></td>
<td>Halulik</td>
<td>Belu</td>
<td>Tasifeto Barat</td>
<td>Naitimu</td>
<td>Thurs</td>
</tr>
<tr>
<td>Flores</td>
<td>Detusoko</td>
<td>Ende</td>
<td>Detusoko</td>
<td>Detusoko</td>
<td>Tues &amp; Wed</td>
</tr>
<tr>
<td></td>
<td>Mataloko</td>
<td>Ngada</td>
<td>Golewa</td>
<td>Mataloko</td>
<td>Sat</td>
</tr>
<tr>
<td></td>
<td>Mbay</td>
<td>Nagekeo</td>
<td>Aesesa</td>
<td>Mbay 1</td>
<td>Sat</td>
</tr>
<tr>
<td>Sumba</td>
<td>Melolo</td>
<td>Sumba Timur</td>
<td>Umalulu</td>
<td>Lumbukori</td>
<td>Thurs-Fri</td>
</tr>
<tr>
<td></td>
<td>Waikabubak</td>
<td>Sumba Barat</td>
<td>Kota Waikabubak</td>
<td>Wailiang</td>
<td>Every Day</td>
</tr>
<tr>
<td></td>
<td>Wetabula</td>
<td>Sumba Barat Daya</td>
<td>Loura</td>
<td>Wetabula</td>
<td>Every Day</td>
</tr>
</tbody>
</table>

3.2.5 Interview Round Time Selection
The study was conducted across two interview rounds to incorporate a high and a low demand period for pigs. This was to allow for the identification of any seasonal trends in relation to the number of pigs entering and leaving a marketplace, as well as the number of pig sellers and buyers depending on cultural and seasonal variations. Information on cultural activities and seasonal influences were obtained from local experts including Dr Maria Geong (Dinas Peternakan Propinsi), and local and government veterinarians from each island. September was selected as the most appropriate month for the high-demand period and November for the low-demand period.
Justification for the selection of the high-demand period:

- West Timor: June to September was classified as wedding season with many pigs exchanged during these months.
- Flores: September was identified as a high-demand month due to first communion celebrations.
- Sumba: September was a high-demand month as many individuals sold their pigs due to the approaching hot weather, resulting in limited feed sources in the upcoming months.
- June and July were high-demand periods across the province as individuals sell their pigs to get money for their children to go to school.
- December was also a time of high demand across the province because of Christmas (due to logistical considerations; however, June, July and December were not feasible for the study).

Justification for the selection of the low-demand period:

- For each island location it was reported that November was a low-demand month with people preparing for Christmas celebrations. In general previously purchased pigs are being fattened on the farm during November ready for slaughter over the Christmas period. Thus the end of October and during November can be classified as a low-demand period.
- Wet season begins in November with many individuals focusing more on working in the field for planting season at this time. High rainfall also makes transportation of animals more difficult.
- Across Sumba it is also reported that there are not many traditional ceremonies during the month of November, which reduces pig demand.

3.2.6 Seller and Buyer Recruitment in the Market

At each market location, the target was to achieve 16 completed questionnaires by sellers and 16 completed questionnaire by pig buyers, totalling 288 seller and 288 buyer interviews across both rounds. Preliminary figures suggested that the number of pig sellers at a marketplace ranged from approximately 5–25 individuals and the number of buyers similar or higher (Geong, M, pers comm, 2009; Dinas Peternakan veterinarians, 2009). By interviewing 16 sellers per market per round, we expected to interview a minimum of 50% of sellers present at a market site. Due to budgetary constraints, the maximum number of
interviews that could be conducted was 288 sellers and 288 buyers (total 576 interviews; with targets of 96 sellers and 96 buyers per island across the two survey rounds).

If the target number of 16 sellers was not present, a complete census of sellers was to be undertaken. Additional buyer questionnaires were then to be completed to obtain a total of 32 interviews per site per visit. Obtaining both pig source and destination information was important to demonstrate the extent of pig movements within the province. During each market visit, the total number of sellers and buyers were estimated to calculate the proportion of the total represented by the 32 individuals interviewed. This was done through observations at the marketplace on the day of interviewing. The estimates were obtained over a 3–4 hour period, during which time the interviews were conducted. Trading practices were observed to categorise individuals as sellers and buyers. Initial estimates were made by the author followed by a secondary estimate obtained from the interview team leader to provide the best overall estimate. Where possible, the market manager provided seller numbers.

A set number of seller and buyer interviews per market visit were implemented because of budgetary constraints, the short time available on a market day to approach and then interview sellers and buyers during the course of their time at the market, and a lack of prior knowledge on seller and buyer numbers per market and on the distribution of their respective practices. For the nine selected markets, information about the number of sellers present on a market day required for proportional sampling of sellers or a census of sellers could not be obtained prior to the study. This was due to the absence of or the inability to contact market managers and a lack of recorded data. The high number of individuals entering a market who are a mixture of sellers, buyers and observers also limited the ability to visually distinguish between person types required for a census approach. Interviews were conducted during market hours when pigs were being sold. This was during the early hours of the morning, with the exception of Camplong Market where there was trading during night hours. Interview teams arrived around 4–7am, according to location, in order to avoid peak selling hours and to maximise interview numbers.

Respondents were identified as sellers with pigs or buyers purchasing pigs at a market and approached by interview team members. The sellers and buyers were given a brief introduction to the project and asked if they were willing to participate. If an individual was not willing to participate another seller or buyer was approached. On completion of
the interviews, all respondents received a T-shirt for participating. They were only told of the T-shirt on completion of the interview so as not to influence their decision to participate. Following the first round of interviews, the names of all of the individuals interviewed were listed and this was referred to during the second interview round to ensure that no respondents were interviewed a second time.

3.2.7 Data Management
Using Epi Info™ Software (Version 3.5.1, CDC, www.cdc.gov/epiinfo, Atlanta, Georgia, U.S) two separate databases were developed, one for each questionnaire type. These were then provided to the team leader of each interview team on a portable USB (Kingston 2GB). On completion of data collection for each round all data were entered into the databases. On completion of the two rounds, the databases from the different islands were combined and cross-matched with the questionnaire hard copies to ensure data entry was correct. Translation revisions and corrections were made where necessary.

3.2.8 Data Analysis
Standard descriptive analyses were conducted separately on data obtained from the seller and buyer interviews using Genstat 11th Edition (PC/Windows XP, 2006, VSN International Ltd., Hemel Hempsted, UK). Initially data were checked and edited for missing values and outliers. Descriptive analyses were used to describe general management of pigs in the marketplace and on the farm, pig movements, biosecurity practices, and knowledge of pig health and CSF. Continuous variables were investigated with means, quartiles and ranges. For categorical variables of interest, proportions were investigated on an island and interview round level and significant differences identified using the chi-squared test to determine if observed frequencies were significantly different from expected frequencies between islands and interview rounds (Equation 3.1; Altman, 1991). When the chi-square test indicated significance (P-values < 0.05) for variables with multiple categories, a z-test using a Bonferroni adjustment was used to compare categories and identify those that were significantly different.

\[ X^2 = \sum \frac{(O - E)^2}{E} \]  

Where: \( X^2 \) = chi squared statistic

\( O \) = observed value

\( E \) = expected value.
To analyse significant differences between pig count data, including the number of pigs sold at market, the number of pigs purchased at market and on-farm herd size (collected only from seller respondents), a generalised linear mixed model (GLMM) was used. The model consisted of four fixed effects: interview round (high-demand, low-demand), breed (local, cross-bred), age group, and island. For age group, analyses were conducted only on pig age groups of a marketable age (≥ 2 months of age), including weaners, growers, fatteners, sows and boars. Due to the misclassification of identified pig age groups from Flores island, only data from West Timor and Sumba were analysed for number of pigs sold by age group and for the number of pigs purchased by age group. Moreover, when interactions were investigated, age group was not included. The random effects included in the model were seller or buyer ID and a term for market nested within island. These random effects were included to account for the expected similarity in pig numbers within respondent (seller or buyer), market and island. Two additional models were fitted to analyse total pig numbers brought to market per seller and total on-farm herd size per seller. The model consisted of two fixed effects: interview round and island. All three islands were included in the analyses as age groups were not distinguished. The random effects included a term for market nested within island. A Poisson distribution was used in both models with a logarithmic link function to account for the presence of count data and predominantly lower pig numbers in the dataset. Due to the application of a GLMM, the calculation of the intra-cluster correlation coefficient (ICC) could not be performed. The output from the models did not find any significant interactions amongst the fixed effects and therefore are not mentioned in the results.

The presence of any significant variations in pig sale prices at market were analysed using a restricted maximum likelihood (REML) model. Due to misclassification of identified pig age groups from Flores island, only data from West Timor and Sumba were analysed. Sale price data were initially assessed for normality, which required Log$_e$ transformation. Clustering (or similarity) between sale prices was anticipated at the seller, market and island levels and was assessed for market and seller by calculation of the ICC using Equations 3.2 and 3.3 respectively. Clustering was considered high with ICC values above 0.1 (Dohoo et al., 2003). The final model included fixed effects for interview round, breed, age group and island (including interactions) and random effects for seller ID and a term for market nested within island. The output from the models did not find any significant interactions amongst the fixed effects and therefore are not mentioned in the results.
ICC = \frac{\sigma_h^2}{\sigma_h^2 + \sigma_s^2} ..................................................Equation 3.2

ICC (seller within market) = \frac{\sigma_r^2 + \sigma_h^2}{\sigma_r^2 + \sigma_h^2 + \sigma^2} .........................................Equation 3.3

Where: ICC = intra-cluster correlation coefficient
\sigma_h^2 = random effect variance
\sigma_r^2 = market variance component
\sigma_s^2 = residual variance.

For clarification, throughout this chapter n is referred to as the number of respondents that answered a question. In addition, for ease of reporting, the term island has been used to refer to West Timor in some sections.

3.3 Results

3.3.1 Market Respondents
A total of 574 interviews were completed within markets with 292 pig seller respondents (round 1: 144; round 2: 148) and 282 pig buyer respondents (round 1: 144; round 2: 138) across the nine market sites. Following completion of the interviews, it was found that one buyer respondent from round 1 was also interviewed in round 2 so this individual was excluded from the round 2 interview data.

3.3.1.1 Interview Numbers
The respondents interviewed comprised 21.0–100.0% of the estimated total number of pig sellers and from 18.2–100.0% of the estimated total number of pig buyers present in the market on the day of interviewing (Table 3.2; Table 3.3). The number of sellers per market was higher than originally estimated for some of the markets. The sample of nine markets across these three islands represented 9.8% of documented live pig markets identified by DLS (refer to Appendix 1 for complete market list).
Table 3.2
Total number of sellers present at market on interviewing day and the number of sellers interviewed on West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 292).

<table>
<thead>
<tr>
<th>Market</th>
<th>Round 1</th>
<th></th>
<th>Round 2</th>
<th></th>
<th>TOTAL</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Seller No.</td>
<td>Interview No.</td>
<td>%</td>
<td>Sellers No.</td>
<td>Interview No.</td>
<td>%</td>
<td>Total Seller</td>
</tr>
<tr>
<td>Camplong</td>
<td>80&lt;sup&gt;1&lt;/sup&gt;</td>
<td>16</td>
<td>20.00</td>
<td>68&lt;sup&gt;1&lt;/sup&gt;</td>
<td>15</td>
<td>22.06</td>
<td>148&lt;sup&gt;1&lt;/sup&gt;</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>49</td>
<td>16</td>
<td>32.65</td>
<td>50</td>
<td>16</td>
<td>32.00</td>
<td>99</td>
</tr>
<tr>
<td>Halulik</td>
<td>61</td>
<td>16</td>
<td>26.23</td>
<td>52</td>
<td>17</td>
<td>32.69</td>
<td>113</td>
</tr>
<tr>
<td>Mbay</td>
<td>89</td>
<td>16</td>
<td>17.98</td>
<td>90</td>
<td>24&lt;sup&gt;2&lt;/sup&gt;</td>
<td>26.67</td>
<td>179</td>
</tr>
<tr>
<td>Detusoko</td>
<td>25</td>
<td>15</td>
<td>60.00</td>
<td>9</td>
<td>9&lt;sup&gt;2&lt;/sup&gt;</td>
<td>100.00</td>
<td>52</td>
</tr>
<tr>
<td>Mataloko</td>
<td>46</td>
<td>17</td>
<td>36.96</td>
<td>40</td>
<td>19</td>
<td>47.50</td>
<td>86</td>
</tr>
<tr>
<td>Melolo</td>
<td>28</td>
<td>16</td>
<td>57.14</td>
<td>23</td>
<td>16</td>
<td>69.57</td>
<td>51</td>
</tr>
<tr>
<td>Wetabula</td>
<td>37</td>
<td>16</td>
<td>43.24</td>
<td>16</td>
<td>16</td>
<td>100.00</td>
<td>53</td>
</tr>
<tr>
<td>Waikabubak</td>
<td>16</td>
<td>16</td>
<td>100.00</td>
<td>16</td>
<td>16</td>
<td>100.00</td>
<td>32</td>
</tr>
<tr>
<td>TOTAL</td>
<td>351</td>
<td>144</td>
<td>41.03</td>
<td>314</td>
<td>148</td>
<td>47.13</td>
<td>665</td>
</tr>
</tbody>
</table>

<sup>1</sup> Figures obtained through consultation with market manager. This market is a night market thus with no light sources the number of sellers present was not able to be estimated; <sup>2</sup> At Detusoko Market there were very few sellers on the day of interviewing during round 2. As only 9 interviews were conducted, additional interviews were conducted at the following market to make up the difference (Mbay was the final market used for interviews, hence this was the only market where additional interviews could be conducted).
Table 3.3
Total number of buyers present at market on interviewing day and the number of buyers interviewed on West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 281).

<table>
<thead>
<tr>
<th>Market</th>
<th>Round 1</th>
<th></th>
<th>Round 2</th>
<th></th>
<th>Total Buyer</th>
<th>Total Interviewed</th>
<th>Total %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Buyer No.</td>
<td>Interview No.</td>
<td>%</td>
<td>Buyer No.</td>
<td>Interview No.</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Camplong</td>
<td>1</td>
<td>16</td>
<td>1</td>
<td>1</td>
<td>15</td>
<td>1</td>
<td>31</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>36</td>
<td>16</td>
<td>44.44</td>
<td>29</td>
<td>16</td>
<td>55.17</td>
<td>65</td>
</tr>
<tr>
<td>Halulik</td>
<td>88</td>
<td>16</td>
<td>18.18</td>
<td>72</td>
<td>16</td>
<td>22.22</td>
<td>160</td>
</tr>
<tr>
<td>Mbay</td>
<td>41</td>
<td>16</td>
<td>39.02</td>
<td>25</td>
<td>18</td>
<td>72.00</td>
<td>66</td>
</tr>
<tr>
<td>Detusoko</td>
<td>16</td>
<td>16</td>
<td>100.00</td>
<td>19</td>
<td>19</td>
<td>100.00</td>
<td>35</td>
</tr>
<tr>
<td>Mataloko</td>
<td>34</td>
<td>16</td>
<td>47.06</td>
<td>20</td>
<td>5</td>
<td>25.00</td>
<td>54</td>
</tr>
<tr>
<td>Melolo</td>
<td>30</td>
<td>16</td>
<td>53.33</td>
<td>28</td>
<td>16</td>
<td>57.14</td>
<td>58</td>
</tr>
<tr>
<td>Wetabula</td>
<td>33</td>
<td>14</td>
<td>42.42</td>
<td>18</td>
<td>16</td>
<td>88.89</td>
<td>51</td>
</tr>
<tr>
<td>Waikabubak</td>
<td>19</td>
<td>18</td>
<td>94.74</td>
<td>16</td>
<td>16</td>
<td>100.00</td>
<td>35</td>
</tr>
<tr>
<td>TOTAL</td>
<td>297</td>
<td>144</td>
<td>48.48</td>
<td>227</td>
<td>137</td>
<td>60.35</td>
<td>524</td>
</tr>
</tbody>
</table>

1 Data not available as during the market survey, no light sources were available at the night market and the market manager did not have previous figures for pig buyers attending market; 2 Difficulties were encountered in finding willing participants for the study at Mataloko Market during round 2 Buyers were not cooperative, entering and leaving the market very quickly following pig purchase, hence a low interview number at this market.
3.4 Results – Pig Sellers

3.4.1 Respondent Demographics

3.4.1.1 Gender
A greater proportion of respondents were male (P < 0.001; 89.0% male and 11.0% female; n = 292). On the island of Flores, a higher proportion of females were interviewed in comparison to Sumba (P > 0.001; West Timor: 28.1%; Flores: 56.3%; Sumba: 15.6%).

3.4.1.2 Age
The mean age for the 292 pig sellers across both market interview rounds was 39.61 ± 10.10 years (standard deviation). There was a wide range of ages from young respondents (minimum 23 years) up to elderly respondents (maximum 71 years).

3.4.1.3 Education
In terms of education, a large proportion of respondents across both interview rounds had completed primary school (48.0%; n = 292) followed by secondary school (27.4%). Only 9.3% of respondents had completed high school and only one individual from West Timor reported having completed an undergraduate university degree.

3.4.1.4 Religion
This area of Indonesia was primarily composed of individuals of a Protestant or Catholic denomination. The majority of respondents were Catholic, with a total of 57.2% (n = 292). In addition, on the island of Sumba, a local religion called Marapu was reported by 3.8% of respondents. West Timor was comprised of both Protestants (63.5%) and Catholics (36.5%).

3.4.1.5 Primary and Secondary Occupation
Pig sellers provided information about their occupation with 66.6% (n = 270, 22 sellers did not provide a response) reporting farming and only 25.0% reporting pig selling as their primary occupation. Of the 171 respondents that specified a secondary occupation, 45.0% reported that it was selling pigs. Other common secondary occupations included livestock sellers (12.3%), pig collectors (5.3%), and ojek drivers (3.0%).
3.4.2 Respondent Background

3.4.2.1 Sellers Role at the Market

It was identified that sellers could have multiple roles within the marketplace. The majority of sellers sold their own pigs (42.8%). This was common across islands ($P = 0.247$; West Timor: 32.0%; Flores: 40.0%; Sumba: 28.0%). A large proportion reported being permanent sellers (refer to Glossary) at the market (41.1%) which was also common across islands ($P = 0.076$; West Timor: 35.0%; Flores: 24.2%; Sumba: 40.8%). A small proportion of pig collectors (11.6%) and traders (28.1%) were identified (refer to Glossary). Only a very limited number (1.5%) reported selling any pig meat products at market.

Additional factors influencing the role of a seller included those such as seasonal changes and the need for money. One respondent reported becoming a seller only when in need of additional money for events such as sending their children to school. One additional seller stated that he remained a permanent seller during the dry season and then returned to agricultural work in the fields during the wet season.

3.4.2.2 Seller Experience

On average pig sellers had been selling pigs at market for $5.61 \pm 4.30$ years. A wide spectrum of experience was found ranging from first-time sellers in the market (2.3%; $n = 292$) to those with 34 years’ experience. An additional 8.2% were unsure how long they had been selling pigs at market.

3.4.2.3 Why Sell Pigs

The major reasons provided for selling pigs was for primary (52.4%) and extra income (43.5%; $n = 292$). Extra income was predominantly needed for money in the household (10.2%), and education costs (9.4%). Only a small proportion of individuals reported selling pigs due to the high demand for pigs (2.4%).

3.4.2.4 Choice of Market

It was found that 30.8% of sellers sold pigs at two or more markets ($n = 289$, three sellers did not provide a response). The selection of a specific market as a location to sell pigs was usually dictated by its reputation as a good market (61.6%) most commonly found in Sumba in comparison to Flores ($P > 0.001$; West Timor: 37.6%; Flores: 15.2%; Sumba: 46.9%). The location of a market close to the respondent’s residence increased its chance of usage (44.5%). Only 5.8% selected markets with large buyer numbers present and
markets where higher prices could be obtained. It was reported by one respondent that Camplong Market is recognised as the largest livestock market in West Timor.

3.4.3 Management of Pigs at Market

3.4.3.1 Volume of Live Pigs at Market

A total of 450 and 349 pigs, respectively, across round 1 and round 2 of interviews were recorded as being brought by seller respondents (Table 3.5). No significant differences were detected for the mean number of pigs brought per seller to market across interview rounds ($P = 0.180$; back-transformed means, round 1: $1.98 \pm 1.08$, round 2: $1.78 \pm 1.16$) or islands ($P = 0.898$; back-transformed means, West Timor: $2.05 \pm 1.39$, Flores: $1.82 \pm 1.39$, Sumba: $1.78 \pm 1.38$). Individuals from Wetaula Market in Sumba had the highest mean number of pigs per seller ($6.19 \pm 4.96$) and Mbay Market in Flores had the lowest ($0.75 \pm 0.63$). The highest number of pigs recorded in markets stratified by island was identified on Sumba (West Timor: 249 pigs; Flores: 181 pigs; Sumba: 369 pigs). Overall the total number of pigs brought to the market by an individual seller ranged from 1–25 (including all marketable age groups; Table 3.4).

Table 3.4
Number of pigs brought to market by pig sellers on a single market day across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 292).

<table>
<thead>
<tr>
<th>Island</th>
<th>Round</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>25% quartile</th>
<th>75% quartile</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>1</td>
<td>48</td>
<td>3.44</td>
<td>2.00</td>
<td>1.00</td>
<td>25.00</td>
<td>1.00</td>
<td>4.00</td>
<td>2.48</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>48</td>
<td>1.92</td>
<td>1.00</td>
<td>1.00</td>
<td>12.00</td>
<td>1.00</td>
<td>2.00</td>
<td>1.17</td>
</tr>
<tr>
<td>Flores</td>
<td>1</td>
<td>48</td>
<td>1.90</td>
<td>1.00</td>
<td>1.00</td>
<td>10.00</td>
<td>1.00</td>
<td>2.00</td>
<td>1.37</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>52</td>
<td>1.73</td>
<td>1.00</td>
<td>1.00</td>
<td>11.00</td>
<td>1.00</td>
<td>2.00</td>
<td>1.44</td>
</tr>
<tr>
<td>Sumba</td>
<td>1</td>
<td>48</td>
<td>4.08</td>
<td>3.00</td>
<td>1.00</td>
<td>20.00</td>
<td>2.00</td>
<td>4.00</td>
<td>3.41</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>48</td>
<td>3.59</td>
<td>3.00</td>
<td>1.00</td>
<td>18.00</td>
<td>2.00</td>
<td>4.00</td>
<td>3.51</td>
</tr>
</tbody>
</table>

3.4.3.2 Age and Breed of pigs

As seen in Table 3.5, no fatteners were reported on Flores. This suggests that there was a problem: a misclassification of age groups. Due to the potential impact on other age groups, suggested by the higher proportion of growers in round 1 and breeders in round 2, it was decided to compare only West Timor and Sumba for age group characteristics. A higher mean number growers and fatteners were sold at market in comparison to sows ($P < 0.05$; back-transformed means, fattener: $2.17 \pm 1.10$, grower: $2.21 \pm 1.09$, weaner: $2.04 \pm$
1.11, sow: 1.60 ± 1.09, boar: 1.72 ± 1.11). A significantly higher mean number of pigs were sold during round 1 of interviews in comparison to round 2 (\(P < 0.05\); round 1: 1.81 ± 1.25; round 2: 1.74 ± 1.70). No significant difference was detected between islands (\(P = 0.486\); West Timor: 1.80 ± 1.02; Sumba: 1.82 ± 1.31).

The two breed types presented for sale were local and cross-bred pigs, each with unique characteristics (Figure 3.2 and 3.3; refer to Glossary). A higher proportion of local breed pigs were sold at market in comparison to cross-breeds (\(P < 0.001\); local breed: 75.6%; cross-breed: 24.4%). Sellers from Sumba sold a significantly higher number of cross-bred pigs at market in comparison to West Timor (\(P < 0.001\); Table 3.5). The markets with the largest proportion of local pigs were Halulik and Detusoko (Table 3.5).
Table 3.5
Number and proportion of pigs by age group and breed brought to market by 292 sellers during round 1 and round 2 interviews across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Breed</th>
<th>Round 2</th>
<th>Breed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No of pigs</td>
<td>Age Group</td>
<td></td>
<td>No of pigs</td>
</tr>
<tr>
<td></td>
<td>W¹</td>
<td>G²</td>
<td>F³</td>
<td>S⁴</td>
</tr>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>Camplong</td>
<td>83</td>
<td>33.73</td>
<td>0.00</td>
<td>20.48</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>38</td>
<td>5.26</td>
<td>26.32</td>
<td>7.89</td>
</tr>
<tr>
<td>Halulik</td>
<td>34</td>
<td>23.53</td>
<td>14.71</td>
<td>14.71</td>
</tr>
<tr>
<td>Flores</td>
<td>91</td>
<td>0.00</td>
<td>53.85</td>
<td>0.00</td>
</tr>
<tr>
<td>Mbay</td>
<td>13</td>
<td>0.00</td>
<td>53.85</td>
<td>0.00</td>
</tr>
<tr>
<td>Detusoko</td>
<td>11</td>
<td>0.00</td>
<td>63.64</td>
<td>0.00</td>
</tr>
<tr>
<td>Mataloko</td>
<td>67</td>
<td>0.00</td>
<td>58.21</td>
<td>0.00</td>
</tr>
<tr>
<td>Total</td>
<td>91</td>
<td>0.00</td>
<td>58.24</td>
<td>0.00</td>
</tr>
</tbody>
</table>

a,b,c Within a column, values without a common superscript letter comparing between islands differ significantly (P < 0.05); d,e,f Within a row, values without a common superscript letter comparing between age groups and breeds during different interview rounds differ significantly (P < 0.05); 1 = weaner; 2 = grower; 3 = fattener; 4 = sow; 5 = boar; 6 = local pig breed; 7 = cross-breed pig breed; Weaner: piglet that has just been separated or stopped suckling (pigs ≥ 2 months and < 3); Grower: A boar or gilt ranging from 3–5 months of age; Fattener: pigs ≥ 6 months of age; Sow: Female pig used for breeding; Boar: Male pig used for breeding.
For pig prices, it was decided to compare only the islands of West Timor and Sumba due to the misclassification of age groups on Flores. Mean pig prices were significantly higher in Sumba compared to West Timor for all marketable age groups \( (P < 0.05; \text{Figure 3.4}) \). The cost of cross-bred pigs was found to be significantly higher than local breeds for weaners \( (P < 0.05) \), growers \( (P < 0.001) \), sows \( (P < 0.001) \) and boars \( (P < 0.001; \text{Table 3.6}) \). No difference was detected for price variations across interview rounds \( (P = 0.217; \text{round 1: Rp 1,519,464 ± 1,356,981; round 2: Rp 1,487,149 ± 1,329,997}) \). The level of clustering was found to be high at the pig seller level \( (\text{ICC} = 0.49) \) and at the market level \( (\text{ICC} = 0.24) \). Refer to Appendices 3 to 7 to view price data for each age group.

**Figure 3.4**
Mean price of pigs being sold in markets by pig sellers across West Timor and Sumba in Nusa Tenggara Timor, eastern Indonesia (Currency: Indonesian Rupiah), 2009 \( (n = 292) \), \( a,b \) columns without a common letter differ significantly within age groups \( (P < 0.05) \).
Table 3.6
Mean price of pigs (currency: Indonesian Rupiah) at market, stratified by age group and breed brought by sellers across West Timor and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Local Price ± SD</th>
<th>Cross-breed Price ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaner</td>
<td>546,538 ± 275,478&lt;sup&gt;a&lt;/sup&gt;</td>
<td>745,455 ± 239,222&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Grower</td>
<td>1,054,630 ± 898,270&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1,662,500 ± 1,095,910&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fattener</td>
<td>2,306,000 ± 1,409,901&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2,333,333 ± 1,098,115&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sow</td>
<td>1,625,641 ± 980,593&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3,313,158 ± 1,480,225&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Boar</td>
<td>2,185,345 ± 1,640,088&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3,981,818 ± 1,208,457&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a, b</sup>Within a row, values without a common letter differ significantly between pig prices of local and cross-breed pigs (<i>P</i> < 0.05).

3.4.3.4 Separation of Pigs

The majority of market seller respondents reported no form of separation among pigs at market (84.3%; n = 289). Mataloko Market in Flores and Wetabula Market in Sumba reported the presence of some separation according to pig age. This information was reported by pig sellers at the market. Further detail can be seen in the observational study conducted at each market site (Chapter 4).

3.4.3.5 Pig Feed at the Market

Among the sellers 46.9% (n = 292) reported providing feed to their pigs at the market. Of these individuals, 83.5% (n = 137) reported providing rice bran mixed with water, and 51.8% local agricultural products (including papaya, cassava and other non-processed vegetable and fruit products) at the market. A further 5.8% reported feeding table scraps brought from home, and 12.2% reported utilising food waste from external sources such as restaurants or neighbouring residences. Few sellers provided purchased commercial feed to their pigs at the market (5.7%).

3.4.3.6 Hygiene at the Market

It was found that 95.9% (n = 291) of respondents had not previously heard of the term biosecurity, and one respondent chose not to answer the question. When provided with a definition of biosecurity, 54.2% reported no use of any biosecurity practices at the market. Pig sellers from Flores were found to have a significantly higher proportion of individuals that performed at least one biosecurity measure (<i>P</i> < 0.001; West Timor: 22.1%, Flores: 64.8%, Sumba: 13.1%).
Cleaning at the marketplace was extremely minimal. The majority of respondents (71.6%) reported that no cleaning was ever done at the markets. The remaining respondents stated that cleaning only occurred once a week (Flores and Sumba market locations) and was performed by sellers at the market. No respondents from West Timor stated that cleaning was performed at any of the market sites. When asked about waste disposal methods in the market, including products such as pig faeces and food waste, response rates to this question were quite low. Only 141 pig sellers provided a response to this question. Of the responses recorded, 73.0% reported throwing material away. A significantly higher proportion of sellers from Sumba chose to ‘throw away’ their waste in comparison to West Timor ($P < 0.001$; West Timor 2.1%, Flores: 35.5%; Sumba: 55.3%). Furthermore, only sellers from Sumba reported the use of market waste as compost (19.1%). Few respondents chose to bury (4.8%) or burn (2.4%) waste.

### 3.4.3.7 Unsold Pigs at the Market

It was found that 81.2% ($n = 285$) of respondents stated that if they were unsuccessful selling a pig at market, the pig would subsequently be taken home. Only 2.0% reported that they would sell their pig at a cheaper price in the event of not being able to trade their pig on a selling day. A further 16.1% reported leaving their pig at market until sold. For those sellers returning with pigs to their residence, 66.4% ($n = 231$) placed this animal back in their herd, allowing direct contact with pigs already on the property.

A unique market included in the study was Detusoko Market in Flores. This market displayed characteristics not seen in other markets. Pigs were brought to market, tied up in the selling area and could remain until sold (Figure 3.5). During the time that pigs remained at this market, sellers were required to pay an individual to watch over the pig/s in order to provide feed and ensure its/their safety during the night (if not performed by themselves).
3.4.4 Pig Origin to Market Movement

3.4.4.1 Pig Sources

Details regarding the origin and destination for pigs were gathered at the village level. In addition to asking the specific location from which respondents sourced their pigs by age group, details were also obtained on the types of sources used. It was found that over half of seller respondents brought their own home-raised pigs to sell at market (52.1%; n = 292). Flores displayed the highest proportion of sellers using home-raised pigs as their primary source (46.7%), significantly higher than Sumba ($P < 0.001$; 24.3%). More concerning was that 44.3% of respondents stated that they traded pigs at different market locations. This was found to be similar across all islands ($P = 0.202$; West Timor: 40.0%, Flores: 33.3%, Sumba: 26.7%). In addition, four pig sellers in Sumba stated that they purchased and collected pigs directly from a ferry that had departed from Aimere in Flores and arrived in Sumba.
3.4.4.2 Monthly Movement Patterns: High Demand

The months of August, September and October were identified as high-demand months for the pig trade ($P < 0.001$; 50.7%, 61.1% and 45.8% respectively; Figure 3.7). Regarding monthly movements stratified by island, Flores and Sumba had the highest proportion of reported movements during this three month period ($P < 0.05$; West Timor: 41.3%, Flores: 56.9%, Sumba: 59.4%).

Those interviewed were then asked for their reasons behind the high demand during these months (Table 3.7). Only 232 respondents provided an answer. Traditional activities were found to be a significant driving factor (43.1%; $n = 232$). For Sumba, sellers reported a significantly higher number of traditional activities (27.8%) as opposed to West Timor ($P < 0.001$; 4.2%).

Figure 3.6
Months selected by pig sellers representing those months with the highest demand for pigs sold at market across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 ($n = 290$). 2 respondents did not provide an answer.
Table 3.7
Reasons for high-demand of pigs during the year provided by pig sellers from West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 224).

| Reasons for higher demand months | Round 1 | | | Round 2 | | | TOTAL |
|----------------------------------|---------|---------|---|---------|---------|---|
|                                  | No.     | %       |   | No.     | %       |   | No.     | %       |
| n                                 | 123     | 85.42   |   | 101     | 69.18   |   | 224     | 76.71   |
| Traditional activities           | 62      | 50.41   |   | 38      | 37.62   |   | 100     | 44.64   |
| Many parties                     | 32      | 26.02   |   | 31      | 30.69   |   | 63      | 28.13   |
| Marriage parties                 | 32      | 26.02   |   | 23      | 22.77   |   | 55      | 24.55   |
| First communion                  | 24      | 19.51   |   | 16      | 15.84   |   | 40      | 17.86   |
| Money from harvest available     | 6       | 4.88    |   | 8       | 7.92    |   | 14      | 6.25    |
| Christmas                        | 12      | 9.76    |   | 2       | 1.98    |   | 14      | 6.25    |
| School expenses                  | 11      | 8.94    |   | 3       | 2.97    |   | 14      | 6.25    |
| Funeral                          | 6       | 4.88    |   | 5       | 4.95    |   | 11      | 4.91    |

3.4.4.3 Monthly Movement Patterns: Low Demand

January, February and March were identified as the lowest-demand months during the year (44.5%, 40.7% and 34.2% respectively; Figure 3.7). A variety of different reasons were identified for this temporal trend. During the rainy season, focus was placed on agricultural production as this was the primary food and income source (29.8%). The rainy season also deterred farmers from transporting pigs to market (23.5%). In Sumba and West Timor, the beginning of the wet season was referred to as the ‘starving season’. This was the time that no money and food was available thus people did not want to risk selling their pigs as they may need an emergency source of money. A reduction in the frequency of traditional ceremonies and cultural events also led to a reduction in the pig trade across this period (36.6%).
Months selected by pig sellers representing those months with the lowest demand for pigs sold at market across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 292).

3.4.4.4 Peak Daily Market Hours

The majority of sellers arrived at market in the morning (before 12:00pm) (81.5%; n = 281) with peak times approximately between 3am to 8am. Many sellers stated that they arrived early and stayed at market for as long as required to sell their pig for the desired price.

A unique market included in the study was Camplong Market in West Timor which functioned during night hours on Friday to early morning hours on Saturday. Pig transactions began around 9pm in the main selling area (refer to Chapter 4) with sellers arriving at night and remaining until the early hours of the morning. Buyers would arrive any time after 9pm and would leave once their transaction was finalised.

3.4.4.5 Most Common Methods Used For Pig Selling

In addition to selling pigs at market, 7.4% reported that the most common method used to sell pigs was directly from their home. An additional 5.3% sold pigs to another pig seller. One respondent reported to exchange boars with buffalo and horses.
3.4.5 Market Interactions with Smallholder Farmers

3.4.5.1 Herd Size

Out of 289 seller respondents (three did not provide a response), 90.0% were found to own a smallholder pig herd. Herd size characteristics are shown in Table 3.8. It was found that 26.5% of farmers had no sow in their herd, with the largest proportion of herds having only one sow (46.2%; Table 3.8). When analysing total herd size, Sumba was found to have a significantly greater mean herd size in comparison to West Timor and Flores ($P > 0.05$; back-transformed mean, West Timor: 2.51 ± 1.12, Flores: 2.32 ± 1.10, Sumba: 3.18 ± 1.12). No difference in herd size was detected across interview rounds ($P = 0.166$; back-transformed means, round 1: 2.52 ± 1.07 round 2: 2.78 ± 1.06). Differences between total herd size and sow numbers can be seen in Table 3.8.

A greater number of local pigs were recorded in herds in comparison to cross-breeds (local breed: 487 pigs; cross-breed: 238 pigs). The proportion of local pigs was similar between islands ($P = 0.408$; West Timor: 31.0%; Flores: 35.9%; Sumba: 33.1%). A significantly larger proportion of cross-breed pigs were detected on Sumba ($P < 0.001$; West Timor: 12.2%; Flores: 19.7%; Sumba: 68.1%).

The mean number of weaners, growers and fatteners per herd was greater than sows and boars when comparing West Timor and Sumba ($P > 0.001$; back-transformed means, weaners: 2.03 ± 1.10, growers: 2.36 ± 1.14, fatteners: 2.02 ± 1.08, sows: 1.51 ± 1.07, boars: 1.53 ± 1.12). Grower pigs had the largest range within herd size across the islands with up to 15 reported in one herd in Sumba. No significant differences in the mean number of pigs were detected between islands ($P = 0.234$; back-transformed means, West Timor: 1.69 ± 1.09; Sumba: 2.05 ± 1.12), round ($P = 0.140$; back-transformed means, round 1: 1.76 ± 1.09; round 2: 1.97 ± 1.08) or breed ($P = 0.719$; back-transformed means, local: 1.87 ± 1.08; cross-breed: 1.77 ± 1.13).
Table 3.8
Size of pig herds (pigs of marketable age from 2 months of age) stratified by sow number owned by pig sellers interviewed at market across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 259, one respondent did not provide details).

<table>
<thead>
<tr>
<th>Island</th>
<th>Parameter</th>
<th>Sow Number</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4&lt;sup&gt;1&lt;/sup&gt;</th>
<th>5&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>No. Sellers</td>
<td>29</td>
<td>24</td>
<td>14</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Total Herd Size</td>
<td>1.72 ± 1.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.79 ± 1.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.07 ± 1.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.80 ± 1.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.00 ± 0.00</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Flores</td>
<td>No. Sellers</td>
<td>25</td>
<td>45</td>
<td>21</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Total Herd Size</td>
<td>1.76 ± 1.33&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.96 ± 1.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.76 ± 1.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.67 ± 2.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.50 ± 2.12</td>
<td>7.00 ± 0.00</td>
<td></td>
</tr>
<tr>
<td>Sumba</td>
<td>No. Sellers</td>
<td>15</td>
<td>51</td>
<td>16</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mean Total Herd Size</td>
<td>3.20 ± 1.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.29 ± 1.20&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.56 ± 2.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.33 ± 5.86&lt;sup&gt;b&lt;/sup&gt;</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a,b</sup>Within a column, values without a common superscript letter comparing mean total herd size differ significantly (P < 0.05); <sup>1</sup>Sample size not appropriate for statistical analysis.
3.4.5.2 Pig Housing Methods

Housing types were similar across the province with some farmers reporting multiple housing methods. The majority of respondents kept their pigs in a pen (80.5%; n = 290) and this was similar across islands ($P > 0.05$; West Timor: 31.3%; Flores: 30.3%; Sumba: 38.4%). The pen, commonly referred to as a kandang, is typically a bamboo structure often built off the ground to allow for appropriate ventilation and waste to fall below the pen (Figure 3.8). An additional 21.8% of respondents tethered their pigs. This was most often to a tree or stable structure such as the stilts of a house. Only a small proportion of farmers had a free roaming herd (13.4%), most commonly seen in Sumba ($P < 0.05$; West Timor: 30.8%; Flores: 15.4%; Sumba: 53.8%). Differences in free roaming herds were seen with 6 respondents from Sumba stating that only piglets were free to roam with another farmer stating that during the summer months pigs can roam freely but during the raining season pigs are penned.

![Figure 3.8](image.png)

Typical kandang (pen) for housing pigs commonly used across Nusa Tengara Timur Province, photo taken in Sumba Barat district, Sumba, 2010.

3.4.5.3 Pig Feed

Feed was provided to pigs by 87.6% (n = 290) of sellers to their on-farm herd, the remainder had free roaming herds that scavenged for food. The primary feed types were agricultural products (94.3%; n = 254), most commonly cassava, banana stem and papaya. In addition, 53.5% of respondents fed table scraps to their pigs and a further 5.5% reported
sourcing waste food from restaurants or neighbours. Only two respondents reported purchasing commercial feed.

3.4.5.4 Dead Pig Disposal

For the disposal of dead pigs on the farm, 48.6% (n = 288) of pig sellers chose to bury them. A further 17.0% stated that they would throw away the pig, and 8.7% stated that they sold the dead pig for consumption. For those individuals that sold dead pig meat, 24.0% sold it using a method called leis (refer to Glossary), which was reported on all islands. Alternatively, 15.3% reported to consume the meat themselves with an additional proportion reporting to eat a deceased pig only if it was believed not to have died from disease (6.3%).

3.4.5.5 Biosecurity

Respondents were asked to identify any biosecurity measures used on the farm (they were provided with a definition rather than the term biosecurity). It was found that knowledge was very limited. From respondents that answered this question (n = 259), 47.9% stated that they used at least one biosecurity measure on the farm. This was found to be significantly higher in Flores (P < 0.001; West Timor: 10.4%; Flores: 30.5%; Sumba: 6.2%). An additional 40.5% did not use any procedures, with 11.6% unsure. The most frequently reported biosecurity measure used by farmers was the separation of sick and healthy animals (84.7%), followed by vaccination (47.6%). It should be noted that the term vaccination was associated with any type of injection provided to the pig. As a result, this figure is most likely an overestimate of the number of sellers vaccinating their pigs. No respondents could identify what their pigs had been vaccinated for. Traditional medicines were also classified as biosecurity measures by some farmers (8.9%).

3.4.5.6 The Use of Pigs Produced by Smallholder Farmers

It was found that 78.9% (n = 289) of respondents sold pigs produced on their farm. In contrast, 15.6% reported keeping pigs to grow on their property for their own use. Overall, 8.0% selected both options, suggesting that pig farmers kept pigs for their own use (such as fattening for consumption and traditional ceremonies) while also selling some for income.

For those respondents that stated selling live pigs produced on their property, data were obtained regarding their selling methods. The majority sold their own pigs at market (81.9%; n = 254) with no differences in proportion detected across islands (P = 0.492; West Timor: 24.4%, Flores: 27.6%, Sumba: 30.0%). Alternatively, 35.0% of sellers
reported that they traded pigs directly from their residence, most commonly in Sumba \((P < 0.05;\text{ West Timor: 24.7%; Flores: 30.3%, Sumba: 44.9%})\). Only 4.7% reported that a third party individual (such as a pig collector; refer to Glossary) was involved in the sale of their pig. It should be noted that respondents were able to select more than one response. Overall, 19.7% selected both market sale and private sale. An additional 2.6% stated that they only sold pigs when they needed money.

### 3.4.6 Pig Health

#### 3.4.6.1 Clinical Signs of Sick Pigs

A large proportion (93.8%; \(n = 292\)) of respondents stated that they could recognise at least one clinical sign of a sick pig. No differences were detected across islands \((P = 0.717;\text{ West Timor: 31.0%, Flores: 34.7%, Sumba: 34.3%})\). Those clinical signs that were recognised most predominantly were loss of appetite (78.5%), diarrhoea (60.2%) and tiredness (58.4%). Sellers from Sumba and Flores had a greater tendency to recognise loss of appetite compared to West Timor \((P < 0.001;\text{ West Timor: 18.1%, Flores: 40.0%, Sumba: 41.9%})\). Moreover, sellers from Sumba reported a higher frequency for recognising diarrhoea in comparison to West Timor and Flores \((P < 0.001;\text{ West Timor: 26.7%, Flores: 24.8%, Sumba: 48.5%})\). Signs such as drooping ears, red eyes and standing hair were also considered as evidence that a pig was sick \((15.7%, 53.3% \text{ and } 22.3\% \text{ respectively})\). Some respondents reported observing red spots on the body \((2.2\%)\), pigs having an unsteady gait \((4.6\%)\), a swollen neck \((3.1\%)\), and discharge from the eyes or nose \((3.6\%)\).

#### 3.4.6.2 Actions Towards a Sick Pig

When a pig was sick, the majority of pig sellers reported providing traditional medicine to their animal \((76.3\%; n = 279\)). A further 9.7% of respondents stated that they used leis as a method to get rid of their sick pig/s, predominantly seen in Sumba \((P < 0.001;\text{ West Timor: 0.0%, Flores: 6.9%, Sumba 93.1%})\). In addition, 14.7% reported doing nothing if they had a sick pig. Respondents that selected ‘Other’ as their response included answers such as calling a vet \((2.1\%)\) and reporting the incident to either a government officer or field extension agent (FEA) \((1.4\%)\).

#### 3.4.6.3 Disposal of Dead Pigs at the Market

The disposal of dead pigs at the market was important to consider in relation to hygiene and biosecurity. Over a third \((38.6\%; n = 272)\) of respondents reported burying dead pigs. Two pig sellers stated that if the animal had died of suspected disease, the animal was
buried. However, if it died of natural causes, the pig would be consumed. Respondents who selected ‘throw away’ (19.0%) reported that the pig’s remains were thrown onto grazing land or in the forest. Other responses included taking the dead pig home for consumption (5.7%) and leis (3.8%). Twenty respondents chose not to answer this question.

3.4.6.4 Reporting Sick or Dead Pigs at the Market

Only 1.0% (n = 273) of respondents stated that they would report a sick pig to the animal health authorities, with a further 10.6% (n = 273) stating they would report a pig death occurring at the market.

A key issue identified for low reporting rates was a lack of personnel to report cases to (24.9%; n = 217; Table 3.9). This was found to be significantly higher in West Timor in comparison to Flores (P < 0.05: West Timor: 50.9%, Flores: 12.3%, Sumba: 36.8%) with respondents stating no officers or animal health workers were available to report to in the market or village. Furthermore, these pig sellers had minimal knowledge about who to report to (9.7%), why there was a need for reporting (4.5%), and, due to concerns of financial loss, people were choosing not to report (4.5%). Sellers from Sumba reported the most concern about a price reduction or loss of a sale due to reporting.
Table 3.9
Reasons why sick or dead pigs at market are not reported to animal health authorities by pig sellers across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 217).

<table>
<thead>
<tr>
<th>Reasons why sick/dead pigs are not being reported</th>
<th>Round 1</th>
<th></th>
<th>Round 2</th>
<th></th>
<th>TOTAL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>n</td>
<td>110</td>
<td>76.39</td>
<td>107</td>
<td>72.30</td>
<td>217</td>
<td>74.32</td>
</tr>
<tr>
<td>No officer to report to</td>
<td>33</td>
<td>30.00</td>
<td>21</td>
<td>19.63</td>
<td>54</td>
<td>24.88</td>
</tr>
<tr>
<td>Not sure who to report to</td>
<td>1</td>
<td>0.91</td>
<td>20</td>
<td>18.69</td>
<td>21</td>
<td>9.68</td>
</tr>
<tr>
<td>Don’t know</td>
<td>8</td>
<td>7.27</td>
<td>12</td>
<td>11.21</td>
<td>20</td>
<td>9.22</td>
</tr>
<tr>
<td>Afraid if report, no sale or price reduction</td>
<td>10</td>
<td>9.09</td>
<td>0</td>
<td>0.00</td>
<td>10</td>
<td>4.61</td>
</tr>
<tr>
<td>No need to report a sick/dead pig</td>
<td>5</td>
<td>4.55</td>
<td>4</td>
<td>3.74</td>
<td>9</td>
<td>4.15</td>
</tr>
<tr>
<td>Far from officer</td>
<td>4</td>
<td>3.64</td>
<td>2</td>
<td>1.87</td>
<td>6</td>
<td>2.76</td>
</tr>
<tr>
<td>Did not know to report</td>
<td>2</td>
<td>1.82</td>
<td>0</td>
<td>0.00</td>
<td>2</td>
<td>0.92</td>
</tr>
<tr>
<td>If report to government, no follow up</td>
<td>1</td>
<td>0.91</td>
<td>0</td>
<td>0.00</td>
<td>3</td>
<td>1.38</td>
</tr>
<tr>
<td>Unaware of regulations for reporting</td>
<td>1</td>
<td>0.91</td>
<td>0</td>
<td>0.00</td>
<td>1</td>
<td>0.46</td>
</tr>
</tbody>
</table>

3.4.7 Transportation of Pigs to Market

3.4.7.1 Transportation Methods

Transportation of pigs by truck (37.0%; n = 292) and motorbike (35.6%) were the most common methods used by sellers. A small proportion of respondents reported using ferry transportation (5.1%) that was limited to movement between Flores and Sumba ferry ports. The majority of sellers (60.7%) rented vehicles to transport pigs to and/or from the marketplace. In addition, public transportation methods such as ojeks (24.6%) and biskayus (8.3%) were commonly used (refer to Glossary). Only 9.8% reported having their own vehicle to transport pigs.

The types of pig restraints used were similar across islands. A large proportion (83.1%; n = 290) of respondents stated that they tied their pigs up during transportation (Figure 3.9 and 3.10), while the remaining 16.9% did not restrain their pigs.
3.4.8 Knowledge and Perceptions of Classical Swine Fever

3.4.8.1 Knowledge of CSF

The majority (85.2%; n = 290) of pig sellers stated they did not know what CSF was. A further 2.4% stated that they were not sure. Ultimately, only 36 pig sellers (12.4%) reported knowing anything about the disease. A greater proportion of sellers from Sumba had knowledge of CSF ($P < 0.001$; West Timor: 6.7%, Sumba: 93.3%) with no sellers from Flores reporting any previous knowledge of the disease.

Regarding knowledge of clinical signs, out of the 36 respondents that stated that they knew what CSF was, only 30 could identify at least one of its clinical signs. The data presented in Table 3.10 represent the clinical signs of CSF that pig sellers reported being able to identify and recognise. An unsteady gait (86.7%), diarrhoea (83.3%), and anorexia (76.5%), had the highest levels of recognition in association with CSF.
Clinical signs of classical swine fever recognised by pig sellers across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 30).

<table>
<thead>
<tr>
<th>Clinical signs known</th>
<th>Round 1</th>
<th>Round 2</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>n</td>
<td>15</td>
<td>10.42%</td>
<td>15</td>
</tr>
<tr>
<td>Unsteady gait</td>
<td>11</td>
<td>73.33%</td>
<td>15</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>12</td>
<td>80.00%</td>
<td>13</td>
</tr>
<tr>
<td>Anorexia</td>
<td>11</td>
<td>73.33%</td>
<td>12</td>
</tr>
<tr>
<td>Fever</td>
<td>9</td>
<td>60.00%</td>
<td>13</td>
</tr>
<tr>
<td>Purple/red skin discolouration</td>
<td>10</td>
<td>66.67%</td>
<td>8</td>
</tr>
<tr>
<td>Tiredness</td>
<td>5</td>
<td>33.33%</td>
<td>0</td>
</tr>
<tr>
<td>Red eyes</td>
<td>2</td>
<td>13.33%</td>
<td>1</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>6.67%</td>
<td>2</td>
</tr>
</tbody>
</table>

3.4.8.2 Selling of Pigs with Suspected CSF in the Market

According to the pig sellers interviewed, only three respondents in Sumba stated previously selling a pig with suspected CSF at a market. Round 1 of interviews saw no reports of the disease. However, in round 2, three respondents reported cases in the market in Sumba. Out of these individuals, one case was reported to have occurred in October 2009 at Wetabula Market. The other two CSF cases were reported to have occurred within the last year in Melolo and Wetabula Markets. All pigs were cross-breeds. No further details were provided by respondents for these suspect CSF cases, nor were they confirmed by laboratory testing.

3.4.8.3 Likelihood of Reporting Suspected CSF Cases

The extent to which sellers were likely to report suspect CSF cases to the animal health authorities varied. The highest proportion of sellers stated that they were not sure (12 respondents), with a further 13 stating they would be likely to report. However, five individuals stated they would be unlikely to report any cases due to the long distance between their village and the city.

3.4.8.4 Sources of Knowledge for CSF

The most commonly reported source of CSF information was from FEA (44.4%; n = 36). This was most commonly found in Sumba (P < 0.001; West Timor: 6.25%; Flores: 0.0%;
93.8%). Additional information sources included the newspaper (38.8%), family and friends (38.8%), other sellers at the market place (13.9%) and the radio (5.6%).

3.4.9 Pig Slaughtering Practices

3.4.9.1 On-Farm Pig Slaughtering

This study found that 46.0% (n = 289) of pig sellers slaughtered pigs on their property. Of those individuals slaughtering pigs, 97.7% (n = 133) slaughtered pigs that they produced and/or raised on their farm, while an additional 3.8% reported that they slaughtered pigs owned by other individuals in their village.

Three respondents stated that slaughtering also occurred at the location of traditional ceremonies in addition to their residence. For pigs that undergo backyard slaughter, the most common use of meat was consumption at the household level (94.7%). Only 7.6% reported selling meat at the market.

Regarding carcass disposal, the most common practice identified was throwing it away (70.2%; n = 133). A further 20.6% burnt it, while only two additional respondents reported feeding waste directly to their pigs.

3.4.9.2 Slaughtering by Other People

It was further clarified that 32.0% (n = 278) of respondents had another individual slaughter pigs for them. Only one respondent, from Watabula Market in Sumba, used an abattoir to slaughter pigs. The majority of respondents reported that a family member (41.3%), or a neighbour (33.6%), would assist in slaughtering their pigs.

3.5 Results—Pig Buyers at Market

3.5.1 Respondent Demographics

3.5.1.1 Gender

Most pig-buyer interviewees were male (87.2%; n = 281). Relative to the gender ratio observed in sellers, there was a greater proportion of females among pig buyers (12.8%).

3.5.1.2 Age

The age of pig buyers was similar to that of pig sellers with a large range from 23 years to 75 years of age (n = 281). The overall mean for both interview rounds was 41.85 $\pm$ 10.10 years of age.
3.5.1.3 Education
Primary school had the highest completion rate amongst pig buyers (41.1%; n = 280), with fewer individuals completing high school (18.9%). Flores had the highest number of individuals who had completed primary school (38.3%), in contrast to West Timor, which had the lowest completion rate (27.1%). This corresponded with the pig seller results, with Flores also having the highest percentage of individuals completing primary school.

3.5.1.4 Religion
The majority of pig buyers were Catholics and Protestants (57.7% and 39.1% respectively; n = 279). A small proportion of individuals from Sumba practised Marapu (3.0%).

3.5.1.5 Primary and Secondary Occupation
Over half of pig buyers (65.9%; n = 276; four individuals did not provide a response) stated that farming was their primary occupation. A variety of secondary occupations were recorded (n = 149) most commonly: pig selling (8.7%) and livestock selling (14.8%).

3.5.2 Respondent Background

3.5.2.1 Live Animals and Products Purchased at Market
In addition to live pigs, respondents also reported purchasing live chickens (67.7%; n = 127), live goats (36.2%), and live dogs (29.1%) at market. Results showed that it was not as common to purchase live cattle or buffaloes at market (7.9% and 2.4% respectively). In addition, no individuals reported purchasing any meat products. The low response rate was due to the large number of respondents that did not purchase additional live animals or animal products at market resulting in this question not being answered.

3.5.3 Live Pig Purchasing—Preferences and Drivers

3.5.3.1 Volume of Live Pigs Purchased by Consumers at Market
The mean number of pigs purchased did not significantly differ between interview rounds ($P = 0.093$; back-transformed means, round 1: 1.56 ± 1.09.; round 2: 1.30 ± 1.12). More locally bred pigs were purchased ($P > 0.001$; back-transformed means, local breed: 1.69 ± 1.04; cross-breed: 1.20 ± 1.14). No significant difference was detected between islands ($P = 0.709$; West Timor: 1.38 ± 1.19; Sumba: 1.48 ± 1.21). Weaners, growers and fatteners were more commonly purchased than sows ($P > 0.05$; back-transformed means, weaner: 1.54 ± 1.12; grower: 1.55 ± 1.14; fattener: 1.67 ± 1.13; sow: 1.10 ± 1.08; boar: 1.34 ±
As seen in Table 3.11, pig buyers from Sumba purchased more growers and fatteners in comparison to West Timor’s pig buyers.

A total number of 326 local bred pigs and 196 cross-bred pigs were purchased. Buyers from Sumba purchased a significantly higher proportion of cross-bred pigs in comparison to West Timor and Flores ($P > 0.001$; West Timor: 8.3%; Flores, 9.7%; Sumba: 82.0%). The largest proportion of local pigs was purchased in West Timor and Sumba ($P > 0.001$; West Timor: 41.9%; Flores, 11.9%; Sumba: 46.2%).

Table 3.11
The number of pig buyers purchasing different pig age groups at market stratified by island and breed across two days of market trade in West Timor and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 ($n = 281$).

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Island</th>
<th>No. Buyers</th>
<th>Total Pig No.</th>
<th>% of Local</th>
<th>% of Cross-breed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weaner</td>
<td>West Timor</td>
<td>10</td>
<td>18</td>
<td>94.44</td>
<td>5.56</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>31</td>
<td>58</td>
<td>58.62</td>
<td>41.38</td>
</tr>
<tr>
<td>Grower</td>
<td>West Timor</td>
<td>27</td>
<td>52</td>
<td>92.31</td>
<td>7.69</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>62</td>
<td>116</td>
<td>63.79</td>
<td>36.21</td>
</tr>
<tr>
<td>Fattener</td>
<td>West Timor</td>
<td>28</td>
<td>65</td>
<td>87.69</td>
<td>12.31</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>64</td>
<td>111</td>
<td>38.74</td>
<td>61.26</td>
</tr>
<tr>
<td>Sow</td>
<td>West Timor</td>
<td>14</td>
<td>18</td>
<td>83.33</td>
<td>16.67</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>19</td>
<td>24</td>
<td>41.67</td>
<td>58.33</td>
</tr>
<tr>
<td>Boar</td>
<td>West Timor</td>
<td>14</td>
<td>20</td>
<td>90.00</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>31</td>
<td>40</td>
<td>25.00</td>
<td>75.00</td>
</tr>
</tbody>
</table>

### 3.5.3.2 High-demand Months for Purchasing

The high-demand months for pig purchasing are from August (30.0%; $n = 273$, eight individuals did not provide a response) to October (29.7%) with a peak reached during September ($P < 0.001$; 37.7%; Figure 3.11). This trend corresponded with months reported by pig sellers as high-demand months for pig sales at market. In relation to island stratification, Sumba showed significantly higher movement across this three-month period than Flores ($P < 0.001$; West Timor: 26.0%, Flores: 24.5%, Sumba: 46.9%). A large proportion of individuals were also unsure of any high-demand periods during the year (42.2%).
Common reasons provided for these peak periods included traditional ceremonies (38.6%): September being a month for wedding parties (17.2%), and May until July having a higher availability of pigs due to households selling pigs for the beginning of the school term resulting in lower prices (5.5%; Table 3.12). These drivers were supported by pig-seller data. Only 145 respondents provided reasons for high-demand months.

Table 3.12
Drivers for high demand months for pigs reported by pig buyers at markets across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009.

<table>
<thead>
<tr>
<th>Drivers for high demand months</th>
<th>Round 1</th>
<th>Round 2</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>n</td>
<td>84</td>
<td>58.33</td>
<td>61</td>
</tr>
<tr>
<td>Traditional activities</td>
<td>35</td>
<td>41.67</td>
<td>21</td>
</tr>
<tr>
<td>Party season/Many parties</td>
<td>24</td>
<td>28.57</td>
<td>20</td>
</tr>
<tr>
<td>Wedding</td>
<td>18</td>
<td>21.43</td>
<td>7</td>
</tr>
<tr>
<td>Christmas</td>
<td>16</td>
<td>19.05</td>
<td>6</td>
</tr>
<tr>
<td>Funeral</td>
<td>8</td>
<td>9.52</td>
<td>3</td>
</tr>
<tr>
<td>First communion</td>
<td>6</td>
<td>7.14</td>
<td>3</td>
</tr>
<tr>
<td>Religious activities</td>
<td>3</td>
<td>3.57</td>
<td>3</td>
</tr>
<tr>
<td>New Year</td>
<td>5</td>
<td>5.95</td>
<td>1</td>
</tr>
</tbody>
</table>
3.5.3.3 Low-demand Months for Purchasing

Low-demand months identified from pig-buyer interviews corresponded with results obtained from pig sellers at the market. A large proportion of respondents (53.5%; n = 258) were unsure which months were low demand for pig purchasing, with an additional 23 respondents choosing not to answer this question. The majority that were unsure stated that they purchased a pig only when they had enough money or when they required an animal. For the remaining pig buyers, an indication that January and February represented the lowest-demand months was obtained (25.2% and 21.7% respectively).

The reasons provided to explain why there was low-pig demand during these months revolved around several common themes. Planting season was a key focus for farmers, primarily from January to March, which was during the wet season (13.6%; n = 258), as the success of a crop ensured access to food during the dry season. One individual from West Timor stated that from January to February there was an abundance of fish at the market, so his family subsisted on fish as their main protein source instead of pork. The rainy season was also a barrier to buy pigs at market, making transportation and market conditions difficult (10.1%). Furthermore, fewer traditional ceremonies occurred at the beginning of the year (6.6%), thus there was a lower demand for pigs.

3.5.3.4 Uses of Purchased Pigs

Information was obtained regarding the purpose or end use of the pigs purchased at market. It can be seen from Table 3.13, that 40.2% (n = 281) of pig buyers purchased pigs in order to sell them. It was not specified whether this was immediately or after further fattening. This was followed by 37.4% of respondents purchasing a pig for inclusion in a traditional ceremony. A significantly higher number of buyers from Sumba were found to procure pigs for ceremonial purposes in comparison to Flores and West Timor (P < 0.001; West Timor: 19.0%, Flores: 13.3%, Sumba: 67.6%). For respondents that indicated ‘Other’, several individuals purchased a pig for different celebrations such as weddings (five respondents) and family parties (six respondents). Interestingly, two pig buyers from Flores stated that the pigs would be taken to the harbour port and sold directly to pig sellers from Sumba.
Table 3.13
Reasons for pigs being purchased at market reported by pig buyers across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (n = 281).

<table>
<thead>
<tr>
<th>Reasons for purchasing pigs at market</th>
<th>Round 1</th>
<th></th>
<th>Round 2</th>
<th></th>
<th>TOTAL</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
<td>No.</td>
<td>%</td>
</tr>
<tr>
<td>n</td>
<td>144</td>
<td>100.00</td>
<td>137</td>
<td>100.00</td>
<td>281</td>
<td>100.00</td>
</tr>
<tr>
<td>Home consumption</td>
<td>15</td>
<td>10.42</td>
<td>14</td>
<td>10.22</td>
<td>29</td>
<td>10.32</td>
</tr>
<tr>
<td>Keep live on farm/property</td>
<td>50</td>
<td>34.72</td>
<td>42</td>
<td>30.66</td>
<td>92</td>
<td>32.74</td>
</tr>
<tr>
<td>Sell the pig</td>
<td>62</td>
<td>43.06</td>
<td>51</td>
<td>37.23</td>
<td>113</td>
<td>40.21</td>
</tr>
<tr>
<td>For customer order</td>
<td>19</td>
<td>13.19</td>
<td>5</td>
<td>3.65</td>
<td>24</td>
<td>8.54</td>
</tr>
<tr>
<td>Religious festival</td>
<td>20</td>
<td>13.89</td>
<td>4</td>
<td>2.92</td>
<td>24</td>
<td>8.54</td>
</tr>
<tr>
<td>Traditional festival</td>
<td>63</td>
<td>43.75</td>
<td>42</td>
<td>30.66</td>
<td>105</td>
<td>37.37</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>11.11</td>
<td>9</td>
<td>6.57</td>
<td>25</td>
<td>8.90</td>
</tr>
</tbody>
</table>

3.5.3.5 Market Selection for Pig Purchase

The most frequently reported market selection characteristic was based on the types of pigs sold at a market (59.0%; n = 278). Other common responses included choosing a market due to its close proximity to a residence (32.0%), or due to cheaper pig prices (13.3%).

It was found that 28.1% (n = 281) of respondents purchased pigs at two or more markets. This did not differ significantly across islands (\( P = 0.997; \) West Timor: 35.4%, Flores: 31.6%, Sumba: 32.9%).

3.5.3.6 Most Common Sources Used to Purchase Live Pigs

In addition to purchasing live pigs from the market, respondents also reported purchasing pigs directly from another farmer (17.8%). Sumba had the largest proportion of pig buyers reporting that they purchased directly from farmers (\( P > 0.001; \) West Timor: 12.2%, Flores: 8.1%, Sumba: 79.6%).

Only 3.1% of live pig consumers reported ever purchasing pig meat at markets. Alternative pig meat products, including smoked or dried pork or sausages, were also, according to their reports, not purchased.

3.5.3.7 Purchasing Times for Live Pigs at Market

A large proportion of pig buyers stated that they purchased pigs at market during the morning hours (87.1%; n = 280). This time frame ranged from 3am to 11am, with
transactions most commonly occurring between 5am to 8am. Alternatively, Camplong Market in West Timor functioned predominantly as a night market, where it reached peak functioning between 10pm–2am on Friday nights. Pigs could still be purchased early Saturday morning until approximately 9am (refer to Chapter 4).

3.5.3.8 Desire for Purchasing Disease-Free Pigs

Pig buyers were questioned regarding any steps taken to ensure that the pigs they purchased were free of disease. A total of 80.3% (n = 279) confirmed that they do check pigs visually prior to purchase including assessing the physical condition (62.9%), the condition of the eyes (18.3%), and observing pig bristles on the body (16.5%). For ‘observing the physical condition’ specifications included ‘looking if the body was fat’, ‘was the pig looking fresh’ and ‘was the pig steady on its feet’. In regards to observing the condition of the eyes, specifications included ‘looking to see if the eyes were red or clear’. Some respondents reported observing the pig bristles to see ‘how easily they fell out’. Another respondent stated that they kick the pig and if there is minimal movement, the animal was classified as sick and not purchased.

3.5.4 Pig Health

Pig buyers were questioned about their knowledge of pig health. A large proportion, (87.9%; n = 281), of respondents were aware of at least one clinical sign that indicated that a pig was sick, and this was similar across islands ($P = 0.265$; West Timor: 32.7%, Flores: 29.5%, Sumba: 37.8%).

A loss of appetite (65.5%), red eyes (61.5%) and tiredness (61.1%) were the most commonly identified clinical signs associated with a sick pig. Red eyes were more commonly associated with a sick pig in West Timor and Sumba ($P < 0.001$; West Timor: 34.19%, Flores: 18.71, Sumba: 47.10%). Only 25.0% of respondents recognised a fever, with a further 21.4% reporting drooping ears to be a clinical sign of a sick pig.

3.5.5 Transportation and Destination of Pigs

3.5.5.1 Pig Destination Following Purchase

A large proportion of respondents stated that following purchase of a pig at market, the pig was transported directly home (90.8%; n = 281). Abattoir usage was minimal, with only 1.1% using these facilities. Only 6.1% reported transporting a pig directly from one market to another to sell.
3.5.5.2 Transportation Methods

The most common transportation methods utilised by pig buyers leaving the market included trucks and motorbikes (33.8% and 27.8% respectively; n = 281). This was similar to that of pig sellers. No ferry transportation was reported. Results demonstrated that 66.5% (n = 275) of respondents used a rented vehicle to collect pigs from market and 10.2% used their own vehicle. Only one respondent reported performing any form of cleaning of vehicle/s between uses, with the remaining buyers chose not to answer the question. It was found that 83.3% (n = 275) of pig buyers tied up pigs for transportation (Figure 3.9 and 3.10). A further 12.0% did not provide any restraint method.

3.5.5.3 Pig Buyers as Smallholder Farmers

The majority of pig buyers (87.1%; n = 271) reported that they kept pigs on their property. This was similar across islands (P = 0.06; West Timor: 26.3%, Flores: 35.3%, Sumba: 38.6%). Ten respondents chose not to answer this question. Results demonstrated that 64.4% kept pigs for income, which was a common finding observed across all three islands (P = 0.495; West Timor: 29.6%; Flores: 38.8%; 31.6%). A further 46.6% stated the reason for keeping pigs was to use in traditional ceremonies. Buyers from Sumba reported the use of pigs more frequently for traditional ceremonies (P < 0.001; West Timor: 5.5%; Flores: 24.5% and Sumba: 70.0%). An additional 31.8% reported keeping pigs for sale in order to obtain money to educate their children. This particular use of pigs was reported across the entire province, predominantly in Sumba (P < 0.001; West Timor: 12.0%; Flores: 32.0% and Sumba: 56.0%).

3.5.5.4 Biosecurity

Pig buyers were questioned about their knowledge of biosecurity and whether as a smallholder farmer, they implemented any methods on-farm. The majority (95.7%; n = 281) had no prior knowledge of the term biosecurity. For those with no knowledge, respondents were then provided a definition of biosecurity (refer to Glossary). Among these individuals, 48.8% (n = 254) stated they performed at least one biosecurity on-farm measure, 13.9% were unsure of any methods, and 15 respondents chose not to respond. The presence of at least one biosecurity on-farm measure was greater for individuals from Flores in comparison to Sumba (P < 0.001; West Timor: 24.4%, Flores: 58.5%, Sumba: 17.1%).
For those that specified implementing biosecurity measures, 37.7% of pig buyers separated sick and healthy pigs, predominantly seen in Flores ($P < 0.05$; West Timor: 26.7%, Flores: 50.0%, Sumba: 23.3%). Vaccination was stated by 23.8% of respondents. However, out of these respondents, no individuals could provide details regarding vaccine type. Similar to pig sellers, respondents referred to any injection given to their pig as a vaccination, with no distinction made between injection types.

### 3.5.6 Knowledge and Perception of Classical Swine Fever

#### 2.5.6.1 Knowledge of CSF

For pig-buyer respondents, the majority did not have any prior knowledge of CSF (83.2%; $n = 281$). The largest proportion of individuals aware of this disease were from Sumba (30 respondents) with the remainder from West Timor (13 respondents). No one from Flores reported hearing of the term CSF or knowing what the disease was.

Of the 43 buyers that reported having some knowledge of CSF, only 35 of them could identify at least one clinical sign of this disease. The most recognised clinical signs associated with CSF were diarrhoea (85.7%), anorexia (80.0%), and fever (71.4%). A large proportion of respondents also recognised skin discolouration, specifically either red or purple marks on the skin, as a clinical sign of the disease (68.6%; $n = 35$).

#### 2.5.6.2 Purchasing of Pigs with Suspected CSF in the Market

In round 1, out of 35 respondents with knowledge of CSF, no reports were made of suspect CSF cases in the market. In round 2, two suspected cases were recorded. These cases were from Sumba and were said to be in 2008 and 2009 at Melolo and Wetabula markets. The pig breed in both cases was local. One respondent stated that the pig was purchased and immediately slaughtered for consumption on arrival at home. The remaining buyer stated that the purchased pig was taken home and introduced to their herd. No further details were provided.

#### 2.5.6.3 Likelihood of Reporting Suspected CSF Cases

When respondents were asked how likely they were to report suspect CSF cases seen at the market or on-farm to animal health authorities, approximately half (50.2%; $n = 28$) selected ‘unsure’ as their response with seven individuals choosing not to respond. Only 25.3% stated that they would be likely to make a report. Only one response for non-
reporting was recorded, which stated the distance from their village to town was too far to travel.

3.5.6.4 Sources of Knowledge for CSF

Similar to market sellers, the newspaper and FEAs were common sources of information about CSF reported by 62.9% (n = 35) and 57.1% of buyers, respectively.

3.5.7 Pig Slaughtering Practices

3.5.7.1 On-farm Pig Slaughtering

A large proportion of pig buyers (48.9%; n = 280) reported slaughtering pigs on their property. The highest percentage was identified on Flores, significantly higher than West Timor ($P < 0.05$; West Timor: 24.7%, Flores: 41.7%; Sumba: 33.8%). It was found that 97.8% (n = 137) of respondents reported slaughtering their own pigs, with only three respondents slaughtering pigs owned by someone else. Only 2.2% reported using an abattoir. An alternative method identified was transporting the pigs to the location of a traditional ceremony where the animal would then be slaughtered (2.2%).

The majority of respondents (79.2%; n = 144) slaughtered pigs for consumption at the household level. Selling meat at the market was minimal (8.3%). It was further noted that 6.9% of respondents chose to sell meat to their family and friends. The method of leis and cooking se’i was also reported by 1.2% of those interviewed (refer to Glossary).

For carcass waste disposal following slaughter, the majority of pig buyers (75.7%; n = 136) reported ‘throwing it away’. A smaller proportion (19.9%) chose to burn their waste with 2.2% using it for fertiliser. No participants reported feeding carcass waste to pigs.

3.5.7.2 Peak Slaughtering Months for Pigs

In common with the trend for high pig-demand months reported by pig sellers and buyers, the highest number of pigs slaughtered occurred from August through to October (22.6%, 20.6% and 14.0% respectively; n = 136). An increase during December (14.7%) was identified as corresponding with an increase in traditional and religious ceremonies. A low period experienced during November saw only 5.8% elect to slaughter during this time. This was continued with a low period during the rainy season across January, February and March with minimal reported incidents of slaughter (1.5%, 1.5% and 0.0% respectively).
3.5.7.3 Slaughtering by Other People

Over a third (35.6%; n = 274) of respondents reported having a third party involved in the slaughtering of their pigs, seven individuals chose not to respond. Only a small proportion (6.2%) utilised an abattoir for slaughter with the majority obtaining help from farmers within their village (54.7%), or family and neighbours (25.7%), when wanting to slaughter a pig.

3.6 Discussion

The purpose of this market study was to investigate the pig market chain, live pig market characteristics and practices of pig sellers and pig buyers with the aim of identifying high-risk practices that may be contributing to CSF transmission. This was to help guide decision making for the development of mitigation strategies to control CSF. This study found market management practices, lack of biosecurity and CSF knowledge by sellers and buyers, on-farm pig management and pig movement practices to pose a risk for CSF transmission.

3.6.1 Characteristics of Pig Market Chain

The trade of live pigs dominated the market chain, with few respondents reporting that they bought pork. Due to cold chain factors, individuals elected to trade in live pigs to maintain meat quality and longevity. A very small proportion (1.5%) of respondents reported that they sold pork. When pork was sold, this generally occurred only in markets located in urbanised areas, where refrigeration was accessible. Income is much lower in rural areas of eastern Indonesia and, as a result, consuming pork on a daily/weekly basis is not economically viable for the majority of households (Wang, 2007).

Identifying movement patterns performed by sellers and buyers needed to be assessed to understand movement networks for formal pathways through markets. Over half of the sellers (52.1%) reported selling their own pigs at market. This indicated that a large proportion of pig sellers were coming directly from their village to market. This was also found to be the case for pig buyers who reported taking pigs directly home from the market following purchase. This is in contrast to the live bird market chain in Bali where middlemen, such as collectors and traders, have specific roles along the market chain collecting poultry from a variety of sources and taking them to market (Roche et al., 2011; Santhia et al., 2009). For NTT, the market chain demonstrated the integration of roles with
smallholder farmers being sellers and buyers, with few reports of collectors. Over one third of sellers also reported that they traded pigs at more than one market. Lemke et al. (2006) found that pig-production households close to town in Vietnam were more market orientated, whereas villages far from town had a stronger utilisation of pigs for sociocultural and financial reasons. This further influenced the configuration of movement patterns and the distances that pigs were moved. It should also be noted that the survey presented in Chapter 5 found that farmers were trading 25.6% of pigs through markets with other pathways including informal movements utilised.

Annual movement trends for both sellers and buyers identified a strong seasonal influence. Periods of high frequency and high-volume movement can lead to an increase of direct contact between susceptible animals (Webb, 2006). The months of August through to October were reported as being peak movement months corresponding with high numbers of traditional ceremonies and weddings. A continual supply of pigs was important during these periods to meet the cultural demand, further driving movements across and between islands. The wet season spans from December through to March, and the dry season from April to November (Asih et al., 2009). The heavy rainfall experienced during the wet season can often hinder transportation into and out of villages. During this time farmers’ efforts are concentrated on other agricultural activities such as working in the fields.

Market operating days supported the ability of individuals to move between markets. Several respondents reported that when attending a market for the purposes of selling a pig, if they were not successful, they would continue to another market to sell their pig. As the majority of livestock markets operate weekly, this allowed individuals to move to different locations in order to obtain the best price for their pig. West Timor was identified as having the largest proportion of sellers trading pigs at two or more markets. This could be due to better road infrastructure in comparison to Flores and Sumba with some livestock markets having consecutive market days (BPS Statistics, 2009; Patunru et al., 2010).

The age and breed of pigs entering the marketplace must be evaluated as these factors can influence CSF transmission (Floegel-Niesmann et al., 2003). The age of a pig and the age at which CSF infection occurs can impact the clinical outcome of the disease (Artois et al., 2002; Moennig et al., 2003). As pigs increase in age, clinical signs become less specific and mortality rates lower (Artois et al., 2002; Moennig et al., 2003). Grower and fattener age groups were most commonly reported in the markets in NTT. Wetabula Market in Sumba had the largest number of pigs entering the market, predominantly of fattener age
Sumba's high demand for live pigs to slaughter for use in traditional ceremonies represents a vital component of the market chain. Fattener pigs ready for slaughter are highly sought after by households to fulfill demand for pork consumption at these events. This further corresponds with pig prices, which tended to be significantly higher on Sumba in comparison with West Timor for different age groups. Sellers from Flores reported transporting pigs to Sumba to obtain these higher prices. Movement of pigs to higher priced markets has been found in other parts of South-East Asia (Cocks et al., 2009).

The presence of both local and cross-breed pigs were identified at market. A larger proportion of local pigs were traded in comparison to cross-breeds. A study conducted by Blacksell et al. (2006) identified breed differences regarding CSF infection. The indigenous Moo Laat pig from Lao PDR and Large White/Landrace cross (LWC) were infected with the CSF genotype 2.2. This moderately virulent strain caused infection in both breeds (Blacksell et al., 2006; Weesendorp et al., 2009a). However, the exotic breed was found to have a shorter survival period and the indigenous breed had a delayed onset of clinical signs (Blacksell et al., 2006; Khounsy et al., 2007). This study suggests that infected local pigs may represent a greater risk for CSF spread because they have the potential to appear healthy for a longer time period before displaying clinical signs. An additional study investigating breed differences was conducted by Sun et al. (2011). It was found that Chinese Bama miniature pigs infected with highly virulent CSF (Shimen strain) developed clinical signs and pathological changes consistent with CSF infection seen in domestic pigs. Clinical signs developed quickly with fever appearing as early as two days post infection with all inoculated pigs (n = 15) and one pig infected by direct contact dying by 15 days post infection.

Seller and buyer respondents both reported the common practice of backyard slaughter. Due to a lack of slaughterhouse facilities and other factors including village location and minimal income, the majority of households slaughtered at their residence. The process of slaughtering pigs in NTT province needs to be considered as a potential risk for CSF transmission due to the potential for swill feeding resulting from improper carcass disposal (Fritzemeier et al., 2000). There are a total of 19 slaughterhouses currently across the province with the majority of government and private slaughterhouses located in West Timor and Flores respectively (Table 2.4) (BPS Statistics, 2009).
3.6.2 Seller and Buyer Characteristics

It was confirmed that market sellers often have multiple roles along the market chain. Respondents verified that the majority of sellers were also smallholder pig farmers. The use of pig collectors was minimal, with those reporting to be collectors also bringing pigs from their own property to market. The flexibility of pig-trade transactions allowed individuals to sell according to their needs. The presence of permanent sellers was also identified at market (41.1%). The role of a permanent seller has limited influence on pig movements as these individuals remain at market to sell pigs. By purchasing pigs directly from farmers who come to market, permanent sellers play the role of a middleman assisting farmers who do not want to remain at market to sell.

For pig buyers within NTT, there are a variety of drivers boosting the sale of live pigs, such as weddings, funerals, traditional ceremonies and parties. Overall, traditional ceremonies were found to have the greatest influence on consumers, particularly in Sumba. Weddings can also be a significant influence as a dowry needs to be paid, which can often consist of up to 40 pigs, depending on the social status of the female (Geong M. pers comm, 2011). For these respondents, the most common sources used to purchase live pigs were identified as live pig markets and directly from farmers.

The food provided to a pig also poses a risk for CSF transmission. The ability of a pig to become infected with CSFV as a result of eating swill has been supported by the literature (Edwards, 2000; Moennig et al., 2003). Fritzemeier et al. (2000) determined that swill feeding was the second major cause for primary outbreaks of CSF in both domestic pigs and wild boars in Germany during the 1990s. Our study identified that 53.5% of respondents reported feeding table scraps to their on-farm pigs with an additional 5.5% sourcing feed scraps from external waste sources. This has been reported by other smallholder farmers in developing countries (Kagira et al., 2010). The length of time that CSFV can survive in meat depends on its storage and processing (Edwards, 2000; Panina et al., 1992). The most stable environment for virus survival is frozen pork, with survival times of up to four years recorded (Edwards, 2000). The minimal cold chain in NTT limits extreme cases. At room temperature storage (20°C) CSFV was able to survive for up to four days (Edwards, 2000). Other food sources provided to the pigs are similar to that of smallholder pig farmers in other areas of South-East Asia, including Vietnam and Cambodia (Lemke et al., 2006; Samkol et al., 2006).
The majority of seller and buyer respondents were found to have smallholder pig herds. Herd size information was only obtained from seller respondents and it was found that on-farm herd sizes varied between islands. The analysis conducted considered only pigs of marketable age (from $\geq 2$ months of age, excluding piglets). The purpose of this was to focus on those pigs that would be entering the pig market chain. Conventional weaning generally occurs between 3–5 weeks (Roese & Taylor, 2006). On smallholder farms across South-East Asia in countries such as Vietnam and the Philippines, weaning age tends to be greater, around 6–8 weeks (Hong et al., 2006; Lemke & Valle Zarate, 2008b; More et al., 2005).

Pig sellers and buyers had relatively good knowledge of clinical signs that allowed them to identify sick pigs. This finding has been replicated in other studies with smallholder farmers in developing countries (Kagira et al., 2010). However, respondents were not able to associate a particular illness with specific signs. Knowledge of CSF-specific signs was extremely minimal. The implementation of farmer educational programs can be effective in improving farmer knowledge and awareness for animal diseases (Msolle et al., 2010; Nampanya et al., 2011). By developing these skills, this can provide farmers with the ability to improve their pig health and on-farm production. Thorpe and Jemaneh (2008) identified gaps in the knowledge of smallholder pig farmers regarding pig health across South-East Asia. This is an area that needs to be improved through increased capacity building and improved communication between the government and rural villages.

Buyer interviews identified a high-risk practice involving newly purchased pigs. No matter their end usage, results demonstrated that pigs on arrival to their on-farm destination, following purchase, were placed directly within a herd already at the farm. No use of quarantine/separation was reported, allowing pigs of unknown health status to mix freely. Respondents stated that if a pig was purchased for fattening they would be placed directly into the on-farm pig herd. If a fattener was purchased for slaughter, it would be kept for 1–2 days prior to being slaughtered for the celebratory event, being mixed with the on-farm herd (Kira and Kasman, 2011). Only a very small proportion of buyers utilised an abattoir for slaughter.

A severe lack of knowledge of both CSF and biosecurity was identified among both sellers and buyers. No one from Flores reported having any prior knowledge of CSF. This could be a result of the disease status classification placed on Flores—with the western end of the island categorised ‘CSF free’ (Dinas Peternakan Propinsi, 2011). Due to this classification,
no CSF vaccination is administered in the area. A seroprevalence survey conducted in 2010 by ACIAR (AH/2006/156) suggested the presence of CSFV in District Manggarai Barat. The lack of information and limited animal health support for farmers in this area needs to be addressed in future investigations.

3.6.3 Characteristics of Markets

Management practices employed at the market had the potential to contribute to disease spread. The severe lack of biosecurity such as the absence of disinfection of the market premises, the mixing of potentially infected pigs and potential fomite contamination (including vehicles and individuals entering the market), all constitute opportunities for CSF transmission (Roman et al., 2006). The lack of education and access to information contributes to a gap in farmers’ knowledge. A focus must be placed on raising awareness of activities that contribute to disease spread. Farmers particularly need to be educated on how to mitigate these risks and minimise impacts (Msoffe et al., 2010; Mudita & Natonis, 2008; Nampanya et al., 2011)

Biosecurity is a key factor in controlling CSF and disease spread in pigs (Donaldson, 2008; Pinto & Urcelay, 2003). Some biosecurity measures were reported at two of the nine markets; however, even these were not effective strategies (refer to Chapter 4 for more details). Where cleaning of a marketplace was said to occur, this was a process of sweeping remaining faeces off concreted areas. However, it still remained at the market location (refer to Chapter 4 for details). Furthermore, pigs were able to mix at every market. It has been confirmed that direct contact poses the highest transmission risk of CSF (Weesendorp et al., 2009b). The introduction of basic biosecurity measures can assist in disease control (FAO, 2010). Thornton et al. (2008) suggested that due to the early opening and closing times of live bird markets in Bali, a practical time to clean the market was available. This could apply to some markets in NTT where concrete and basic infrastructure is present. However, some markets consisted of an open area where pigs were placed on a soil ground with no infrastructure.

This further brings into question the virus survival time of CSFV in soil and excretory waste. The survival of CSFV in faeces and urine was found to be inversely correlated to environmental temperature (Weesendorp et al., 2008b). Average temperatures across eastern Indonesia tend to be above 20ºC, which is a factor reducing the potential survival period of CSFV in the environment (Widjana & Sutisna, 2000). Extended survival periods
have been detected in faeces with a mean survival of 4.8 days detected during periods of maximum excretion by an animal. Currently, estimates of CSFV decay rate in soil have only been made based on decay rates in slurry (Gale, 2004; Haas et al., 1995).

Transportation methods are another factor influencing CSF transmission (Fritzemeier et al., 2000; Moennig et al., 2003). Contaminated vehicles were reported to be the main vectors spreading CSFV during the Netherlands outbreak in 1997 (Greiser-Wilke et al., 2000). Transportation methods were similar across the province, mostly utilising public transportation and ojeks (refer to Glossary). It was found that 60.7% of respondents were renting vehicles with minimal cleaning being performed on both rented and owned vehicles. Transportation methods present a risk for disease spread throughout the network.

3.6.4 Constraints of Survey

The proportion of sellers interviewed varied between markets (Table 3.2). The smallest proportion of sellers interviewed was at Camplong Market, where 21.0% of sellers were interviewed. This was the market that operated only at night and seller numbers were provided by the market manager. Alternatively at Wetabula and Melolo markets in Sumba, over 60.0% of sellers were interviewed reaching 100.0% at Waikabubak Market. The overall proportion of sellers interviewed was slightly lower than the original expected 50% of sellers present in market on day of interview, with 43.9% achieved overall. For pig buyers, the interviewed sample represented overall 53.6% of the buyers present at the market.

The most appropriate sampling method was used considering logistics (refer to Methodology, section 3.2.1.5, for details) and the lack of data available from selected markets on seller and buyer numbers. In terms of sampling, there was no potential to conduct formal random sampling in the market as a list of sellers could not be obtained for any of the nine markets. For an alternative approach to sample size we could consider the seller and buyer populations as one due to the fact that they were all pig raisers. The initial estimate of maximum 25 sellers per market provided by Dr Maria Geong suggests an expected total population of 50 pig raisers per market visit. For 50% prevalence of this characteristic and 5% precision, a total of 45 invididuals would need to be interviewed. For a 10% precision level 33 individuals would need to be interviewed. If we compare our results per market, a 10% precision level was achieved (Table 3.2 and 3.3).
Consideration needs to be given to interview round selection in association with its influence on pig volume reported at market. Prior to starting the study, information was obtained from local experts (Dinas Peternakan and local veterinarians) regarding high- and low-demand periods on an annual basis. This allowed appropriate months to be selected for interview rounds. The high-demand period during September has been supported by pig seller and buyer results. The low-demand period during November was also supported by results although the months of January and February were reported to have a lower demand on an annual basis. Given the wet season provided logistical restraints for this survey, November was the most appropriate low-demand month to select for this work. Overall the trend in pig numbers between rounds at the nine selected markets corresponded with high- and low-demand designations, with the exception of Mataloko in Flores and Melolo in Sumba that had more pigs present in the market during September. For Sumba, it was reported by respondents that an extended dry season was being experienced during 2009. This permitted continued movement and trade of pigs beyond November, when the rainy season typically begins during this month. The presence of bias in the interpretation of high and low-demand periods needs to be acknowledged due to the fact that the same individuals were not interviewed across both interview rounds. However, respondents from all interview rounds were able to identify months of the year when higher and lower numbers of pigs were being moved through the market chain, corresponding with our results.

To maximise data quality in this survey, interview teams underwent a training program that incorporated pilot testing of both the seller and buyer questionnaires. Focus was placed on ensuring that interview teams understood all terms used in the questionnaire and translations were correct across the different island locations. One limitation that was encountered was with age group misclassification seen on Flores. The absence of fatteners recorded in the interviews highlighted a potential problem. This issue was further supported by the observational study in Chapter 4, confirming the presence of fatteners at markets in Flores. This issue was addressed by excluding the Flores data for the relevant analyses.

3.7 Conclusions

This study has identified some important baseline information on live pig markets in NTT province. It has highlighted the multiple roles of smallholder farmers along the market
chain, for both formal market movements and informal movements directly between villages. The management practices at live pig markets have the potential to influence disease spread with a lack of biosecurity coupled with large numbers of pigs. The results from this study need to be utilised for future investigations into the development of appropriate mitigation measures for CSF that may be implemented in market settings.
Chapter 4: Investigations into Live Pig Markets across Nusa Tenggara Timur with reference to the Potential Spread of Classical Swine Fever

4.1 Introduction

A traditional market in Indonesia can be defined as a place where many sellers congregate to sell products including food, live animals and household products (Aye & Widjaya, 2006). In eastern Indonesia, a large proportion of the population lives in rural areas where traditional markets are the primary source of such products (FAO, 2010; Wang, 2007). Pigs in NTT fill important economic and social roles for smallholder farmers (Johns et al., 2009). Their trade through many traditional markets across the province provides pig sellers and consumers with an income source and access to live pigs for purchase, respectively. Markets are locations which allow mixing of pigs from different sources that also facilitating movement which enables disease transmission to occur between infected and susceptible animals (Dubé et al., 2010; FAO, 2011; Robinson & Christley, 2007). In NTT, CSF continues to be a priority disease that can be spread by pig movement (Christie, 2007; Hutabarat & Santhia, 1999). Despite this, no studies have been conducted on live pig markets in NTT to identify management and biosecurity practices that present a risk for classical swine fever (CSF) transmission.

Studies have been conducted in traditional markets in Jakarta, Indonesia, demonstrating the presence of market managers appointed by the government (Suryadarma et al., 2007). Their role is to ensure regular collection of market service fees from sellers (Suryadarma et al., 2007). Pressure is often placed on managers to ensure that income targets are achieved through this collection. As a result, poor management is often seen at market sites because the primary role of the manager is to collect retribution payments from sellers (Suryadarma et al., 2007). Biosecurity practices are often of secondary concern. This lack of biosecurity and management can facilitate disease spread. However, in NTT the presence of market managers at traditional markets has not been documented.

Observations made at market sites provide important information regarding structural attributes, management practices, biosecurity issues, consumer and seller behaviours and
practices that might pose a risk for CSF transmission. The aim of this observational study was to provide baseline information on live pig markets across Nusa Tenggara Timur by:

- Describing the physical attributes of each market site included in the repeated market survey (refer to Chapter 3).
- Identifying practices performed at markets that pose a risk for classical swine fever transmission.

4.2 Methodology

4.2.1 Market Locations

Nine market locations were included in the observational study. These are the same markets incorporated in the repeated market survey and justification for their selection is presented in Chapter 3 (Section 3.2.4).

4.2.2 Data Collection and Site Observations

Observations were conducted at markets that sold live pigs on days that live pig trade occurred. Observations using structured and semi-structured methods were recorded at each site. A set of observational categories were established prior to the study to allow comparisons to be made between markets. This involved direct observations in the market setting and open interactions with marketgoers who were aware that research was being conducted at the market site. The observational unit was the market.

An absence of market data was identified in the early stages of the study with no list of live pig markets in the province available. As a result, Dinas Peternakan departments from each district (DLS) were contacted to provide a list of all relevant markets in their jurisdiction. Data were collated on the number of live animal markets trading live pigs in West Timor, Flores and Sumba. The results are summarised in Table 2.11 (Chapter 2) and can be seen in full in Appendix 1. It should be noted that it is probable that some markets are missing from the list.

In association with the market interviews described in Chapter 3, observational recordings occurred across two days for each market site (during round 1 and round 2 of interviews). Initial observations were made during September 2009. This was followed by an additional interview day at each market during November 2009, when initial observations were checked and any additional information was recorded as appropriate.
At each site the following observations were made:

- Overall site description and sketch.
- The presence of a market manager.
- Estimates of the number of pigs present at market on the day of interviewing (including age and breed characteristics).
- Direct animal contact of pig and non-pig species present at market.
- Modes of transport that brought pigs to and from market including restraint methods utilised and pig numbers per vehicle.
- Management techniques being used including feed types, waste disposal and biosecurity practices used at market sites.
- Presence of residential areas on market sites.
- Presence of a wet market and the types of meat sold.

Pig numbers present at market were based on estimates on the day of observation. To obtain the most accurate estimate of pig numbers during peak market hours, observations were conducted over a 3–4 hour period during the conduction of face-to-face interviews (outlined in Chapter 3). On arrival at each market, baseline estimates were obtained by the observer during the market’s early opening hours. During a 3–4 hour period, repeated estimates were made to determine the total number of pigs present at market on an observational day. The total number of pigs were estimated each time to avoid counting the same animals. Where possible, a market manager was consulted to provide previous estimates of pig numbers and pig sellers at the market from 2009 to 2010. The highest count of pigs recorded at market are presented in Table 4.1.

### 4.2.3 Observer Training and Observation Refinement

The observer (E.E.C.L) was familiarised with live pig markets in NTT before commencing the observational study. Pilot testing of the seller and buyer questionnaires (refer to Chapter 3) at market locations (Camplong, Melolo and Detusoko) enabled observational categories to be refined based on preliminary observations.

### 4.2.4 Data Management and Statistical Analysis

A database was developed in Microsoft Office Excel (2007, Microsoft Corporation, Redmond, WA, USA) in which all observational data collected were entered. Descriptive analyses were conducted on the data. Due to the small sample size (n = 9), only limited statistical analysis was possible. At each market, the number of pigs present was recorded
along with details on age groups and breed. Chi-squared tests were performed to determine significant differences between proportions of pigs of a marketable age (weaner, grower, fattener, sow and boar) and breed types (local or cross-breed) on an island and market level. A z-test using a Bonferroni adjustment was used to compare which age groups and breed types were significantly different due to comparisons of multiple outcomes. Data were analysed for normality to fulfil the assumptions of a z-test. Significance was indicated by P-values < 0.05. For clarification, for ease of reporting, the term island has been used to refer to West Timor in some sections. The same definition of age groups was used for the observer and the interviews performed in Chapter 3.

### 4.3 Results and Discussion

#### 4.3.1 Overview of Live Pig Markets in Nusa Tenggara Timur

Live pig markets across NTT province are an important trading route for pigs, confirmed through the repeated market survey (refer to Chapter 3). Traditional type markets sell live pigs and other livestock species in addition to other products. From Table 2.11 and Appendix 1 it can be seen that West Timor currently has the highest number of markets where live pigs are sold, compared to Sumba and Flores. On Flores the majority of live pig markets are located in the central region of the island with no live pig markets present in Manggarai Barat, Manggarai Timur, and Flores Timur (Dinas Peternakan Propinsi, 2011). Traditional markets where livestock are sold tend to operate weekly. For markets that are a primary trading point for many different products it was found that the pig and livestock sale only occurred on particular days, despite trade being conducted daily for other goods.

#### 4.3.2 Live Pig Market Comparisons Across West Timor, Flores and Sumba

Details for each individual market included in the market survey are shown in Table 4.1. This table summarises the major findings of the observational study.
Table 4.1
Market characteristics recorded during an observational study at nine live pig markets during September and November in Nusa Tenggara Timur, eastern Indonesia, 2009.

<table>
<thead>
<tr>
<th>Island</th>
<th>Market</th>
<th>Pig Numbers¹</th>
<th>Ground Coverage</th>
<th>Shelter</th>
<th>Pig Restraint</th>
<th>Animal Contact²</th>
<th>Biosec</th>
<th>Residential Area</th>
<th>Wet Market</th>
<th>Market Manager Document</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>R1</td>
<td>R2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Timor</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camplong</td>
<td></td>
<td>103</td>
<td>100</td>
<td>S</td>
<td>No</td>
<td>T, B</td>
<td>P, G, D, C</td>
<td>No</td>
<td>Yes</td>
<td>No (s’ei babi)</td>
</tr>
<tr>
<td>Niki Niki</td>
<td></td>
<td>61</td>
<td>42</td>
<td>S</td>
<td>No</td>
<td>T, B</td>
<td>P, G, D, C</td>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Halulik</td>
<td></td>
<td>86</td>
<td>86</td>
<td>S</td>
<td>No</td>
<td>T, B</td>
<td>P, G, D, C</td>
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<td>No</td>
<td>Yes (beef)</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
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<td>120</td>
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<td>T, B</td>
<td>P, C, D</td>
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<td>No</td>
<td>No</td>
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<tr>
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<td>45</td>
<td>S, Conc</td>
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<td>T, B</td>
<td>P, G</td>
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<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Mbay</td>
<td></td>
<td>163</td>
<td>140</td>
<td>S</td>
<td>No</td>
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<td>P, G, D, C, Sh</td>
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<td>No</td>
<td>Yes (beef)</td>
</tr>
<tr>
<td>Sumba</td>
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<td></td>
<td></td>
</tr>
<tr>
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<td>No</td>
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<td>T, B</td>
<td>P, C</td>
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<td>No</td>
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<tr>
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<td>T, B</td>
<td>P, G, D, C</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

¹Pig numbers represent estimates for the total number present on an observational day; ²No cattle contact was recorded at any market location; R1: Round 1 of interviews representing high-demand period (September); R2: Round 2 of interviews representing low-demand period (November); Market Manager Document: refers to the presence of a market manager that checks documentation from pig sellers on arrival; Biosec: at least one attempted biosecurity practice present at market; Residential Area: the presence of a residential area on market site; S: soil; Conc: concrete; Bm: Bamboo; T: Tie pig up with rope or dried palm fronds; B: pig restrained in bag; P: Pig; G: Goat; D: Dog; C: Chicken; Sh: Sheep; s’ei babi: specialised process for barbequing pork.
4.3.2.1 Market Sites Included in Observational Study: Location, Site Description, Market Type and Market Layout

a. Camplong Market

Camplong Market is located in West Timor, Kabupaten Kupang, Kecamatan Fatulau and Kelurahan Camplong 1. It is approximately one hour drive north from the capital Kota Kupang. This market is a traditional type market that functions weekly. Pig trading takes place on Friday afternoons and continues through the night to early Saturday morning (Figure 4.1). Observations at this market were conducted on 18 September 2009 for round 1 and 27 November 2009 for round 2. On the Friday afternoons at approximately 4pm farmers brought their pigs to market to trade in the secondary pig selling area (Figure 4.2). Following these transactions, any remaining sellers then moved to the primary selling area at 6–7pm (Figure 4.2). Trade continued throughout the night until Saturday morning at approximately 9–10am. The marketplace began to reach peak attendance around 8pm when the majority of buyers arrived. Figure 4.2 shows the overall layout of the market.

Figure 4.1
Camplong Market early Saturday morning (7am) with pig sellers and buyers trading pigs of different ages, West Timor, Nusa Tenggara Timur, eastern Indonesia, 2009.
b. Niki Niki Market

Niki Niki Market is located in West Timor in Kabupaten Timor Tengah Selatan in Kecamatan Amanuban Tengah in Desa Niki Niki. The site for pig trading is not the official Niki Niki Market location. Pigs are sold in a site further north along the main road approximately 200m away. The pig selling site is located on a side road parallel to the official site, allowing for the separation of animal trading from other market products (Figure 4.3). Observations were conducted on 23 September 2009 and 24 November 2009. Sellers arrived at market on Tuesday nights for the official market day starting on Wednesday morning. Many sellers slept at the market to be the first available sellers in the morning for buyers. Buyers began to arrive by 4–5am and the market finished by approximately 9–10am. The market location and layout is shown in Figure 4.3.
Diagrammatic representation of Niki Niki Market layout in West Timor, Nusa Tenggara Timur, eastern Indonesia, 2009 (not to scale); PP = pig pen owned by residential houses adjacent to market; Pig Selling Area 1º: primary pig selling area; PSA 2º: secondary pig selling area.

c. Halulik Market

Halulik Market is located in West Timor in Kabupaten Belu, Kecamatan Halulik and Desa Halulik. It is approximately a 30-minute drive south from the district capital Atambua. The market is a traditional type market that operates every Thursday starting early in the morning from approximately 4–5am, with pig trade finishing around 11am–12pm. Observations were conducted on 24 September 2009 and 25 November 2009. Animal trading occurred at the front of the market site, which allowed direct road access for transportation (Figure 4.4). Market stalls were at the rear of the site and other agricultural and household products were sold throughout the day (Figure 4.4).
Mataloko Market

Mataloko Market, also known as Toda Market by locals, is located on Flores in Kabupaten Ngada, Kecamatan Golewa and Desa Toda. The closest major town to this market is Kota Bajawa, which is approximately a 30-minute drive west. This market operates daily and sells a variety of products. Pigs are sold only on Saturdays. Often transactions begin on Friday afternoon, stop during the night and resume on Saturday morning. Observations were conducted on 2 and 3 October 2009 for round 1 and 21 November 2009 for round 2. On Saturdays the pig transactions at the market started around 6–7am and finished at approximately 11am. The pig-selling site was located at the rear of the market with animals sold in one area (Figure 4.5).
e. Detusoko Market

Detusoko Market is located on Flores in Kabupaten Ende, Kecamatan Detusoko and Desa Detusoko. This market is located approximately a one hour drive south from Mbay Market. The official market operating day is Wednesday. For farmers coming to sell their pigs, transactions began on Tuesday mornings at approximately 6am. This often occurs with some sellers arriving the day before market to select a location on site to sell their pig/s so they are prepared to meet buyers early the following morning. A unique practice was identified at Detusoko Market where sellers would arrive at market and sell their pig/s to permanent pig sellers stationed at the market who would resell these animals on market day. When pigs arrived at market, they were tethered in the outdoor pig area and remained at market until sold (Figure 4.6). Sellers would either remain at market to safeguard their pig/s or hire someone to perform this task. Observations were conducted on 29–30 September 2009 for round 1 and 17–18 November 2009 for round 2.

Figure 4.5
Diagrammatic representation of Mataloko Market layout, Kabupaten Ngada, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009 (not to scale).
Figure 4.6
Diagrammatic representation of Detusoko Market layout, Kabupaten Ende, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009 (not to scale).
- Off-loading area for pigs; PSA: pig selling area; x: trees; Warung: small restaurant.

f. Mbay Market

Mbay Market is located on Flores in Kabupaten Nagekeo, Kecamatan Iesesa and Kelurahan Danga. It is a traditional market that sells pigs and other livestock. The site is combined with a bus terminal. The market functions every Saturday with pig trade occurring approximately from 7am–12pm. Observations were conducted on 26 September 2009 for round 1 and 21 November 2009 for round 2. The site had a variety of different products for sale including live animals, agricultural and other food products. Both local buses and bemos (Figure 4.25) were observed to leave the terminal transporting pigs. The market layout is shown in Figure 4.7.
Figure 4.7
Diagrammatic representation of Mbay Market layout of pig-selling area, Kabupaten Nagekeo, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009 (not to scale).

g. Melolo Market
Melolo Market is located on Sumba in Kabupaten Sumba Timur, Kecamatan Umalulu and Kelurahan Lumbukori. There is one main road from Kota Waingapu, capital of Sumba Timur, heading west to this location. It takes approximately one hour to drive to the site. It is a traditional market functioning every Thursday and Friday. Observations were conducted on 11 September 2009 for round 1 and 29–30 October 2009 for round 2. Thursdays are known to be busier than Fridays, with higher sales of pigs (as stated by the market manager). Sales occurred from approximately 7am–12pm on Thursday and from 7am–9am on Friday. Due to the heat and lack of shelter in the main pig-selling area, pig transactions occurred early in the morning. The market sold additional produce, including agricultural and household goods. A tree, to which pigs were tethered, stood inside the
main pig-selling site (Figure 4.12). Sellers and buyers would then meet to discuss transactions. The market structure and layout can be viewed in Figure 4.8.

![Diagram of Melolo Market layout](image)

**Figure 4.8**
Diagrammatic representation of Melolo Market layout, Kabupaten Sumba Timur, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009 (not to scale); 1° selling site: main pig selling area with largest volume; 2°: smaller external pig selling area along roadside.

**h. Wetabula Market**

Wetabula Market is located on Sumba in Kabupaten Sumba Barat Daya, Kecamatan Loura and Kota Tambolaka. This market site is a central livestock market close to the major ferry terminal in Sumba Barat with direct access by road allowing efficient animal transportation to the site. Pig movements from Flores island to this market were confirmed through respondent interviews (refer to Chapter 6, Social Network Analysis). The market functions daily with pigs being traded only on Wednesdays and Saturdays. Observations were conducted on 11 September 2009 for round 1 and 30 November 2009 for round 2. Pig transactions began at approximately 5:30am and continued throughout the day. The market layout can be viewed in Figure 4.9.
i. Waikabubak Market

Waikabubak market is located on Sumba in Kabupaten Sumba Barat, Kecamatan Waikabubak and Kelurahan Wailiang. This is a traditional type market that functions daily with a small pig-selling area where trade occurs between approximately 8am–12pm. Observations were conducted for round 1 on the 13–14 September 2009 and on the 2–3 November for round 2. The market sold primarily agricultural products, other food items and traditional weavings, with only two small live animal selling areas (Figure 4.10). The primary pig-selling site had only pigs. The secondary site sold pigs, dogs and goats.
4.3.2.2 Market Structural Features, Pig-selling Sites and Surrounding Environment

Market sites had basic structures for stalls to be used for the sale of products such as vegetables, fruit, rice and traditional weavings (Figure 4.11). Pigs and livestock were sold in areas adjacent to these market stalls. This was generally in a vacant area at the rear or side of the market site where sellers would congregate with their pigs (Figure 4.12). The majority of markets (six of the nine) were held in an outdoor environment with no infrastructure (Figure 4.2 and 4.12).

Wetabula and Mataloko Market were the only two markets with permanent on-site structures for pig trade (Figure 4.13). Both structures were open-air sheds with a concrete base and basic roof. Waikabubak Market was found to have a stand-alone bamboo structure to house pigs situated on the roadside at the entrance to the market (Figure 4.14).

The presence of a primary market entrance was only identified at three of the nine markets (Camplong, Wetabula and Waikabubak). This was an important feature to identify if
mitigation measures for disease spread—such as inspection—are to be implemented. Although these markets had a central entrance location, individuals could also enter the market via smaller informal entrances across the premises. The area of the markets where pigs were sold was generally small. The maximum area was observed at Mbay Market covering approximately 1200m$^2$.

Two markets, Camplong and Melolo, were identified with multiple selling sites for pigs. The sites had different functions for pig trade. For Camplong Market the primary selling site was used by sellers during night hours from Friday to Saturday. The secondary site was utilised outside of market peak hours, Friday afternoons from approximately 4pm to 6pm. This site was used by farmers who did not want to remain at the market for lengthy periods to sell their pigs. These animals were sold to individuals who either took the purchased pig directly from the market or resold the animal later that night in the primary pig-selling area. Melolo Market had two selling areas. The primary selling site was on the market premises and held the largest number of pigs. A secondary site, external to the market, was also used for trading pigs. This site was located along the main road where sellers would sell directly to buyers on the roadside. This allowed sellers to avoid paying a market tax. In addition, it was reported by several sellers that individuals with sick pigs would often choose to sell pigs at this site for cheaper prices.

Residential areas were commonly located on market sites. Their disposal of household food scraps presented a risk for CSF transmission to pigs at markets (Ribbens et al., 2004). Moreover, at six out of nine markets, (Niki Niki, Camplong, Wetabula, Mataloko, Detusoko, and Melolo), at least one house that was on a market site was identified as a smallholder pig farmer with pig pens containing live pigs located in close proximity to pig selling areas. Furthermore, at three of the nine markets, free-roaming pigs were seen wandering around the selling areas coming in direct contact with pigs being sold.

Sale of fresh meat was only found at three of the nine markets (Table 4.1). Halulik and Mbay Market provided fresh beef to consumers (Figure 4.15). At Camplong Market s’ei babi was sold in a small restaurant directly adjacent to the pig-selling area. Information was not obtained on the location of pig slaughter for this restaurant. There is a risk of CSF transmission due to the disposal of kitchen waste and potential for swill feeding. No wet market was observed to be functioning at Wetabula Market. However, during observation on 30 October 2009 a pig waiting to be sold at this market died. As a result, the pig was
prepared onsite for meat distribution, being burned, washed and cut up (Figures 4.16 and 4.17). Customers at the market then came and purchased the meat. Pig meat was not regularly sold at this market.

Figure 4.11
Detusoko Market identifying market stalls prior to opening hours with sellers yet to arrive, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.12
Main pig selling area at Melolo Market, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.
Figure 4.13
Primary selling location for pigs at Wetabula Market in Sumba Barat Daya, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.14
Primary selling location for pigs at Waikabubak Market in Sumba Barat, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.
Figure 4.15
A wet market located at Mbay market where beef was sold, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.16
Pig slaughtered and meat distributed at Wetabula Market following the death of a pig, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.17
Pig slaughtered and meat distributed at Wetabula Market following the death of a pig, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.
4.3.2.3 Pig Volume, Breeds and Age Groups at Market

Pig volume estimates were made at each market site, accounting for breed and age group. Wetabula Market was found to have the largest number of pigs during September and November observations (Table 4.2). Figure 4.18 shows a comparison between the total number of pigs estimated to be at market sites on an observational day with the number of pigs recorded during pig-seller interviews (Chapter 3). For several markets (including Camplong, Melolo and Niki Niki markets), the estimated total pig volumes were similar to those recorded during seller interviews. At these markets the total proportion of sellers that were interviewed was 21.0%, 62.8%, and 32.3% respectively.

For Melolo and Waikabubak markets, lower pig volume estimates were made than the total volume documented during seller interviews. This is because there were two selling sites at these markets and due to the presence of only one observer being able to record in one selling area at a time, pigs were missed in adjacent sites, being sold before they could be recorded.

At markets such as Mbay and Wetabula, much larger estimates of the total number of pigs were made than were recorded during interviews. This was due to the proportion of sellers interviewed—only 22.4% and 60.4% respectively—of sellers being interviewed on these observational days. Therefore, only a proportion of total pig numbers were captured during interviews at these markets. Moreover, a higher number of pigs per seller were detected at Wetabula Market.

In regard to age groups, weaners had the lowest proportion present at market and no significant differences were detected between markets or islands (markets: $P = 0.189$; islands: $P = 0.754$; Table 4.2). The age group with the greatest presence at market were fatteners followed by growers, which were significantly higher than other age groups ($P < 0.001$; weaner: 3.3%, grower: 38.5%, fatterner: 58.0%, sow: 0.2%; boar: 0.00%). A significantly greater proportion of fatteners was observed at markets on Sumba ($P < 0.001$; West Timor: 20.8%; Flores: 28.9%; Sumba: 50.3%). In addition, a significantly greater proportion of growers were observed at markets on Flores in comparison to West Timor and Sumba ($P < 0.001$; West Timor: 16.9%; Flores: 71.7%; Sumba: 11.3%).

Breed differences were detected on a market and island level. Overall, the proportion of local and cross-bred pigs recorded did not significantly differ across the province ($P = \ldots$).
0.987; local: 50.8%, cross-breed: 49.2%). Niki Niki, Halulik and Detusoko markets had significantly higher proportions of cross-breed pigs (Niki Niki: $P > 0.05$, local: 35.0%, cross-breed 65.0%; Halulik: $P < 0.001$, local: 31.4%, cross-breed: 68.6%; Detusoko: $P < 0.001$, local: 21.4%, cross-breed: 78.6%). Alternatively, Mbay and Waikabubak markets had significantly higher proportions of local pig breeds (Mbay: $P > 0.05$, local: 67.0%, cross-breed: 33.0%; Waikabubak: $P > 0.05$; local: 66.7%, cross-breed: 33.3%).

On an island level, the proportions of local and cross-breed pigs were similar on Flores ($P = 0.992$, local: 50.7%, cross-bred: 49.3%). However, for Sumba, a higher proportion of local pigs were identified ($P < 0.05$; local: 61.1%, cross-breed: 38.9%). For Camplong Market (a night market) estimates could not be obtained on the day of observation. Total pig volumes present at market without age group and breed stratification were subsequently collected from the market manager. When comparing the remaining two West Timor markets, Niki Niki and Halulik, a higher proportion of cross-breed pigs were present at these markets ($P < 0.05$, local: 32.7%, cross-breed: 67.3%). When comparing between islands, Flores had a significantly higher proportion of local breed pigs present at market in comparison to West Timor ($P < 0.001$; West Timor: 12.7%; Flores: 45.5%; Sumba: 41.8%). Flores also had a significantly higher proportion of cross-bred pigs in comparison to West Timor and Sumba ($P < 0.001$; West Timor: 26.9%; Flores: 45.7%; Sumba: 27.5%). Variations in CSF infection have been reported in the literature, particularly regarding indigenous and crossbred pigs. Blacksell et al. (2006) compared the susceptibility of indigenous pig breeds from Lao PDR and a Large White/Landrace cross-breed to CSF infection. This study reported shorter survival periods for exotic cross-breed and a delayed onset of clinical signs for indigenous pig breeds.
The number of pigs at live pig markets recorded during interviews and observations at nine live pigs markets, interviews were conducted across two different time periods, Round 1 represents interview and observations conducted in September, representing a high-demand month, Round 2 represents interviews and observations conducted in November, representing a low-demand month. The number of pigs is the number identified on one functional market day, Rnd 1 total est: the total number of pigs estimated on market day during Round 1; Rnd 1 TSV: Round 1 total seller pig number, the total pig number recorded during interviews with pig sellers; Rnd 2 total est: the total number of pigs estimated on market day during Round 2; Rnd 2 TSV: Round 2 total seller pig number, the total number of pigs recorded during interviews with pig sellers.
Table 4.2
Pig number estimates at live pig markets stratified by age group and breed across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009 (for age group and breed classifications refer to Glossary).

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1Camplong Market was a night market; as a result age and breed estimates could not be obtained during observations. Total figures were collected from the market manager.
4.3.2.4 Husbandry Practices

Husbandry practices tended to be similar across markets. Pigs at market were either tethered or restrained with their legs tied (Figure 4.19, 4.20, 4.21). At Wetabula Market fattener pigs were housed under shelter (Figure 4.13). Within the open-air shed, a grid of bamboo poles was positioned on the ground, which allowed pigs to be tethered (Figure 4.19). This feature was unique to Wetabula Market and, with such large pig volumes present on a market day, this allowed for an even distribution of pigs within the shelter. At other markets, pigs were tethered with ropes attached to their front legs or through their ears (Figure 4.20). Younger pigs often had their legs restrained (Figure 4.21).

Sellers were observed feeding their pigs at each market site. The most common food included rice bran mixed with water, cassava root, water spinach (kangkung), cassava leaves, papaya, rice and corn. More sellers were seen providing pigs with food at markets where pigs were kept for a longer period, such as overnight or for several days. Detusoko Market was a unique site where pigs remained for several days. Feed was provided to the majority of pigs and rice bran could be purchased at the market site to be provided to the pigs. Due to the high volume and density of pigs at Wetabula Market, sellers who chose to feed their pigs had to do so directly to ensure their pig consumed the feed. The use of buckets (Figure 4.22) and directly feeding their pigs was observed. At four markets (Mataloko, Detusoko, Melolo and Wetabula), common feeding devices were provided (Figure 4.23). The use of common feeding devices for pigs at these markets presented the potential for direct and indirect CSFV transmission.

It needs to be acknowledged that this thesis describes practices at markets and during transportation as they currently occur in NTT following cultural practices in this region. I do not condone the practices observed where the welfare of the pigs has been affected. The practices seen cannot be changed in the short term. However, through further research and education in the area future improvements in practical measures to improve pig welfare should be sought.
Figure 4.19
Fattener pigs tethered in Wetabula Market for sale on Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.20
Local pig tethered by ears in Detusoko market for sale, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009.
Figure 4.21
Local pigs restrained in Detusoko Market for sale on Flores, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.22
Food provided to a pig at Wetabula Market consisting of rice bran mixed with water, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.
4.3.2.5 Transportation Methods

A variety of transportation methods were observed at market. As confirmed through market interviews, a large proportion of individuals used public passenger transportation. Johnston (2007) stated that throughout Indonesia, a low proportion of rural households own motor vehicles, such that rural bus services play an important role in the transportation of individuals, produce and live animals. The practice of hiring and borrowing vehicles was also confirmed through market interviews (refer to Chapter 3).

Observations on market day identified that public transportation vehicles waited at the entrance to the market for customers (Figure 4.24). At three markets (Mbay, Waikabubak and Wetabula), a bus terminal was located on the market site allowing easy access to transportation to and from the market. At the terminals, small vehicles such as bemos were seen to transport pigs from market (Figure 4.25). These vehicles were seen to transport small numbers of pigs, in groups of one to three. In addition, larger buses and trucks were observed transporting people, products and livestock (Figure 4.26). On Flores, a large proportion of individuals were observed using a local truck with seating (termed a biskayu) for transportation. These vehicles generally carry livestock under the passenger seats. A variety of livestock were observed on biskayus with pigs, chickens and goats transported.
together (Figure 4.34). Up to eight fattener pigs were observed on one vehicle. Through investigations of local buses in Indonesia, Johnston (2007) demonstrated that this transportation type travels greater distances than smaller modes of transportation such as ojeks. The availability of transport in the smallholder farmer sector dictates their involvement at particular markets. The distance from farm to point of sale has been identified as a constraint for market participation (Omiti et al., 2009).

Due to the limited road access at Mataloko Market, a greater number of trucks transporting only pigs to market was observed. The holding capacities of these vehicles were large: up to 30 pigs were observed on one vehicle (Figure 4.28). On arrival, once the pigs were removed from the vehicles, the drivers would remain at market to transport any purchased pigs or other livestock away from the market.

The use of ojek transportation to and from the market was the most common transportation method identified across all islands. Ojek transportation, a paratransit method, provides a cheap transportation source for those who are income poor (Joewono & Kubota, 2005). Ojeks were seen to carry one to two pigs per vehicle depending on pig size (Figure 4.27). At two markets (Detusoko and Melolo), ojek drivers were seen to return to market on the same day following the transfer of previous customers. Johnston (2007) found that the mean distance per trip for ojeks in West Java, Indonesia, was less than public buses, with ojek drivers tending to operate across a more localised area.

For individuals living in close proximity to the market, pigs were often carried or walked to market, depending on their size. Unique carry devices were often used for younger pigs (Figure 4.29). Moreover, for sellers travelling by vehicle where maximum holding capacity was reached, pigs would be tied to the outside of the vehicle for transport (Figure 4.30). It was observed that the devices used to restrain pigs, including ropes, cords and bags were discarded at the marketplace and left in the surrounding environment. Practices such as this have the potential to act as an additional source of fomite transmission of CSF.
Figure 4.24
Transportation vehicles waiting at the entrance to Melolo Market, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.25
Bemo transportation leaving Halulik Market, West Timor, Nusa Tenggara Timur, eastern Indonesia, 2009.
Figure 4.26
A truck leaving Waikabubak Market bus terminal transporting people, food products and livestock, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.27
An ojek (motorbike taxi service) transporting pigs from Niki Niki Market, Nusa Tenggara Timur, eastern Indonesia, 2009.
Figure 4.28
Large truck (biskayu) transporting live pigs to and from Mataloko Market, Flores, eastern Indonesia, 2009.

Figure 4.29
A pig transportation method to market, carrying device made from palm fronds, Niki Niki Market, Nusa Tenggara Timur, eastern Indonesia, 2009.
4.3.2.6 Biosecurity Practices and Issues

The use of biosecurity is an effective approach to reduce the risk of CSF transmission on the farm and at live animal markets (FAO, 2010, 2011; Kiss et al., 2006; Moennig et al., 2003; Pritchard et al., 2005). Biosecurity practices at the markets were found to be extremely limited across all nine sites. Ineffective removal of waste, absence of cleaning or disinfection, mixing of pigs on transport and at market and common feed containers were all observed at live pig markets in NTT. These factors have the potential to lead to disease transmission in a market environment (Dharma. et al., 2008; FAO, 2010). Overall seven out of the nine markets did not perform any biosecurity measures.

The only biosecurity measures observed were at Wetabula and Waikabubak markets. The observer recorded the removal of pig faeces from within the pig-selling areas. This involved the use of a makeshift broom (Figure 4.31) where pig faeces were swept to the edges of the pig enclosures. This was seen only during observations in November. The method itself was ineffective as faeces were not actually removed from the environment, rather just moved to a different location within the pig-selling area. It can be seen in Figure 4.31 that the concrete floor at Wetabula Market was covered in faeces, which had not been removed for some time. The survival of CSFV in the environment has previously been
investigated by Weesendorp et al. (2008b), Botner and Belsham (2011) and Gale (2004). Weesendorp et al. (2008b) concluded that CSFV can survive in faecal matter for $0.61 \pm 0.15$–2.5 to $4.8 \pm 1.2$–20 (95% CI) days depending on the environmental temperature and virus strain.

Transportation vehicles have been identified as key factors in CSF transmission (Dewulf et al., 2000; FAO, 2010; Moennig et al., 2003). The mixing of pigs during transport and the role of transportation vehicles as fomites can potentially lead to CSF spread (Ribbens et al., 2004). On arrival at market, it was observed that pigs brought by different sellers from various villages were mixed together on one vehicle (Figure 4.34). Moreover, once pigs were off-loaded at market for trade, the vehicles were reused and reloaded with patrons leaving the market with their newly purchased pigs. Larger modes of public transportation, such as buses and biskayus, were seen to wait on the roadside until they reached full capacity before leaving. Furthermore, seller interviews confirmed the transportation of pigs in vehicles that had not been cleaned or disinfected, with vehicles also being hired and borrowed. The reusing of these vehicles presents a risk for the indirect transmission of CSFV. Water sources at the market place vary with some having direct access while others require collection and transportation to the market. Locations closer to urban areas such as Waikabubak Market had a direct water source whereas at markets such as Melolo Market, market sellers were required to walk several kilometres to collect water. Soap and washing detergent is available at the market place for purchase, often between Rp 5000-20,000. However, market patrons are generally unaware of the risks of reusing vehicles that have not been cleaned. Moreover, the limited number of vehicles makes them in high demand and a fast turnover rate for moving pigs is more economical.

The contact between pigs and other animal species while at market was identified at all locations (Table 4.2). Live animal markets in developing countries are important resources for smallholder trade (FAO, 2010). However, they are also mixing points that provide a potential reservoir for disease spread (FAO, 2010). Direct contact occurred between pigs, regardless of restraint methods, at every site. At Camplong, Mataloko and Melolo, free-roaming pigs were seen wandering around the pig-selling areas, coming into direct contact with pigs at market. Dogs, goats and chickens were commonly observed being sold at the same markets and coming into contact with pigs (Table 4.2). Published literature suggests that swine species are the only animals capable of becoming infected with CSFV (Dewulf et al., 2001a; Kaden et al., 2003).
A livestock identification system enables traceability of animals from farm to slaughter, assisting in quality assurance and disease control (McKean, 2001; Schembri et al., 2006). In NTT, there are no such requirements and the majority of farmers are smallholders with minimal management practices in place. However, the use of paint to mark pigs during transportation and at market was identified at Wetabula and Mataloko markets (Figure 4.32). At these two markets it was observed that large numbers of pigs arrived on individual trucks. As a result, farmers elected to individually identify their pigs to make trading transactions easier.

Multiple payments—including official and unofficial levies, market tax, vehicle hiring, and fuel costs—are often required for a pig and other products to be sold at a market (Patunru et al., 2010). This can deter some individuals from selling pigs formally through a market (Patunru et al., 2010; Suryadarma et al., 2007). At Wetabula Market, two pig sellers were seen bringing animals into the market informally by sneaking pigs over its rear fence (Figure 4.33). The lack of knowledge about animal disease and the use of biosecurity measures to minimise disease spread are key issues that need to be targeted to reduce CSF transmission.

Observations recorded the minimal presence of sick and dead pigs at market sites. No sick pigs were observed, and only one dead pig was identified at Wetabula Market during observations conducted in November. At Camplong, Detusoko, Wetabula and Waikabubak markets, pig sellers were observed to be trading live pigs outside the pig selling areas. This method, often used to avoid market tax payments, results in lower pig prices than in the market pig-selling area. Sick pigs are more likely to be traded in these locations.
Figure 4.31
A makeshift broom made from dried grass used for sweeping waste and faeces from Wetabula Market, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.32
Fattener pigs at Wetabula Market in Sumba that were marked with paint for identification during transportation, Nusa Tenggara Timur, eastern Indonesia, September, 2009.
Figure 4.33
Pig sellers entering Wetabula Market through an informal entrance to avoid market tax payment, Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009.

Figure 4.34
Local pigs from different villages being transported on a biskayu to Mbay Market, Flores, Nusa Tenggara Timur, eastern Indonesia, 2009.
4.3.2.7 Market Management

Only four markets had a manager present on the day of observations. At Camplong, Niki Niki, Watabula and Detusoko markets, the managers checked pig-seller documentation and collected market tax on entry to the market (Figure 4.35). The market managers were not seen to examine or observe live pigs to assess their health. Traditional markets in NTT are all meant to have a general manager who collects taxes from all sellers for both live animal sales and other products. For the selected markets where managers were not observed, they were most likely present in another area of the market at time of observations or absent on the day.

It is unclear whether market managers know how to identify sick pigs. From the interviews it suggests that those in the pig industry are able to identify basic clinical signs of sick pigs. However, managers at different markets vary in their knowledge for example: at animal specific markets such as Niki Niki, managers may be more knowledgeable on clinical signs. However, for markets such as Halulik where the manager was required to collect tax from all market patrons and the market sold a variety of products, not just live animals, the manager may not have as much knowledge in this area.
4.4 Conclusion

The observations across market sites have provided baseline information about the practices at live pig markets. Improving our understanding and knowledge of these practices will enable the establishment of effective mitigation strategies readily applicable in this environment. Moreover, this study has been able to document the unique structural attributes, pig management practices and the importance of pig trade through traditional markets for smallholder farmers within NTT.
Chapter 5: Smallholder Pig Farmer Survey across Nusa Tenggara Timur Province

5.1 Introduction

Livestock play an important role in supporting the livelihoods of those living in poverty in the developing world (FAO, 2002). Their multiple uses as a source of income, financial security and savings, as a bartering tool and for their role in traditional ceremonies are vital in many developing countries (Huynh et al., 2007; Millar & Photakoun, 2008; Nampanya et al., 2011). Moreover, it was recognised by Barham and Chitemi, (2009) and Kefasi et al. (2010) from studies in Africa that agricultural development aiming to alleviate poverty cannot occur without engaging smallholder farmers who represent the majority of livestock owners.

Pig farming represents an important sector in South-East Asia (Huynh et al., 2007). Within Indonesia, NTT province has the largest pig population with households having small backyard herds of 1–3 sows (BPS Statistics, 2009; Christie, 2007; Johns et al., 2009). It is common to see mixed farming systems within Indonesia where farmers have both livestock animals and cropping systems, with a focus on subsistence farming (Thorne and Tanner, 2002). In a study on Sumba and Flores islands (NTT), Russell-Smith et al. (2007) found this to be the case. Recent studies on pig production in eastern Indonesia have provided important information regarding on-farm management systems, pig feed and nutrition and commercial production. A study by Johns et al. (2009) investigated smallholder commercial pig production to identify areas for improved market integration. This study provided baseline information on smallholder and semi-commercial pig farms in NTT and a better understanding of the pig market chain. Cargill et al. (2009) conducted an extensive study in Papua province, eastern Indonesia, to improve the sweet potato–pig production system (sweet potato provides a feed source for both pigs and humans across this region). Despite these studies there is still a lack of information regarding pig movements across NTT province and eastern Indonesia, with the focus previously being on improving pig production.

The introduction of classical swine fever (CSF) to NTT province in 1998 caused a substantial reduction in the pig population (BPS Statistics, 2009; Hutabarat & Santhia,
1999). Fluctuations in the size of the population have continued, and the number of cases of CSF continues to increase (Dinas Peternakan Propinsi, 2011). Farming practices—such as minimal biosecurity, pig movements and limited knowledge regarding pig health and disease, commonly noted among smallholder farmers in developing countries—can significantly impact on disease spread (FAO, 2010; Nampanya et al., 2011).

With a lack of knowledge regarding smallholder farming pig practices and the current impacts of CSF across NTT, this study was developed to improve our understanding of pig-production systems in this region so as to develop appropriate mitigation strategies to control CSF. The overall objective of this survey was to obtain information regarding live pig movement, pig management, biosecurity practices and knowledge of pig health and CSF from smallholder pig farmers across NTT.

5.2 Methodology

5.2.1 Farmer Survey

A pig farmer survey was conducted in the eastern Indonesian province of Nusa Tenggara Timur on the islands of West Timor, Flores and Sumba. Face-to-face interviews were conducted with smallholder pig farmers in 18 randomly selected villages during March and April 2010 (University of Sydney Human Ethics Approval No: 08-2008/11866).

5.2.1.1 Questionnaire

A questionnaire was developed for smallholder pig farmer respondents to obtain information regarding live pig movement, pig management, biosecurity practices and knowledge of pig health and CSF. The questionnaire was initially developed in English and then translated into Bahasa Indonesia by a native speaker of local origin (Dr Maria Geong, Dinas Peternakan Propinsi). The questionnaire was pilot tested and interview teams involved in the study were trained to use the developed questionnaire. The pilot testing occurred in two stages. The first stage saw the questionnaire pilot tested with six farmers in Kota Kupang, which allowed clarification and removal of any questions that caused confusion or were ambiguous. The questionnaire was further assessed by each interview team to ensure questions were understood and translations were appropriate for each island.
The questionnaire consisted of both open and closed questions: checklist type questions, where respondents could select more than one response, and short answer questions (Appendix 9). Interview duration to complete the questionnaire was approximately 30 minutes. Throughout the questionnaire, CSF was referred to as hog cholera. In the results presented, the term CSF is used.

5.2.1.2 Interview Teams

The interview teams (from local NGOs) that conducted the farmer survey were the same as those used for the market study (Refer to Chapter 3). These included four individuals each from Nusa Cendana University in West Timor, Yaspem Maumere in Flores and Yayasan Cendana Mekar in Sumba. In addition to the training they received for the market study, another training day took place for each team to familiarise themselves with the new questionnaire and verify translations to local languages. Questionnaire structure remained similar to that of the seller and buyer questionnaires.

5.2.1.3 Sampling

Stage 1: Selection of Districts

Purposive selection was used to select three districts per island. This was based on previous knowledge regarding reported CSF cases in the area and high numbers of pig movements, and on the expert opinion of Dr Maria Geong and Dinas Peternakan veterinarians regarding the suitability of areas to sample. Flores is a unique location regarding CSF infection status with two districts classified as infected, one district as suspect and five CSF-free districts. Therefore, one district with infected status, one with suspect CSF infection and one classified as CSF free were selected for inclusion in the study. The final districts are shown in Table 5.1, and inclusion and exclusion criteria in Table 5.2.
Table 5.1
Districts (Kabupatens) selected for inclusion in a smallholder pig farmer survey in Nusa Tenggara Timur, eastern Indonesia, 2010.

<table>
<thead>
<tr>
<th>Island</th>
<th>District 1</th>
<th>District 2</th>
<th>District 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Kota Kupang</td>
<td>TTS</td>
<td>Belu</td>
</tr>
<tr>
<td>Flores</td>
<td>Flores Timur</td>
<td>Sikka(^1)</td>
<td>Manggarai Barat(^2)</td>
</tr>
<tr>
<td>Sumba</td>
<td>Sumba Timur</td>
<td>Sumba Barat</td>
<td>Sumba Barat Daya</td>
</tr>
</tbody>
</table>

\(^1\)Sikka district is classified as a suspect region for CSF infection; \(^2\)Manggarai Barat district is classified as CSF free.

**Stage 2: Selection of Subdistricts**

Simple random sampling with a random number generator was used to select one subdistrict per selected district (Microsoft Excel, 2007, Microsoft Corporation, Redmond, WA, USA). A total of nine subdistricts were selected. Inclusion and exclusion criteria are shown in Table 5.2. Exclusion criteria removed any subdistricts that were remote or considered unsafe and where communities were likely to be uncooperative.

**Stage 3: Selection of Villages**

Simple random sampling with a random number generator was used to select two villages per subdistrict (Microsoft Excel, 2007, Microsoft Corporation, Redmond, WA, USA). A total of 18 villages were selected following the exclusion of any villages based on criteria presented in Table 5.2. The village locations are shown in Figure 5.1.

**Stage 4: Selection of Pig Farmers**

From each selected village, a sampling frame was established by obtaining a list of pig owners from the Village Head. This was requested during a preliminary visit to each selected village by government veterinarians while also obtaining permission to conduct the survey in that area. The government veterinarians obtained basic demographic and pig-movement information for each village from the Village Heads. This included information on trading practices for pig herds of varying size and composition, common methods for selling pigs and selling frequency. These data agreed with our hypothesis that pig farmers with larger pig herds were responsible for the majority of pig movements into and out of a village. Based on expert opinion we understood that pig owners with herd sizes of 1–3 pigs generally keep pigs for home consumption or use in traditional ceremonies. Therefore, selection of farmers from the sampling frame was done purposively based on herd size. Interviews were conducted with the 16 farmers from each village with the largest pig herds.
(based on total herd size excluding piglets < two months old) based on the list of pig owners provided by the Village Head. The aim was to interview the primary caretaker of the pigs in each household. When a selected pig owner did not meet the inclusion criteria (Table 5.2), the next pig owner in the sampling frame list based on herd size (from largest to smallest) was selected.

Figure 5.1
Selected village sites for inclusion in a smallholder pig farmer survey on West Timor, Flores and Sumba, Nusa Tenggara Timur province, eastern Indonesia, 2010.
Table 5.2
Inclusion and exclusion criteria for selection of pig farmers for interviewing across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010.

<table>
<thead>
<tr>
<th>Site</th>
<th>Inclusion</th>
<th>Exclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>District</strong></td>
<td>Known CSF status—based on reporting of clinical cases of CSF to Dinas Peternakan Kupang (Dinas Peternakan Propinsi, 2011).</td>
<td>Unknown CSF status—based on no reports of animal disease occurrence or unreliable reports of animal disease occurrence (including clinical CSF cases) to Dinas Peternakan Kupang (Dinas Peternakan Propinsi, 2011).</td>
</tr>
</tbody>
</table>
| **Subdistrict** | Accessible by vehicle  
No security concern—known to be safe for research team to visit  
Cooperation expected | People are not cooperative  
Remote area  
Security concern |
| **Village**  | Co-operation expected                                                     | People are not cooperative                                                 |
| **Pig farmer** | Present on day of visit  
Gives consent to participate  
Pigs present at household on day of visit | People are not cooperative                                                  |

5.2.1.4 Interview Time Selection

The study was conducted during the months of March and April 2010 at the end of the wet season to ensure that the research teams would be able to travel to all selected villages. This period coincided with Easter, an important festival in Nusa Tenggara Timur, particularly in Flores, with a large proportion of the population being Catholic. Thus interviews were conducted in Sumba initially, followed by West Timor then Flores; none were conducted on Good Friday and Easter Sunday (Table 5.3).
Table 5.3
Schedule for smallholder pig farmer interviews across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010.

<table>
<thead>
<tr>
<th>Organisation</th>
<th>Date</th>
<th>Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yayasen Cendana Mekar</td>
<td>18–19 March</td>
<td>Sumba Timur Collection</td>
</tr>
<tr>
<td></td>
<td>20–21 March</td>
<td>Sumba Barat Daya Collection</td>
</tr>
<tr>
<td></td>
<td>22–24 March</td>
<td>Sumba Barat</td>
</tr>
<tr>
<td>Nusa Cendana University</td>
<td>27–28 March</td>
<td>Belu Collection</td>
</tr>
<tr>
<td></td>
<td>29–31 March</td>
<td>TTS Collection</td>
</tr>
<tr>
<td></td>
<td>1–3 April</td>
<td>Kota Kupang Collection</td>
</tr>
<tr>
<td>YASPEM Maumere</td>
<td>6–8 April</td>
<td>Flores Timur Collection</td>
</tr>
<tr>
<td></td>
<td>9–11 April</td>
<td>Sikka Collection</td>
</tr>
<tr>
<td></td>
<td>12–17 April</td>
<td>Manggarai Barat Collection</td>
</tr>
</tbody>
</table>

5.2.1.5 Data Management

Using Epi Info™ Software (Version 3.5.1, CDC, www.cdc.gov/epiinfo, Atlanta, Georgia, U.S) a database was developed for the farmer questionnaire. This database was provided to the team leader of each interview team on a portable USB (Kingston 2GB). When all of the data had been collected, all data were entered into the database. Database files from different islands were then combined and cross matched with the hard copies of the questionnaire to ensure data entry was correct. Translation revisions and data entry corrections were made where necessary.

5.2.1.6 Data Analysis

Analyses were conducted on data obtained from farmer interviews using Genstat 11th Edition (PC/Windows XP, 2006, VSN International Ltd., Hemel Hempsted, UK). Initially data were checked and edited for missing values and outliers. Descriptive analyses were used to describe general on-farm management of pigs, pig movements, biosecurity practices and knowledge of pig health and CSF. Continuous variables were investigated with means, quartiles and ranges. For categorical variables of interest, proportions were analysed at the island level and significant differences identified using the chi-squared test to determine if observed frequencies were significantly different from expected frequencies between islands (Equation 3.2; Altman, 1991). When the chi-squared test indicated significance (P-values < 0.05) for variables with multiple categories, a z-test using a Bonferroni adjustment was used to compare categories and identify those that were significantly different.
To analyse pig count data, including the number of pigs in smallholder herds, the number of pigs sold, and the number of pigs purchased by farmers, a generalised linear mixed model (GLMM) was used. For the number of pigs in herd by age group the model consisted of three fixed effects: breed (local, cross-breed), age group and island. For age group, analyses were conducted on pig age groups only of a marketable age (i.e. ≥ 2 months), including weaners, growers, fatteners, sows and boars. For this study, the issue of fatter age group misclassification, experienced during the market survey, was rectified so that analysis included all islands. The random effects included in the model were farmer ID and a term for village nested within island. These random effects were included to account for the expected similarity in pig numbers on a respondent, village and island level. For the models of pigs sold and purchased by farmers, the fixed effects were age group and island. No breed data were collected from these questions. The random effects in the model were farmer ID and village nested within island. An additional model was fitted to analyse total on-farm herd size (the total number of pigs per herd of a marketable age group). The model consisted of two fixed effects, island and breed. For this model breed was classified as local, cross-bred or both local and cross-bred. Random effects included a term for village nested within island. For all models interactions were also investigated. A Poisson distribution was used in all four models with a logarithmic link function to account for the presence of count data and predominantly smaller pig numbers in the dataset. Due to the application of a GLMM, the calculation of the intra-cluster correlation coefficient (ICC) could not be performed. Moreover, the output from the models did not find any significant interactions amongst the fixed effects and therefore are not mentioned in the results. For clarification, throughout this chapter n is referred to as the number of respondents that answered a question. In addition, for ease of reporting, the term island has been used to refer to West Timor in some sections.

5.3 Results

5.3.1 Pig Farmer Interview Results
The farmer interviews conducted across Nusa Tenggara Timur involved 289 pig farmer respondents from 18 different villages: 97 respondents from West Timor, 96 from Flores and 96 from Sumba (Table 5.4). Basic demographic information for each village, obtained from each Village Head, is shown in Table 5.5.
Table 5.4
Total number of smallholder farmers interviewed from 18 selected village locations during a pig farmer survey across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010.

<table>
<thead>
<tr>
<th>Island</th>
<th>District</th>
<th>Subdistrict</th>
<th>Village</th>
<th>No. Interview</th>
<th>Total Per District</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Kab. Kupang</td>
<td>Alak</td>
<td>Nunbaun Delha</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Manutapen</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TTS</td>
<td>Batu Putih</td>
<td>Boentuka</td>
<td>17</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Benlutu</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Belu</td>
<td>Nanaet</td>
<td>Dubesi</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Duabesi</td>
<td>Nanaet</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Flores</td>
<td>Flores Timur</td>
<td>Ile Bura</td>
<td>Riangburra</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Nurri</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sikka</td>
<td>Waiblama</td>
<td>Ilinmedo</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pruda</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Manggarai Barat</td>
<td>Sano</td>
<td>Nampar Macing</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nggoang</td>
<td>Golo Mbu</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Sumba</td>
<td>Sumba Timur</td>
<td>Rindi</td>
<td>Rindi</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Kayuri</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sumba Barat</td>
<td>Kodi</td>
<td>Walla Ndimu</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Bangedo</td>
<td>Waikarara</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sumba Barat Daya</td>
<td>Loli</td>
<td>Sobawawi</td>
<td>16</td>
<td>32</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Waekrau</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>289</td>
</tr>
</tbody>
</table>
Table 5.5
Demographic information gathered by government veterinarians from Village Heads of villages included in a farmer survey across West Timor, Flores and Sumba in Nusa Tenggara Timur province, eastern Indonesia, 2010.

<table>
<thead>
<tr>
<th>Island</th>
<th>Village</th>
<th>Number of HH(^1) with pigs</th>
<th>Number Pig Free HH(^1)</th>
<th>Pig Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Manutapen</td>
<td>68</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td>Nunbaun Delha</td>
<td>83</td>
<td>4</td>
<td>192</td>
</tr>
<tr>
<td></td>
<td>Benlutu</td>
<td>204</td>
<td>31</td>
<td>589</td>
</tr>
<tr>
<td></td>
<td>Boentuka</td>
<td>235</td>
<td>No data</td>
<td>424</td>
</tr>
<tr>
<td></td>
<td>Nanaet</td>
<td>137</td>
<td>2</td>
<td>385</td>
</tr>
<tr>
<td></td>
<td>Duabesi</td>
<td>193</td>
<td>1</td>
<td>1047</td>
</tr>
<tr>
<td>Flores</td>
<td>Nurri</td>
<td>158</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td>Riangburra</td>
<td>60</td>
<td>0</td>
<td>160</td>
</tr>
<tr>
<td></td>
<td>Ilinmedo</td>
<td>134</td>
<td>0</td>
<td>475</td>
</tr>
<tr>
<td></td>
<td>Pruda</td>
<td>293</td>
<td>201</td>
<td>1254</td>
</tr>
<tr>
<td></td>
<td>Golo Mbu</td>
<td>252</td>
<td>0</td>
<td>525</td>
</tr>
<tr>
<td></td>
<td>Nampar Macing</td>
<td>217</td>
<td>0</td>
<td>427</td>
</tr>
<tr>
<td>Sumba</td>
<td>Rindi</td>
<td>100</td>
<td>0</td>
<td>367</td>
</tr>
<tr>
<td></td>
<td>Kayuri</td>
<td>96</td>
<td>18</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>Walla Ndimu</td>
<td>573</td>
<td>0</td>
<td>857</td>
</tr>
<tr>
<td></td>
<td>Sobawawi</td>
<td>320</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td>Waekrau</td>
<td>256</td>
<td>No data</td>
<td>No data</td>
</tr>
<tr>
<td></td>
<td>Waikarara</td>
<td>143</td>
<td>No data</td>
<td>No data</td>
</tr>
</tbody>
</table>

\(^1\)HH: Household

5.3.2 Respondent Demographics

5.3.2.1 Gender

Gender proportions of pig farmer respondents differed across the province. The majority were male (79.2%; \(n = 289\)) and this was common across islands (\(P = 0.115\); West Timor: 23.2%; Flores: 24.6%; Sumba: 31.5%). A greater proportion of females were interviewed during this study (20.8%) compared to the market survey. On Sumba a significantly lower number of women were interviewed (\(P < 0.001\); West Timor: 30 respondents; Flores: 25 respondents; Sumba: 5 respondents).
5.3.2.2 Respondent Age
The mean age of pig farmer respondents was similar across islands \((P = 0.434;\) West Timor: 44.50 ± 13.33 (standard deviation), Flores 45.40 ± 11.93, Sumba 46.83 ± 10.04). A large range of ages was identified (23 to 100 years).

5.3.2.3 Education
Across the three islands, primary school was the level of education most commonly completed by the pig farmers (42.4%; \(n = 289\)). Flores was found to have the highest number of individuals that had completed primary school, similar to pig sellers and buyers during market interviews (45.9%; \(n = 122\)). Only 18.8% had completed high school across the three islands and only 3.1% of individuals reported having completed some form of tertiary education.

5.3.2.4 Religion
Religious denominations varied between islands. Over half of pig farmers in this region were Catholic (61.1%; \(n = 288\)) with Catholicism the only religion reported in Flores. Both Protestant and Catholic respondents were interviewed in West Timor (39.2% and 60.1% respectively). In Sumba three religious groups were represented, Catholic (22.9%), Protestant (55.2%) and Marapu (22.9%).

5.3.2.5 Primary Occupation of Smallholder Farmers
The majority of pig farmers regarded farming as their primary occupation (74.7%; \(n = 285\)). The next most commonly reported primary occupations were housewife (6.7%), civil servant (3.9%), business owner (2.5%), and teacher (1.6%).

5.3.3 Respondent Background

5.3.3.1 Other animal species kept by smallholder farmers
Pig farmers in this region were most likely to keep chickens (71.3%; \(n = 289\)) and dogs (61.6%; Figure 5.2). A larger proportion of pig farmers from Sumba kept chickens \((P < 0.05;\) West Timor: 31.1%, Flores: 24.3%, Sumba: 44.7 %) and dogs \((P < 0.05;\) West Timor 32.0%, Flores: 19.1%, Sumba: 48.9%) on the farm compared to Flores. Only 29.1% of respondents reported keeping cattle on the farm.
Other animal species kept by smallholder farmers across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010 (n = 289).

**5.3.3.2 Experience as a Pig Farmer**

Respondents reported practising pig farming for an average of $14.02 \pm 7.40$ years, across all three islands. Sumba had the highest mean (17.22 ± 8.65 years) and Flores the lowest (10.32 ± 7.40 years). A range of up to 80 years was recorded.

**5.3.3.3 Purpose of Keeping Pigs**

It was reported that 68.5% (n = 289) of pig farmers kept pigs as a source of extra income for their household. Pig production was reported to be the primary income source for 31.8% of farmers. Cultural traditions were reported to be important: 47.4% of respondents reported keeping pigs for traditional ceremonies. Only 22.2% of respondents reported keeping pigs solely for consumption (Table 5.6). Overall, 50.9% of respondents selected more than one response.
Table 5.6
Reasons provided by smallholder pig farmers for keeping pigs in West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2010.

<table>
<thead>
<tr>
<th>Purpose for Keeping Pigs</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>97</td>
<td>96</td>
<td>96</td>
<td>289</td>
<td>100.00</td>
</tr>
<tr>
<td>Primary Income</td>
<td>20</td>
<td>28</td>
<td>44</td>
<td>92</td>
<td>31.83</td>
</tr>
<tr>
<td>Extra Income</td>
<td>77</td>
<td>67</td>
<td>54</td>
<td>198</td>
<td>68.51</td>
</tr>
<tr>
<td>Cultural Traditions</td>
<td>4</td>
<td>48</td>
<td>85</td>
<td>137</td>
<td>47.40</td>
</tr>
<tr>
<td>Food Consumption</td>
<td>4</td>
<td>13</td>
<td>47</td>
<td>64</td>
<td>22.15</td>
</tr>
<tr>
<td>Other</td>
<td>0</td>
<td>5</td>
<td>11</td>
<td>16</td>
<td>5.54</td>
</tr>
</tbody>
</table>

5.3.4 On-farm Pig Management

5.3.4.1 Herd-Composition and Size

Total marketable herd size (pigs ≥ two months of age) did not differ significantly between islands ($P = 0.215$; back-transformed means, West Timor: 4.58 ± 1.17, Flores: 4.41 ± 1.16, Sumba: 6.01 ± 1.17) or pig breeds ($P = 0.096$; back-transformed means, local: 4.67 ± 1.09; cross-breed: 5.59 ± 1.12; both local and cross-breed: 4.64 ± 1.12). The village with the largest mean total herd size by island was Pruda Village in Flores (8.12 ± 4.27 pigs), Sobawawi Village in Sumba (7.38 ± 4.00 pigs) and Duabesi Village in West Timor (5.60 ± 3.44 pigs). Total herd size ranged from one to 31 pigs (Table 5.7).

The mean number of weaners, growers and fatteners present in herds was greater than sows and boars ($P > 0.001$; back-transformed means, weaners: 2.83 ± 1.07, growers: 2.43 ± 1.07, fatteners: 2.18 ± 1.08, sows: 1.61 ± 1.07, boars: 1.49 ± 1.12). A significantly higher mean number of local breed pigs were present in herds in comparison to cross-breed pigs ($P < 0.05$; back-transformed means, local: 3.4 ± 1.06; cross: 1.7 ± 1.02).

The age groups reported most commonly in herds were sows and boars (83.04% and 46.7%, respectively). When herds were stratified by sow number, it was found that a larger proportion of farmers had only one sow in their herd (44.6%) versus two (26.3%; Figure 5.3). Weaner and grower pigs were found in 42.2% and 39.8% of herds, respectively. Only 24.2% of respondents reported having a fattener in their herd.
Table 5.7
Pig-herd characteristics recorded and herd size information during a smallholder farmer survey for pigs ≥ 2 months (marketable age groups) across West Timor, Flores and Sumba in Nusa Tenggara Timor stratified by island and breed type, eastern Indonesia, 2010 (n = 289).

<table>
<thead>
<tr>
<th>Island</th>
<th>Village</th>
<th>n</th>
<th>Total Pigs Number recorded (≥ 2 months, piglet not included)</th>
<th>Average Total Herd Size (≥ 2 months, not including piglet)</th>
<th>Herd Size Range (min, max)</th>
<th>Weaner (%)</th>
<th>Grower (%)</th>
<th>Fattener (%)</th>
<th>Sow (%)</th>
<th>Boar (%)</th>
<th>Local (%)</th>
<th>Cross (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Manutapen</td>
<td>16</td>
<td>72</td>
<td>4.50 ± 3.93</td>
<td>1, 16</td>
<td>22.22</td>
<td>18.06</td>
<td>4.17</td>
<td>26.39</td>
<td>29.17</td>
<td>38.89</td>
<td>61.11</td>
</tr>
<tr>
<td></td>
<td>Nunaun Delha</td>
<td>16</td>
<td>50</td>
<td>2.94 ± 1.57</td>
<td>1, 8</td>
<td>4.00</td>
<td>10.00</td>
<td>8.00</td>
<td>40.00</td>
<td>32.00</td>
<td>58.00</td>
<td>42.00</td>
</tr>
<tr>
<td></td>
<td>Benlutu</td>
<td>17</td>
<td>69</td>
<td>4.31 ± 1.25</td>
<td>2, 7</td>
<td>5.80</td>
<td>11.59</td>
<td>2.90</td>
<td>42.03</td>
<td>37.68</td>
<td>86.96</td>
<td>13.04</td>
</tr>
<tr>
<td></td>
<td>Boentuka</td>
<td>16</td>
<td>88</td>
<td>4.53 ± 2.60</td>
<td>1, 12</td>
<td>13.64</td>
<td>11.36</td>
<td>6.82</td>
<td>32.95</td>
<td>22.73</td>
<td>79.55</td>
<td>20.45</td>
</tr>
<tr>
<td></td>
<td>Nanaet</td>
<td>16</td>
<td>86</td>
<td>4.00 ± 2.96</td>
<td>1, 13</td>
<td>5.81</td>
<td>26.74</td>
<td>0.00</td>
<td>26.74</td>
<td>19.77</td>
<td>93.02</td>
<td>6.98</td>
</tr>
<tr>
<td></td>
<td>Duabesi</td>
<td>16</td>
<td>84</td>
<td>5.60 ± 3.44</td>
<td>1, 14</td>
<td>13.10</td>
<td>28.57</td>
<td>0.00</td>
<td>38.10</td>
<td>20.24</td>
<td>100.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Flores</td>
<td>Nurri</td>
<td>16</td>
<td>82</td>
<td>4.73 ± 2.55</td>
<td>1, 10</td>
<td>32.93</td>
<td>19.51</td>
<td>1.22</td>
<td>24.39</td>
<td>8.54</td>
<td>54.88</td>
<td>45.12</td>
</tr>
<tr>
<td></td>
<td>Riangburra</td>
<td>16</td>
<td>129</td>
<td>6.65 ± 3.20</td>
<td>2, 16</td>
<td>27.91</td>
<td>10.85</td>
<td>6.20</td>
<td>24.81</td>
<td>17.83</td>
<td>77.52</td>
<td>22.48</td>
</tr>
<tr>
<td></td>
<td>Ilinmedo</td>
<td>16</td>
<td>55</td>
<td>3.00 ± 2.53</td>
<td>1, 9</td>
<td>25.45</td>
<td>12.73</td>
<td>3.64</td>
<td>38.18</td>
<td>7.27</td>
<td>69.09</td>
<td>30.91</td>
</tr>
<tr>
<td></td>
<td>Pruda</td>
<td>16</td>
<td>137</td>
<td>8.12 ± 4.27</td>
<td>3, 18</td>
<td>29.93</td>
<td>20.44</td>
<td>8.03</td>
<td>26.28</td>
<td>10.22</td>
<td>95.62</td>
<td>4.38</td>
</tr>
<tr>
<td></td>
<td>Golo Mbu</td>
<td>16</td>
<td>77</td>
<td>2.81 ± 1.56</td>
<td>1, 6</td>
<td>10.39</td>
<td>12.99</td>
<td>0.00</td>
<td>20.78</td>
<td>14.29</td>
<td>27.27</td>
<td>72.73</td>
</tr>
<tr>
<td></td>
<td>Nampar Macing</td>
<td>16</td>
<td>55</td>
<td>3.44 ± 1.46</td>
<td>2, 6</td>
<td>32.73</td>
<td>18.18</td>
<td>14.55</td>
<td>23.64</td>
<td>10.91</td>
<td>61.82</td>
<td>38.18</td>
</tr>
<tr>
<td>Sumba</td>
<td>Rindi</td>
<td>16</td>
<td>122</td>
<td>6.75 ± 3.68</td>
<td>2, 13</td>
<td>26.23</td>
<td>18.85</td>
<td>12.30</td>
<td>20.49</td>
<td>10.66</td>
<td>73.77</td>
<td>26.23</td>
</tr>
<tr>
<td></td>
<td>Kayuri</td>
<td>16</td>
<td>118</td>
<td>4.62 ± 2.36</td>
<td>2, 9</td>
<td>16.95</td>
<td>16.10</td>
<td>11.02</td>
<td>15.25</td>
<td>3.39</td>
<td>56.78</td>
<td>43.22</td>
</tr>
<tr>
<td></td>
<td>Walla Ndimu</td>
<td>16</td>
<td>154</td>
<td>6.12 ± 5.80</td>
<td>2, 31</td>
<td>11.04</td>
<td>6.49</td>
<td>12.99</td>
<td>21.43</td>
<td>11.69</td>
<td>42.86</td>
<td>57.14</td>
</tr>
<tr>
<td></td>
<td>Sobawawi</td>
<td>16</td>
<td>128</td>
<td>7.38 ± 4.00</td>
<td>2, 17</td>
<td>33.59</td>
<td>19.53</td>
<td>17.97</td>
<td>14.06</td>
<td>7.03</td>
<td>47.66</td>
<td>52.34</td>
</tr>
<tr>
<td></td>
<td>Waekrau</td>
<td>16</td>
<td>134</td>
<td>5.94 ± 2.62</td>
<td>3, 13</td>
<td>17.16</td>
<td>15.67</td>
<td>20.15</td>
<td>14.18</td>
<td>3.73</td>
<td>58.21</td>
<td>41.79</td>
</tr>
<tr>
<td></td>
<td>Waikarara</td>
<td>16</td>
<td>170</td>
<td>5.38 ± 2.36</td>
<td>3, 12</td>
<td>12.94</td>
<td>11.76</td>
<td>6.47</td>
<td>13.53</td>
<td>5.88</td>
<td>58.82</td>
<td>41.18</td>
</tr>
</tbody>
</table>
The distribution of breeding sows in smallholder pig herds from a farmer survey in Nusa Tenggara Timur, eastern Indonesia, 2010 (n = 289).

5.3.4.2 Pig Housing

There were various techniques used for housing pigs across this region with some farmers having multiple methods depending on the age of the pig. The use of a kandang as a pig pen was reported across this province (74.4%; n = 289) and was common across islands ($P = 0.046$; West Timor: 40.9%; Flores: 31.6%; Sumba: 27.4%). Tethering of pigs was also utilised by 24.9% of pig farmers and this was significantly greater in West Timor in comparison to Flores ($P < 0.001$; West Timor: 5.6%; Flores: 59.7%; Sumba: 34.7%). These were the two main methods for confined housing. When pigs were tethered, they remained in one location tied to a tree or stable structure close to the house where they could be observed. A small proportion (7.3%) of pig farmers allowed their adult pigs to be free roaming while piglets were penned. Alternatively, 1.0% reported pigs to be free roaming during daylight hours and penned during the night.

5.3.4.3 Pig Nutrition and Feed

Only a very small proportion of pig farmers purchased commercial feed (1.7%; n = 288). The most popular feed types were different agricultural products (93.1%) including fruit products (such as papaya, coconut and banana) and vegetable products (such as corn, rice bran, cassava and taro). Rice bran was also a commonly utilised feed type (43.8%). In addition, the feeding of table scraps and food waste was reported (32.3% and 4.5%...
respectively). Pig owners in Sumba reported the use of ‘brem’ which is a fermented mixture of rice and other vegetables (1.4%).

5.3.4.4 Water Source for Pigs

It was determined that 97.9% (n = 289) of pig farmers provided water to their pigs. The largest proportion of farmers used a river as their water source (31.1%), which was significantly higher in West Timor in comparison to Flores (P < 0.05; West Timor: 19.3%; Flores: 48.9%; Sumba: 31.8%). The next most used water source was a well (23.7%) which was significantly higher in Sumba (P < 0.001; West Timor: 13.4%; Flores: 9.0%; Sumba: 77.6%). Only 21.9% reported using government/pipe water for their pigs. This was reported most commonly in West Timor and Flores (P < 0.001; West Timor: 35.5%; Flores: 59.7%; Sumba: 4.8%). An additional 9.9% used alternative water sources, including dam water and run-off water from rice fields.

5.3.4.5 Cleaning of Pigpen Areas

Overall, 21.3% (n = 286) of pig farmers stated that no on-farm cleaning procedures occurred, this was common across islands (P = 0.08; West Timor: 31.1%; Flores: 23.0%; Sumba: 45.9%). For the 78.7% of pig farmers that reported cleaning pig pens, the methods used were basic and included sweeping waste from the pen to the surrounding area or using water to wash the kandang. Different housing methods influenced cleaning procedures. Farmers with kandangs elevated off the ground stated that cleaning was not necessary as waste would fall below the pen. The proportion of farmers with kandangs that were elevated off the ground was not captured in the questionnaire. Rather than removing the waste, tethered pigs were moved to different areas.

It was found that 35.9% (n = 284) of pig farmers took no action to dispose of pig manure, this was most commonly seen in West Timor and Sumba (P < 0.05; West Timor: 44.1%; Flores: 19.6; Sumba: 36.3%). Few farmers buried (4.2%) or burned (7.0%) waste; 27.8% utilised pig manure for compost, most commonly seen in Sumba (P < 0.05; West Timor: 24.1%; Flores: 24.1%; Sumba: 51.9%). Some other responses included throwing the waste next to the pigpen (6.0%) or throwing away the waste (16.9%).

5.3.4.6 Identification Methods Used with Pigs

Only 20.4% (n = 289) of pig farmers reported using some form of identification system for their pigs and this was common across islands (P = 0.802; West Timor: 32.2%; Flores: 37.3%; Sumba: 30.5%). Of this small proportion (n = 59), 78.0% used ear notching (P =
0.393; West Timor: 39.1%, Flores: 23.9%, Sumba 37.0%), 18.6% used ear tagging ($P < 0.001$; West Timor: 9.1%, Flores: 91.0%, Sumba 0.0%) and 3.4% docked tails (one respondent from Flores and one from Sumba). No reports of tattoos or paint being applied were provided by respondents.

5.3.5 Pig Health

5.3.5.1 Clinical Signs of a Sick Pig

Most (86.5%; $n = 289$) smallholder farmers reported being able to identify at least one clinical sign of a sick pig. This did not differ between islands ($P = 0.151$; West Timor: 33.6%, Flores: 28.4%, Sumba: 38.0%).

Figure 5.4 shows clinical signs that were recognised by farmers. Appetite loss was the most recognised sign (73.7%), significantly higher in Sumba compared to Flores ($P = 0.026$; West Timor: 32.4%, Flores: 26.3%, Sumba: 41.3%). In Sumba a large proportion of pig farmers associated red eyes with a sick pig (27.6%), greater than the other two islands ($P < 0.001$; West Timor: 24.8%, Flores: 18.2%, Sumba: 57.0%). In addition, hair standing on end was also considered to be a sign of sickness (38.8%).

Figure 5.4
Recognised clinical signs of a sick pig by smallholder farmers across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010 ($n = 250$).

178
5.3.5.2 Quarantine and Separation of Sick Pigs

For respondents that were capable of identifying a sick pig, only 52.4% (n = 250) reported separating or quarantining sick animal/s from the herd. This was predominantly seen in Flores and Sumba (P < 0.001: West Timor: 22.9%, Flores: 37.4%, Sumba: 39.7%).

5.3.5.3 Sudden Death

Respondents were asked to provide information regarding any pigs that had died suddenly without signs of illness during the previous 12 months (March 2009 to March 2010). A small proportion of farmers did not provide a response (13.1%; n = 289). Over a third of respondents (38.2%; n = 249), reported at least one sudden death, with an additional 1.6% being unsure. A total of 95 cases were reported, representing 264 deaths (Figure 5.5). The highest proportion of farmers reporting cases of sudden death were from West Timor. However, this did not vary significantly between islands (P = 0.271: West Timor: 41.1%, Flores: 28.4%, Sumba: 30.5%). The average number of sudden deaths occurring per farmer per month was highest for West Timor (West Timor: 3.0 ± 1.4 pigs; Flores: 2.9 ± 2.1 pigs; Sumba: 2.2 ± 1.3 pigs).

Temporal trends are shown in Figure 5.5. The highest number of farmer-reported cases across the province occurred in January, February and March (14.7%, 17.9% and 16.8%, respectively). West Timor farmers reported the highest number of pig deaths (112), followed by Flores (87) and Sumba (65). Overall, the highest number of pig deaths recorded (51) was in March.
5.3.5.4 Cases of Sick or Dead Pigs on the Farm

In addition to cases of sudden death, 40.2% \( (n = 249) \) of farmers reported at least one sick pig within the last year (Table 5.8). A small proportion did not provide an answer to this question (13.8%), with an additional 3.6% unsure of their response. This question required respondents to provide information in addition to sudden deaths. However, it should be noted that differentiating between the sudden death of a pig and another that died from illness over time was not easy for respondents; thus, the results obtained in this section and the previous question may represent some of the same animals.

It was found that local pig breeds experienced a higher rate of illness compared to cross-bred types with 68.4% of sick pigs being of a local type \( (n = 98) \). The months in which the highest number of pig farmers reported having sick pigs were February, March and December (Figure 5.6). Combined, these months represented over half of reported cases. Weaner and grower pigs were the age groups that experienced the highest proportion of sick pigs (weaner: 20.7%; grower: 29.8%; fattener: 4.0%; sow: 19.8%; boar: 13.9%).

When farmers experienced sick pigs on the farm, this resulted in a mean of 2.6 \( \pm 1.9 \) pig deaths across all three islands. The time period from onset of clinical signs to death did not significantly vary across islands \( (P = 0.087; \ Table \ 5.9) \).
The clinical signs that were most highly recognised by farmers across the three islands were loss of appetite (53.6%), fever (28.6%; n = 97), diarrhoea (26.5%), tiredness (25.5%) and red eyes (19.4%). One respondent did not remember any clinical signs.

![Figure 5.6](image)

**Figure 5.6**
The number of pig farmers with a sick pig stratified by month across West Timor, Flores and Sumba in Nusa Tenggara Timur, Indonesia, 2009-2010 (n = 98).

**Table 5.8**
The number of pigs that died as a result of a single illness case reported by smallholder pig farmers stratified by island across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009–2010 (n = 821 refers to the total number of farmers).

<table>
<thead>
<tr>
<th>Island</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>25% quartile</th>
<th>75% quartile</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>32</td>
<td>3.03</td>
<td>2.00</td>
<td>1.00</td>
<td>13.00</td>
<td>1.00</td>
<td>4.00</td>
<td>2.90</td>
</tr>
<tr>
<td>Flores</td>
<td>25</td>
<td>2.64</td>
<td>2.00</td>
<td>1.00</td>
<td>8.00</td>
<td>1.00</td>
<td>3.25</td>
<td>2.12</td>
</tr>
<tr>
<td>Sumba</td>
<td>25</td>
<td>2.12</td>
<td>2.00</td>
<td>1.00</td>
<td>5.00</td>
<td>2.00</td>
<td>2.00</td>
<td>0.88</td>
</tr>
</tbody>
</table>

1A total of 18 farmers did not answer the questions in this section.
Table 5.9
The number of days taken for a pig to die from initial onset of clinical signs to death across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2009–2010 (n = 78).\(^1\)

<table>
<thead>
<tr>
<th>Island</th>
<th>n</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
<th>25% quartile</th>
<th>75% quartile</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>32</td>
<td>5.62</td>
<td>4.00</td>
<td>1.50</td>
<td>30.00</td>
<td>2.00</td>
<td>6.50</td>
<td>5.77</td>
</tr>
<tr>
<td>Flores</td>
<td>21</td>
<td>3.02</td>
<td>3.00</td>
<td>1.00</td>
<td>7.00</td>
<td>2.00</td>
<td>3.25</td>
<td>1.71</td>
</tr>
<tr>
<td>Sumba</td>
<td>25</td>
<td>5.28</td>
<td>4.00</td>
<td>2.00</td>
<td>14.00</td>
<td>3.00</td>
<td>7.00</td>
<td>3.17</td>
</tr>
</tbody>
</table>

\(^1\)A total of 22 farmers did not answer the questions in this section.

5.3.5.5 Process of Treatment for a Sick Pig

When a sick pig was identified in the herd, the majority of farmers reported using traditional medicine (33.2%; n = 250). This was preferred over calling a veterinarian or FEA (8.4% and 14.4%, respectively). Some of the traditional methods used included pigs being provided with ‘salt water to drink with coconut oil rubbed on the body’, ‘ginger and onion rubbed all over the body’ and ‘drinking coconut water’. A similar proportion of farmers (30.4%) stated that they did nothing when a pig became sick. Several households reported the slaughter and consumption of the pig (4.0%) while other chose to sell the meat using the leis method (2.0%) or to sell the pig live (5.6%).

5.3.5.6 Hearing of Pig Illness by other Individuals or Villages

Almost half (45.1%; n = 288) of the pig farmers reported hearing of other individuals, either a neighbour or an individual within their village or in another subdistrict, having sick pigs during the previous 12 months. This was similar across islands \(P = 0.119\); West Timor: 40.0%, Flores: 34.6%, Sumba: 25.4%). A large proportion of farmers reported knowing if an adjacent neighbour had had sick pigs in the previous 12 months (43.7%; n = 130). Farmers recalled clinical signs that included fever (11.2%), depression (12.9%), appetite loss (28.4%), unsteady gait (9.5%), diarrhoea (22.4%), and red spots on the body (3.4%; n = 116). Fourteen respondents could not recall any clinical signs.

5.3.5.7 On-farm Visitation by Veterinarians and/or FEA

The majority of pig farmers (64.5%; n = 287) stated they had never had a veterinarian or an animal health worker visit their village. This was common across all islands \(P = 0.347\); West Timor: 34.1%, Flores: 37.3%, Sumba: 28.6%). Field Extension Agents (47.1%; n =
102) or veterinary assistants (43.1%) were the specific animal health authorities reported to visit villages. Only 14.7% of respondents stated that veterinarians had visited their village.

For those pig farmers who had received visits by various AHWs, 65.7% (n = 99) reported that this was to check on a sick pig. An additional 47.5% stated that it was to provide a vaccination/injection. Similar to the market survey, the term vaccination was used by farmers to refer to any injection given to a pig. Only 9.1% of pig farmers reported that FEAs had given them animal health information.

### 5.3.5.8 Disposal of Dead Pigs

Across NTT, farmers used various methods to dispose of dead pigs depending on whether they were suspected to have died from disease, died a sudden death or were considered disease free. The largest proportion of farmers reported consuming pigs when they had died which was done more often if the animal was considered not to have died from disease ($P < 0.001$; suspected disease: 25.6%; sudden death: 39.6% and considered disease free: 69.0%). For those consuming pigs that were considered disease free, this was found to be common across islands ($P = 0.06$; West Timor: 31.6%; Flores: 27.3%; Sumba: 41.2%). For animals that had died of suspected disease or sudden death, there was a greater tendency for these pigs to be buried (57.1% and 44.5%, respectively; Table 5.10).
Table 5.10
The disposal method of dead pigs according to death type (including suspected disease, sudden death and considered free from disease) across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010 (suspected disease: n = 273; sudden death: n = 265; considered disease free: n = 271).

<table>
<thead>
<tr>
<th>Disposal Method</th>
<th>Suspected Disease</th>
<th>TOTAL</th>
<th>%</th>
<th>Sudden Death</th>
<th>TOTAL</th>
<th>%</th>
<th>Considered Disease Free</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WT(^1) F(^2) S(^3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burn</td>
<td>1 2 6</td>
<td>9</td>
<td>3.30</td>
<td>1 4 3</td>
<td>8</td>
<td>3.02</td>
<td>1 0 2</td>
<td>3</td>
<td>1.11</td>
</tr>
<tr>
<td>Bury</td>
<td>45 33 78</td>
<td>156</td>
<td>57.14</td>
<td>42 27 49</td>
<td>118</td>
<td>44.53</td>
<td>30 12 15</td>
<td>57</td>
<td>21.03</td>
</tr>
<tr>
<td>Eat</td>
<td>47 17 6</td>
<td>70</td>
<td>25.64</td>
<td>49 20 36</td>
<td>105</td>
<td>39.62</td>
<td>59 51 77</td>
<td>187</td>
<td>69.00</td>
</tr>
<tr>
<td>Other</td>
<td>4 30 4</td>
<td>38</td>
<td>13.92</td>
<td>4 24 6</td>
<td>34</td>
<td>12.83</td>
<td>6 18 0</td>
<td>24</td>
<td>8.86</td>
</tr>
</tbody>
</table>

\(^1\)West Timor; \(^2\)Flores; \(^3\)Sumba
### 5.3.5.9 Reporting of Sick or Dead Pigs

It was found that 71.5% (n = 284) of pig farmers did not report cases of sick pigs and a further 76.0% (n = 283) did not report cases in which pigs had died to appropriate authorities (including FEAs, veterinarians or veterinary assistants). This was similar across islands (dead pigs: $P = 0.619$, West Timor: 34.4%, Flores: 35.3%, Sumba: 30.23%; sick pigs: $P = 0.519$, West Timor: 35.5%, Flores: 35.0%, Sumba: 29.6%). Reasons for this involved several common themes recognised on all islands. Farmers were unaware of the practice of reporting (25.2%), did not know where to report (13.9%) and distances to town to report were too great to travel (7.9%; Table 5.11).

An additional 3.4% stated that even if reporting occurred, the government does not respond. One individual stated that the government is only concerned with large animals and pigs are of little concern. Respondents were more reluctant to report dead pigs because the government would confiscate the carcass and they would not be able to consume the meat. Farmers were fearful of the impact on future selling prospects if people from other villages heard that they had a sick or dead pig. One respondent stated ‘currently there is so much disease that there is no point in reporting as the government never does anything’.

Table 5.11
Reasons for not reporting sick or dead pigs on smallholder pig farms across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2010 (n = 266).

<table>
<thead>
<tr>
<th>Why Not Reporting</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>91</td>
<td>90</td>
<td>85</td>
<td>266</td>
<td>100</td>
</tr>
<tr>
<td>Unaware of reporting practice</td>
<td>30</td>
<td>30</td>
<td>7</td>
<td>67</td>
<td>25.19</td>
</tr>
<tr>
<td>Do not know where to report</td>
<td>6</td>
<td>8</td>
<td>16</td>
<td>30</td>
<td>13.91</td>
</tr>
<tr>
<td>Too far to travel to make a report</td>
<td>3</td>
<td>1</td>
<td>17</td>
<td>21</td>
<td>7.89</td>
</tr>
<tr>
<td>No FEA or officer</td>
<td>3</td>
<td>5</td>
<td>9</td>
<td>17</td>
<td>6.39</td>
</tr>
<tr>
<td>Pig is owned by the farmer</td>
<td>9</td>
<td>6</td>
<td>0</td>
<td>15</td>
<td>5.64</td>
</tr>
<tr>
<td>No regulation to report</td>
<td>4</td>
<td>6</td>
<td>1</td>
<td>11</td>
<td>4.14</td>
</tr>
<tr>
<td>No response from government if reported</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>9</td>
<td>3.38</td>
</tr>
</tbody>
</table>

### 5.3.5.10 Protecting Pigs from Disease

The majority of farmers believed that if they performed regular cleaning of their pigpens and regularly fed their pigs that they would be protected from disease (24.6% and 25.0%
respectively; n = 244). This response was significantly different between West Timor and Sumba (clean pen: \( P < 0.001 \), West Timor: 68.3%, Flores: 21.7%, Sumba: 10%; feed regularly: \( P < 0.001 \), West Timor: 70.5%, Flores: 24.6%, Sumba: 4.9%). It was interesting to note that 14.3% of farmers stated that vaccination was effective protection against disease. However, no respondents could identify any types of vaccinations required for pigs. Separating sick and healthy pigs, providing drinking water and washing pigs were also believed to protect them from disease (11.1%, 8.6% and 8.2%, respectively). An additional 13.5% were unsure of any methods that could assist in protecting a pig from disease.

5.3.6 Buying Practices and Farm Biosecurity

5.3.6.1 Pig Purchases Made During 2009–2010

It was found that out of 289 respondents, 61.6% reported that they had not purchased any pigs over the previous year; an additional 2.8% did not remember. For farmers that had purchased a pig during the previous 12 months (\( n = 103 \)), 86.4% had purchased at least one pig and a further 13.6% confirmed two or more purchases. The mean number of pigs purchased was similar across islands (\( P = 0.460 \); back-transformed means, West Timor: 1.61 ± 1.20; Flores: 2.19 ± 1.63; Sumba: 2.67 ± 1.59).

The largest proportion of pigs purchased based on pig numbers were weaner age group (48.5%). Although fatteners only represented a small proportion of purchases (12.6%), predominantly from Sumba (West Timor: 30.8%, Flores: 0.0%; Sumba: 69.2%), a greater mean number of fatter pigs were purchased per farmer compared to other age groups (\( P > 0.05 \); back-transformed means, fattenner: 4.30 ± 2.15; boar: 1.82 ± 1.49; grower: 2.58 ± 1.43; sow: 2.21 ± 1.34; weaner: 1.45 ± 1.33). One respondent reported purchasing 10 fatteners in one transaction (Table 5.1). A total of 209 pigs of marketable age (≥ 2 months) were reported as being purchased on an annual basis for 2009–2010 (West Timor: 77; Flores: 67; Sumba: 65).

The majority of purchases occurred during January, February and March (14.75%, 12.30% and 12.30%, respectively). The largest number of pigs purchased during a single month was 18 (October on Sumba; Figure 5.7). Purchasing sources varied between respondents. Only 32.0% of pig farmers reported purchasing pigs from market, largely in West Timor (\( P < 0.05 \); West Timor: 57.6%, Flores: 21.2%, Sumba 21.2%). A large proportion of farmers purchased directly from another farmer (65.0%). This was similar across islands
(P = 0.257; West Timor: 38.8%; Flores: 37.3%; Sumba: 23.9%). The majority of farmers stated that they purchased a pig in order to raise the animal on their farm (73.0%; n = 103). Other common reasons included consumption at: a traditional ceremony (7.4%); and a funeral (4.9%).

Figure 5.7
The total number of pigs purchased by 103 smallholder pig farmers on an annual basis from 2009-2010 across West Timor, Flores and Sumba in Nusa Tenggara Timor, eastern Indonesia 2009–2010.
Table 5.12
Number of pigs of a marketable age (≥ 2 months of age) purchased between March 2009 and March 2010 stratified by age group and per transaction across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia (n = 103).

<table>
<thead>
<tr>
<th>Island</th>
<th>Age Group</th>
<th>Number of Farmers</th>
<th>Total No. of Pigs Purchased</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Weaner</td>
<td>19</td>
<td>28</td>
<td>1.47</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Grower</td>
<td>5</td>
<td>12</td>
<td>2.40</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Fattener</td>
<td>4</td>
<td>9</td>
<td>2.25</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Sow</td>
<td>10</td>
<td>15</td>
<td>1.50</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Boar</td>
<td>9</td>
<td>13</td>
<td>1.44</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Flores</td>
<td>Weaner</td>
<td>22</td>
<td>35</td>
<td>1.59</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Grower</td>
<td>10</td>
<td>16</td>
<td>1.60</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Fattener</td>
<td>0</td>
<td>0</td>
<td>0.00</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Sow</td>
<td>5</td>
<td>11</td>
<td>2.20</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Boar</td>
<td>4</td>
<td>5</td>
<td>1.25</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Sumba</td>
<td>Weaner</td>
<td>9</td>
<td>22</td>
<td>2.44</td>
<td>2</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Grower</td>
<td>5</td>
<td>8</td>
<td>1.60</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Fattener</td>
<td>9</td>
<td>26</td>
<td>2.89</td>
<td>2</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Sow</td>
<td>4</td>
<td>6</td>
<td>1.50</td>
<td>1.5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Boar</td>
<td>3</td>
<td>3</td>
<td>1.00</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

5.3.6.2 Pigs as Gifts

Only 16.0% of farmers reported receiving pigs as gifts during the previous year (March 2009 to March 2010; n = 287). This was particularly reported by farmers from Sumba (P < 0.001; West Timor: 10.9%, Flores: 32.6%, Sumba: 56.5%). The three most common events that resulted in pigs being given as a gift were funerals (32.2%), traditional ceremonies (27.1%) and marriages (10.2%). The months with the highest number of gifts given were August (26.8%), September (17.9%) and October (12.5%).

A total of 122 pigs were reported as being given as gifts, and the highest proportion of those were fatteners (49.2%). Pig volume was highest for fatteners, sows and growers (60, 25 and 16 pigs, respectively). Only 14 boars and three weaners were reported as being given as gifts. It was found that 78.3% (n = 46) of farmers slaughtered a pig that was given as a gift on the day it was received. In addition, 56.5% stated that the introduced pig had
direct contact with pigs already on the farm prior to slaughter. This was more likely to occur in Sumba ($P < 0.001$; $n = 26$; West Timor: 23.1%, Flores: 3.8%, Sumba: 73.1%).

5.3.6.3 Quarantine of Newly Purchased Pigs

Almost half of respondents did not keep newly introduced pigs separated from their current on-farm herd (47.9%; $n = 257$).

5.3.6.4 Knowledge of Biosecurity

Only a very small proportion (2.2%; $n = 278$) of pig farmers had heard of the term biosecurity (11 respondents did not provide a response). When biosecurity was explained to respondents, an additional 65.1% ($n = 249$; 29 respondents did not provide a response) stated that they performed at least one biosecurity practice on the farm. A larger proportion of farmers from Flores reported using at least one biosecurity measure on-farm, which was significantly higher than Sumba ($P < 0.05$; West Timor: 28.4%, Flores: 30.5%, Sumba: 16.1%). The separation of sick and healthy pigs was the most recognised and used biosecurity measure across the three islands (74.4%; Figure 5.8). This was most commonly reported in Flores, compared to West Timor ($P < 0.05$; West Timor: 18.4%, Flores: 47.2%, Sumba: 34.4%). Other measures, such as cleaning pigpens (25.0%), cleaning equipment (20.2%) and vaccination/injection (17.3%), had a much lower reported usage by farmers. For those that vaccinated their pigs, two reported vaccinating for CSF and an additional two respondents reported vitamin B injections (which they believed to be vaccinations). The remaining 19 respondents did not know what vaccinations their pigs received. Traditional medicine was also reported (2.4%), along with providing a good feed ration (3.0%), as measures to prevent disease.

5.3.6.5 Contact between Domestic and Foreign Pigs

It was found that 39.6% ($n = 283$) of farmers reported that their pigs came in contact with foreign pigs (defined as pigs that were not owned by the farmer, which could include other pigs from the village or wild pigs) on a regular basis. This was predominantly reported by farmers from Sumba and Flores ($P < 0.001$; West Timor: 7.1%, Flores: 47.3%, Sumba: 45.5%). Of those that reported foreign pig contact, 94.6% reported contact with pigs owned by neighbours, a further 18.8% with village pigs (free roaming pigs owned by other members of the village) and 8.9% with wild pigs, with multiple options selected.
5.3.7 Selling Practices of Live Pigs

5.3.7.1 Pigs being Sold or Leaving a Herd

Just under half of farmer respondents (48.3%; n = 288) had no pigs leave their herd during the year from March 2009 to March 2010. An additional 5.9% could not remember if this had occurred and one respondent chose not to answer. Therefore it was concluded that 45.8% (132 respondents) of farmers had at least one pig leave their herd over the previous year.

Only 25.8% of pigs were traded through a market; a further 27.3% were purchased directly by other pig farmers. A larger proportion of pigs were given to family or relatives (40.2%). It was found that 15.9% sold their pigs to pig collectors, and this was predominantly seen in Flores (P < 0.001; West Timor: 4.8%; Flores: 85.7%; Sumba: 9.5%).

A reported total of 329 pigs exited herds during the previous 12 months (West Timor: 76 pigs, Flores: 123 pigs, Sumba: 130 pigs). The mean number of pigs exiting a herd was similar between islands (P = 0.338; back-transformed means: West Timor: 1.49 ± 1.17; Flores: 1.54 ± 1.19; Sumba: 1.87 ± 1.19). The mean number of weaners exiting was significantly higher than all other age groups (P < 0.001; back-transformed means: weaner: 2.54 ± 1.20; grower: 1.86 ± 1.17; fattener: 1.51 ± 1.16; sow: 1.05 ± 1.02; boar: 1.50 ± 1.16). A significantly greater number of growers and fatteners exited a herd compared to sows (P < 0.05). Descriptive statistics for each village are shown in Table 5.1. Golo Mbu village in Manggarai Barat district reported the highest number of pigs exiting a herd.

The most common reasons given by farmers for pigs exiting a herd were selling these pigs to obtain money to purchase household necessities and food (53.2%), to pay for school and education costs for their children (14.7%), and for use in traditional ceremonies (21.1%). These pigs were primarily traded via markets (25.6%), sold to other farmers (27.7%) or given to a relative or family member (40.6%). In addition, our findings demonstrated that farmers tended to sell their pigs only when money was required, with respondents being unsure about months during the year for peak pig trading. The majority of these transactions occurred during January (11.5%), and from August through to October (10.9%, 12.2% and 10.9%, respectively; Figure 5.8).
It was determined that the dominant age groups being sold by farmers were boars (31.6%; \(n = 133\)) and fatteners (26.3%). A significantly higher proportion of farmers from Sumba reported selling fatteners \((P < 0.001;\) West Timor: 22.9%, Flores: 2.9%, Sumba: 74.3%).

Figure 5.8
The number of pigs exiting 133 smallholder herds during an annual period (2009–2010) across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia.
Table 5.13
Descriptive statistics for the number of pigs exiting 133 smallholder herds, from 18 different villages during an annual period (2009–2010) in Nusa Tenggara Timur, eastern Indonesia.

<table>
<thead>
<tr>
<th>Island</th>
<th>Village</th>
<th>n</th>
<th>Total No. of Pigs Exiting Herds</th>
<th>Mean</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Timor</td>
<td>Nunbaun Delha</td>
<td>4</td>
<td>5</td>
<td>1.25</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Manutapen</td>
<td>10</td>
<td>29</td>
<td>2.64</td>
<td>1.00</td>
<td>1.00</td>
<td>15.00</td>
</tr>
<tr>
<td></td>
<td>Boentuka</td>
<td>3</td>
<td>3</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td></td>
<td>Benluta</td>
<td>7</td>
<td>16</td>
<td>1.60</td>
<td>1.00</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Duabesi</td>
<td>7</td>
<td>15</td>
<td>1.88</td>
<td>2.00</td>
<td>1.00</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Nanaet</td>
<td>7</td>
<td>8</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Flores</td>
<td>Riangburra</td>
<td>6</td>
<td>19</td>
<td>2.71</td>
<td>1.00</td>
<td>1.00</td>
<td>7.00</td>
</tr>
<tr>
<td></td>
<td>Nurri</td>
<td>9</td>
<td>18</td>
<td>1.50</td>
<td>1.00</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>Ilinmedo</td>
<td>3</td>
<td>4</td>
<td>1.33</td>
<td>1.00</td>
<td>1.00</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Pruda</td>
<td>5</td>
<td>17</td>
<td>2.83</td>
<td>3.00</td>
<td>1.00</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Nampar Macing</td>
<td>12</td>
<td>25</td>
<td>2.08</td>
<td>1.00</td>
<td>1.00</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>Golo Mbu</td>
<td>11</td>
<td>40</td>
<td>2.86</td>
<td>1.00</td>
<td>1.00</td>
<td>20.00</td>
</tr>
<tr>
<td>Sumba</td>
<td>Rindi</td>
<td>8</td>
<td>27</td>
<td>3.00</td>
<td>2.00</td>
<td>1.00</td>
<td>10.00</td>
</tr>
<tr>
<td></td>
<td>Kayuri</td>
<td>11</td>
<td>23</td>
<td>1.77</td>
<td>2.00</td>
<td>1.00</td>
<td>4.00</td>
</tr>
<tr>
<td></td>
<td>Walla Ndimu</td>
<td>6</td>
<td>10</td>
<td>1.67</td>
<td>1.50</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Waikarara</td>
<td>11</td>
<td>19</td>
<td>1.46</td>
<td>1.00</td>
<td>1.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>Sobawawi</td>
<td>7</td>
<td>33</td>
<td>4.12</td>
<td>3.00</td>
<td>1.00</td>
<td>16.00</td>
</tr>
<tr>
<td></td>
<td>Waekrau</td>
<td>6</td>
<td>18</td>
<td>2.25</td>
<td>2.00</td>
<td>1.00</td>
<td>4.00</td>
</tr>
</tbody>
</table>

5.3.7.2 Factors Influencing the Selling Behaviour of Farmers

Farmers were asked to rate the likelihood that they would sell a pig according to three different factors: when money was required, when their pig was sick, and when their pig became old. The two factors that were most likely to influence the sale of a pig were: the need for money (89.3%; n = 243), and the age of a pig (40.3%). A large proportion of respondents stated that they would be unlikely to sell a sick pig (46.5%). However, farmers from West Timor had a greater tendency to sell a sick pig compared to Flores (P < 0.001; West Timor: 51.7%; Flores: 6.7%; Sumba: 41.7%).
5.3.7.4 Transportation of Pigs to and from the Home

The most utilised transportation method for pigs was reported to be the motorbike (33.6%; n = 259). This was predominantly found in West Timor and Sumba (P < 0.001; West Timor: 59.8%, Flores: 3.4%, Sumba: 36.8%; n = 87). Moreover, 18.5% of farmers transported pigs by foot. A higher proportion of individuals from Flores chose to transport pigs using this method (P < 0.05; West Timor: 18.8%; Flores: 81.3%; Sumba: 0.0%; n = 48). Additional transportation methods included trucks (11.6%) and buses (4.6%), and 27.0% of farmers also reported that they had their own vehicles.

5.3.7.5 Restraint of Pigs during Transport

The dominant restraint method for pigs during transportation involved the use of ties made of dried palm fronds or cord (96.1%; n = 255). This was similar across islands (P = 0.275; West Timor: 38.0%, Flores: 32.2%, Sumba: 30.0%; n = 245). A smaller proportion chose to place pigs in a bag (9.8%).

5.3.7.6 Informing the Village Head of Pig Movements

In West Timor, 20.6% of farmers reported pig movements in and out of a village to the Village Head. Only minimal reporting occurred in Sumba (2.4%). For West Timor, reporting was observed to occur mainly during instances when a pig was being transported to market for sale or when it left the village as a gift. In Flores no individuals stated ever having reported pig movements to their Village Head.

5.3.8 Pig Meat Products and Slaughtering

5.3.8.1 Slaughtering of Pigs on the Farm

Over half of pig farmers reported slaughtering pigs on their farm (54.7%; n = 289), most commonly on Flores and Sumba (P < 0.001; West Timor: 12.0%, Flores: 34.8%, Sumba: 53.2%). The slaughtering procedure was performed predominantly by the respondent (48.7%) or a family member (55.7%). It was further reported that for some traditional ceremonies, pigs were transported to the event location for slaughter. A small proportion (8.1%) of farmers stated that pigs were brought to their farm by other members of the village for slaughter on their property.
5.3.8.2 Inspection of Pig Prior to Slaughter

Although the government states that it is a requirement that all pigs be inspected prior to slaughter, 72.4% (n = 158) of farmers reported never having done this. A further 12.9% were unsure what this meant.

5.3.8.3 Usage of Pig Meat Following Slaughter

The majority of pig farmers stated that pigs were slaughtered for home consumption (89.2%; n = 158). A further 17.8% specified that this was for pig meat consumption at a traditional ceremony. The leis method of meat distribution (refer to Glossary) was also reported by 6.4% of respondents. No respondent reported selling pig meat at market and two respondents from West Timor sold meat from their residence.

The largest proportion of pig farmers elected to throw away waste following slaughter (79.5%; n = 156). Only a small proportion of farmers chose to bury (5.1%) or burn waste (19.2%).

5.3.8.4 Peak Months for Pig Slaughter

The highest number of pig slaughters by farmers occurred in July, August and September (14.5%, 25.0% and 19.4%, respectively; n = 124). Reasons provided for this high-demand period included traditional ceremonies (45.0%; n = 49), first communion (26.5%) and marriage ceremonies (20.4%). All reports of first communions came from Flores.

Only 7.3% (n = 289) of farmers reported having pigs slaughtered at locations other than their farm/residence. For these individuals, this mostly occurred at another household within their village (47.2%; n = 17). No respondent reported using an abattoir to slaughter their pigs.

5.3.8.5 Most Common Locations to Purchase Pig Meat

The most common locations for purchasing pig meat varied across islands (27 respondents did not provide a response for this question). Over half of the farmers reported that they did not purchase any pig meat (55.0%; n = 262). A greater number of respondents in Sumba were found not to purchase pig meat compared to West Timor (P < 0.001; West Timor: 11.8%, Flores: 38.2%, Sumba: 50.0%). It was found that 24.8% of farmers reported purchasing meat from market. These individuals were predominantly from West Timor (P < 0.001; West Timor: 85.2%, Flores: 9.2%, Sumba: 4.6%). The leis method was also
reported by 17.6% of respondents. This was mostly observed in West Timor and Flores. An additional 2.3% purchased meat from sellers within their village, and another 2.3% purchased meat from sellers outside their village.

5.3.9 Pig Breeding

5.3.9.1 On-farm Breeding

A large proportion of smallholder pig farmers (82.2%; n = 289) confirmed that they bred pigs on their farms. This was similar across all three islands (P = 0.251; West Timor: 30.7%, Flores: 34.6%, Sumba: 34.6%). The most common method utilised for breeding was natural mating; very few respondents reported using artificial insemination (98.3% and 1.3% respectively; n = 232, five respondents did not provide an answer). The reported cases of artificial insemination were from West Timor (two respondents, performed by FEA) and Sumba (one respondent, performed by veterinarian).

5.3.9.2 Borrowing a Boar for Mating

The borrowing of boars for the purpose of on-farm mating was reported across all three islands. A total of 55.3% (n = 229) of smallholder farmers reported borrowing a boar for mating. This was similar across islands (P = 0.257; West Timor: 27.0%, Flores: 34.1%, Sumba: 38.9%). It was reported that 96.8% (n = 126) of boars borrowed came from within the same village; only a very small proportion was reported as coming from another village (2.4%).

5.3.9.3 Months of the Year Selected for Breeding

The majority of farmers were unsure what months of the year their pigs were mated (91.4%; n = 197). Farmers stated that pigs were mated to ensure high feed availability when piglets were born, often following harvest (11.3%; n = 69). A further 35.2% of farmers reported the ability to identify a sow when in oestrus. This was mainly through observation of increased displays of interest towards boars.

5.3.9.4 Use of Piglets Produced on the Farm

For farmers that produced piglets on their property, the majority kept these animals for their own use on the farm (93.1%; n = 216) or sold them within their village (28.7%).
5.3.10 Classical Swine Fever

5.3.10.1 Knowledge of CSF

It was found that 85.5% (n = 289) of smallholder farmers had not heard of CSF and four respondents were unsure. Of the 38 respondents that were familiar with the term, only 26 had any knowledge of the disease. These farmers were predominantly from Sumba (West Timor one respondent, Flores: 0 respondents, Sumba 25 respondents). A small proportion (18.4%), of those that had heard of CSF were unsure what it was.

5.3.10.2 Recognised Clinical Signs of CSF

Farmers reported identifying a variety of different clinical signs associated with CSF. Diarrhoea (76.9%) and anorexia (69.2%) were most commonly reported (Table 5.14).

Table 5.14
Clinical signs reported by pig farmers believed to be associated with classical swine fever across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010 (n = 26).

<table>
<thead>
<tr>
<th>CSF Clinical Signs</th>
<th>West Timor</th>
<th>Sumba</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>1</td>
<td>25</td>
<td>26</td>
<td>9.00</td>
</tr>
<tr>
<td>Diarrhoea</td>
<td>0</td>
<td>20</td>
<td>20</td>
<td>76.92</td>
</tr>
<tr>
<td>Anorexia</td>
<td>0</td>
<td>18</td>
<td>18</td>
<td>69.23</td>
</tr>
<tr>
<td>Purple/red discolouration of skin</td>
<td>1</td>
<td>11</td>
<td>12</td>
<td>46.15</td>
</tr>
<tr>
<td>Unsteady of feet</td>
<td>0</td>
<td>11</td>
<td>11</td>
<td>42.31</td>
</tr>
<tr>
<td>Depression</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>38.46</td>
</tr>
<tr>
<td>Fever</td>
<td>1</td>
<td>7</td>
<td>8</td>
<td>30.77</td>
</tr>
<tr>
<td>Red eyes</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>3.85</td>
</tr>
</tbody>
</table>

5.3.10.3 Suspect On-farm CSF Cases

Only nine pig farmers reported having a suspected case of CSF on their farm and all these cases were in Sumba. The age range of pigs with suspect CSF varied. One respondent did not provide any details for this section. The majority were weaners (50.0%; n = 8) and fatteners (25.0%). No piglets were reported to be affected. A mean of 2.56 pigs (median: 3.00; range: 1-5) became sick per suspect CSF event, and a mean of 2.17 pigs died (median: 2.00; range: 1-3). The mean time period from the identification of clinical signs to death was 7.50 days (median: 7.50, range 3–12).
Only four respondents specified the months and years that pigs became sick: two cases in March 2010, one in August 2009 and another two in June 2009. Pigs were predominantly of a local breed (75.0%; \( n = 8 \)). The clinical signs identified during these cases included diarrhoea (75.0%) and fever (62.5%).

To treat these pigs, the majority of farmers chose an injection of antibiotics (50.0%; \( n = 8 \)) or purchased vitamins for their pigs (25.0%). A smaller proportion of respondents chose to call appropriate animal health authorities for assistance, either a veterinarian (12.5%) or a FEA (12.5%).

### 5.3.10.4 Likelihood of Reporting Suspect CSF Cases

For the 26 farmers who could recognise CSF, the majority stated they would be likely to report a case (likely: 31.5%; very likely: 54.5%). Three respondents stated that due to the long distance of their village to any veterinarians or FEAs they would be unlikely to report.

### 5.3.10.5 Are Pigs Vaccinated for CSF?

Only 7.3% (\( n = 246 \)) of farmers, all from Sumba, reported ever having their pigs vaccinated for CSF. For this question 14.9% of farmers did not provide a response and an additional 14.6% were unsure. The majority of vaccinations were provided during the months of August (23.1%; \( n = 13 \)) and October (30.8%).

Table 5.15 presents the reasons provided by 158 farmers for not having their pigs vaccinated for CSF. It was found that 17.1% stated AHWs never make visits to their village and 17.1% stated that they did not have any knowledge of CSF vaccination. A proportion of farmers (14.6%) chose more than one response.
Table 5.1
Reasons provided by smallholder farmers as to why they do not have their pigs vaccinated for CSF across West Timor, Flores and Sumba in Nusa Tenggara Timur, eastern Indonesia, 2010 (n = 158).

<table>
<thead>
<tr>
<th>Reasons for No CSF Vaccination</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>TOTAL</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>45</td>
<td>33</td>
<td>80</td>
<td>158</td>
<td>100.00</td>
</tr>
<tr>
<td>No knowledge of CSF vaccination</td>
<td>16</td>
<td>8</td>
<td>3</td>
<td>27</td>
<td>17.09</td>
</tr>
<tr>
<td>¹AHW never comes to village</td>
<td>11</td>
<td>1</td>
<td>15</td>
<td>27</td>
<td>17.09</td>
</tr>
<tr>
<td>Not enough money</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>5.06</td>
</tr>
<tr>
<td>Unsure</td>
<td>30</td>
<td>0</td>
<td>1</td>
<td>31</td>
<td>19.62</td>
</tr>
<tr>
<td>Unsure where to get vaccine</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0.63</td>
</tr>
<tr>
<td>Pigs are never sick</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>1.27</td>
</tr>
<tr>
<td>No vaccine available</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>1.27</td>
</tr>
<tr>
<td>Vaccination officer only brings vitamin and antibiotics</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
<td>1.90</td>
</tr>
</tbody>
</table>

¹AHW: Animal health worker.

5.3.10.6 Knowledge Sources for CSF

The majority of pig health information about CSF provided to smallholder pig farmers was obtained through FEAs (64.0%; n = 25) and veterinarians (44.0%) as well as through newspaper reports (32.0%) and friends (20.0%).

5.4 Discussion

5.4.1 Introduction

Information obtained from this farmer survey has provided baseline information for pig raising practices across NTT province. It has allowed the identification of key factors of pig management that present potential risks for CSF transmission including swill feeding, the borrowing of boars for breeding, live pig contact and movements, and lack of effective biosecurity. Furthermore, by improving our understanding of smallholder farmers within this area regarding important social and economic uses of pigs, more viable strategies can be established to assist in the control of CSF.

A limitation to our sampling method needs to be addressed. Although expert opinion and reports from Village Heads supported our hypothesis that farmers with larger herds were more likely to trade outside the village, the use of pigs in traditional ceremonies may result
in pig movements outside the village which would influence farmers with both small and large herds. Thus, some informal movements may not have been captured in these results. Moreover, for villages with large pig populations, not all large herds were captured in the study therefore some formal movements may also have been missed. It also needs to be considered that with the selection of farmers with larger herd sizes, this may have biased some of the figures regarding herd size. In the market survey in Chapter 3, herd size information captured from pig sellers averaged 2.7 pigs per farm, slightly lower than that determined for the farmer survey. Moreover, the selection of farmers with larger herd sizes would explain the identification of a small number of farmers performing artificial insemination.

5.4.2 Demographics and Background

Within NTT province, women play an important role in pig production which is similar to other smallholder livestock farmers in developing countries (Johns et al., 2009; Kagira et al., 2010; Roy et al., 2009). Gender roles in pig management could not be analysed in this study. Although best efforts were used to interview those at each residence that managed the pigs, often the head of the household (the male) elected to answer the questions on behalf of the family. During the interviews however, the wives of each household were present allowing the husbands to clarify their responses if unsure of an answer. This was observed and demonstrates that the remainder of the data has not been impacted by this issue. Studies have shown that pigs are the primary livestock species in NTT province with 85% of households owning pigs, and only 10% owning cattle (Johns et al., 2009; Russell-Smith et al., 2007). The most common additional species kept on the farm included chickens and dogs with few farmers found to keep cattle and goats, corresponding with findings from Drayton et al. (2010) and Johns et al. (2009). Through the literature, it has been demonstrated that swine are the only species susceptible to CSF infection (Dewulf et al., 2001a; Kaden et al., 2003). However, pigs and ruminants are susceptible to Bovine Viral Diarrhoea Virus (BVDV) and Border disease virus (BDV) infection, different pestiviruses from the Flaviviridae family (Loeffen et al., 2009). Wieringa-Jelsma et al. (2006) determined that the presence of BVDV antibodies in weaner pigs could limit the transmission of CSFV. Currently the prevalence of BVDV has yet to be confirmed in NTT.

The primary purpose of keeping pigs was found to be for extra income (68.5%). In developing countries occupational multiplicity is important where a diverse range of income sources are utilised by farming households (Mertz et al., 2005). In northern
Vietnam it was determined that pigs contributed 9–41% of total household income (Le Coq et al., 2002). This corresponded with our results, which showed that pigs were a secondary income source. Moreover, Lemke et al. (2006) found an association between household income and pig age groups kept on the farm. Sows were kept more commonly among less-poor households with poorer households having a greater tendency to keep fatteners without sows. Our study found that the highest number of farms with at least one sow were from Sumba. Across NTT province, the majority of individuals live below the poverty line, with 95% of individuals in rural communities living in poverty (Wang, 2007). The poorest districts include Sumba Barat, Kupang, TTS, TTU, Lembata and Manggarai (Barlow & Gondowarsito, 2007). The importance of live pig trade and pig usage in traditional ceremonies in NTT may be influencing the presence of sows in herds, particularly on Sumba, accounting for this disparity.

5.4.3 On-farm Pig Management

All farmers reared pigs using traditional housing type systems: either penning in a kandang, tethering or allowing free roaming. These types of systems can be influential in disease spread due to direct contact between pigs and other livestock species combined with minimal implementation of biosecurity (FAO, 2010). The majority of pig-raising households had one or two sows in their herd. This is similar to other smallholder farmers in countries such as Vietnam (Lemke et al., 2006), Lao PDR (Phengsavanh & Stür, 2007) and Kenya (Kagira et al., 2010).

Only 24.2% of farmers reported owning at least one fattener. This could have been influenced by the timing of the study. Interviews were undertaken during March and April and this overlapped with Easter, an important religious festival in the Christian calendar. This was particularly the case for Flores, where the majority of the population is Catholic. During this period, pigs are slaughtered in large numbers for traditional ceremonies and parties (Kira & Kasman, 2011). This fact may explain the absence of fattener pigs in herds in Duabesi and Nanaet villages in West Timor and Golo Mbu in Flores. In contrast to the market survey, fattener age group classifications appeared to be correct.

A small proportion of farmers reported using pig manure from their pig production systems as fertilizer (27.8%). Manure has the potential to contain viruses that pose a risk to animal and human health and its disposal needs to be considered in a biosecurity program (FAO, 2010; Vu et al., 2007). Additionally, farmers reported that they relocated tethered pigs to
new clean areas rather than disposing of accumulated waste. The survival of CSFV in the environment represents a risk for indirect transmission and is affected by factors such as temperature and pH (Ribbens et al., 2004). Weesendorp et al. (2008b) demonstrated that CSFV has the potential to survive in urine and faeces for several days, depending on the virulence of the strain and environmental temperature. For the Paderborn 2.1 CSF strain, hypothesised to be present in NTT province, the virus can survive in faeces for up to 4.8 days and in urine for up to 2.1 days (Weesendorp et al., 2008b).

Limited use of on-farm biosecurity was identified across the province. Where biosecurity was identified, only basic procedures were performed. The most common was the separation of sick and healthy pigs. Although this occurred, usually when there was the introduction of a new pig into a herd, almost half of the farmers did not keep the newly introduced animal separated from their herd or perform any type of quarantine. FAO (2010) recommends that pigs be placed in quarantine for a minimum period of 30 days to allow clinical signs to be displayed. The cleaning of pigpens and equipment was reported by 78.7% of farmers, with water used as a cleaning agent with no disinfectants. Similar results have been found from surveys in West Timor and on Flores by Malo (2011) and Drayton et al. (2010). It was interesting to note that when farmers were asked if they performed any on-farm practices to reduce the introduction of disease (ie biosecurity), only 25.0% stated that they cleaned pigpens. This suggests that farmers do not associate cleaning as a method to reduce disease introduction. The FAO animal product and health manual (FAO, 2011) supports the use of on-farm biosecurity to help protect farms from TADs and other endemic diseases. By following the three suggested basic principles of segregation, cleaning, and disinfection, farmers can greatly reduce the risk of introducing a disease onto their farm (FAO, 2010, 2011). By improving smallholder knowledge of biosecurity, a reduction in risk behaviours that influence disease spread was observed in Cambodia following a study with smallholder cattle farmers (Nampanya et al., 2011). Through improved farmer education with training programs and ‘on the job’ training, a reduction in foot-and-mouth disease (FMD) cases was observed (Nampanya et al., 2011). The uptake of biosecurity measures by pig farmers depends on several factors including the pig production system in place as well as local geographic and socioeconomic conditions (FAO, 2010). For successful change in rural areas, improving farmers’ understanding of the economic importance of pig production to their livelihood and the impacts of biosecurity is essential (FAO, 2010). Mudita and Natonis (2008) also found that
interest in biosecurity, in association with plant products, across villages in NTT was increased by more frequent communication and availability of information sources to a community.

The breeding of pigs on the farm can present problems for CSF transmission. Both the issue of direct contact between a sow and boar, and the transfer of semen has been shown to result in CSF transmission (De Smit et al., 1999; Gue’rin & Pozzi, 2005; Maes et al., 2008). The borrowing of boars for the purposes of breeding is not uncommon in the smallholder sector. In addition to Indonesia, it has been identified in countries such as Vietnam (Lemke et al., 2006), Kenya (Wabacha et al., 2004) and the Philippines (Huynh et al., 2007). In NTT, this practice was found to occur predominantly within a village, with few farmers reporting using boars from different villages. The sow owner paid for boar service either with money or piglets from the subsequent litter.

5.4.4 Pig Health

Smallholder pig farmers in developing countries are often greatly affected by disease (Colling et al., 2010; Costard et al., 2009a; Huynh et al., 2007; Wabacha et al., 2004). Animals kept by poorer households tend to be more vulnerable to disease due to issues such as the absence and unsuitability of animal health and production inputs and economic constraints (FAO, 2002). The primary diseases affecting pig production in Indonesia consist of classical swine fever, brucellosis and erysipelas (Liano & Siagian, 2002). In the smallholder sector, pigs within one village tend to be classified with the same health status due to the production systems used and the high level of contact among animals. As a result, for epidemiological and biosecurity purposes, the village is generally considered as the unit of interest (FAO, 2010).

Reports by farmers in NTT identified that weaner and grower pigs represented the age groups with the highest number of sick pigs from 2009–2010. Pig diseases including erysipelas, PRRS, Japanese encephalitis and neonatal diarrhoea have been identified in NTT with the potential to negatively impact pig production (AQIS, 2008). Drayton et al. (2010), following a seroprevalence study on Flores, identified that pigs of 3–6 months of age were a risk factor for CSF. Investigations conducted on within- and between-pen transmission by Klinkenberg et al. (2002a), further identified that when comparing pig age groups, weaners were found to have the highest basic reproductive ratio ($R^0$).
An important avenue to consider in order to improve farmer knowledge and animal health in the smallholder sector, is the development of communication between animal health workers and farmers in rural villages. A study in Malawi, Africa, showed that farmers with access to animal health services had improved herd sizes of ruminants and lower mortality rates (Huttner et al., 2001). This farmer survey identified that 64.5% of farmers had never had a veterinarian or animal health worker visit their village. This is an issue that needs further investigation. Perry et al. (2002) identified that the last decade has seen a deterioration in animal health services in developing countries with the data available coming from more commercial production systems or areas that are more accessible. The investment of veterinary services in smallholder farmers can provide much needed support for rural areas (Perry et al., 2002). A study conducted by Robertson et al. (2010a), investigated the use of a mobile phone-based disease surveillance system in Sri Lanka where field veterinarians were able to report animal health information. They concluded that in a lower-resource setting this type of surveillance system can be feasible when the appropriate stakeholders and users are involved in its implementation. With the majority of farmers not reporting sick or dead pigs in the province, this type of system could be implemented in NTT if the appropriate stakeholders groups were approached such as the newly established Pig Association in NTT, as of July 2011, local NGOs and Dinas Peternakan at the provincial and district level. Moreover, it was recognised through a study on Alor in NTT (Robertson et al., 2010b), that greater involvement of AHW with farmer groups can lead to improvements in farmer knowledge on pig health and CSF.

5.4.5 Buying Practices

The age group with the highest number of purchased pigs were weaners (40.7%). This was most common in West Timor and Flores. For Sumba; however, farmers reported purchasing a higher proportion of fatteners. This corresponded with the understanding that Sumba had a higher number of traditional ceremonies where pigs were required, thus pigs were being purchased ready for slaughter. Correspondingly, Sumba has the smallest pig population of the islands included in the study, identifying a need for pigs to be purchased ready for use in traditional events (BPS Statistics, 2009). One farmer from Sumba was found to have purchased 10 fattener pigs in one transaction.

No farmers from Flores reported purchasing any fattener pigs. Due to issues encountered in the market survey where fattener age group was incorrectly classified, this concern was subsequently addressed in the farmer survey interview team training. As a result, it can be
seen that farmers from Flores reported fattener pigs in other sections of the questionnaire including herd size and pigs exiting their herds. This suggests that this issue has been rectified however the low numbers should still be interpreted with caution. Other factors could be contributing to low purchase of fatteners such as households being provided fattener pigs by relatives or households tended to have fattener pigs on-farm when required, removing the need for purchase.

The purchase of pigs was often observed following the end of harvest during January, February and March, which ensured an increased availability of pig feed. This type of practice has been found in other areas of South-East Asia (Huynh et al., 2007). In Cambodia, for example, it was identified that a greater number of pigs were generally kept on the farm following the harvest season due to the availability of rice and rice by-products as a feed source (Huynh et al., 2007).

5.4.6 Selling Practices

A study conducted in Lao PDR by Colling et al. (2010) found that inadequate sources for pig feed and fear of disease resulted in pigs being sold at younger ages to anticipate these effects. Our study identified that boars and fatteners represented the most frequently traded age groups by farmers. This corresponded with the high demand for pigs ready for slaughter for various uses in the province for traditional ceremonies, weddings and other celebratory events.

Information obtained from the market survey (Chapter 3) identified high- and low-demand periods throughout the year for formal pig trading. The farmer survey, however, identified that for informal pig movements between farmers, peak trade periods were not as prominent. Pigs were found to be traded throughout the year with farmers stating that they were unsure of high- and low-demand seasons; they simply sold pigs when they needed money. Pigs were sourced from both markets and other farmers across the province. This study found that 54.9% of farmers purchased directly from other farmers. Informal movement pathways for pigs have also been identified by Malo (2011) in West Timor and Kira and Kasman (2011) in Flores and Sumba. Furthermore, the months with the highest number of live pigs being given as gifts were August, September and October (12.5%), corresponding with reports suggesting that a greater number of traditional ceremonies and celebrations occur in the second half of the year, which is less affected by the rainy season.
5.4.7 Transportation

Farmers from Flores reported the highest proportion of pigs being transported by foot, while no one from Sumba stated that this method was used. Flores is very mountainous island with poor road conditions, which has the potential to influence transportation methods (BPS Statistics, 2009; Windiyaningsih et al., 2004). Villages in Sumba were often isolated and households sparsely distributed within a village, therefore vehicles are more necessary for the transportation of livestock. Informal farm-to-farm movement was generally found to be more localised, thus enabling pigs to be transported by foot in contrast to formal market movements where with greater distances, it was necessary to use vehicles (refer to Chapter 3 and 6).

Similar to farmers transporting pigs to and from market, the use of motorbikes and ojeks was reported. Ojek transportation is an easily accessible and cheap transportation method (Joewono & Kubota, 2005). Focus groups in Flores also highlighted the use of both registered ferry transportation and small boats to move pigs around the province (Kira & Kasman, 2011; Patunru et al., 2010).

5.4.8 Classical Swine Fever Knowledge and Attitudes

Farmers’ knowledge regarding CSF was very limited, similar to that found in the market survey (Chapter 3). No farmers from Flores had any knowledge of the disease, which was also found in the market survey, identifying a key area that needs further investigation. The current government classification system for CSF-infected districts states that the western districts of Flores are CSF-free (Dinas Peternakan Propinsi, 2011). As a result, no vaccines are distributed in this region, with limited access to CSF information available to farmers. Although Hutabarat and Santhia (1999) recommended that surveillance be conducted in regions classified as CSF-free across Indonesia, this is not performed. In order to improve herd success, farmers need assistance from appropriate veterinary authorities and local NGOs to provide education and information on pig production and disease control (Kagira et al., 2010).

For farmers that had suspected cases of CSF on the farm, the time from infection to death was estimated to range from 3–12 days. This suggests the presence of a highly virulent strain due to the presence of acute infection (Artois et al., 2002; Dahle & Liess, 1992). Current literature supports the presence of both a highly virulent strain and the moderately
A virulent strain Paderborn (subgroup 2.1) in Indonesia (Frias-Lepoureau & Greiser-Wilke, 2002; Hutabarat & Santhia, 1999; Paton & Greiser-Wilke, 2003).

The use of CSF vaccinations was extremely minimal. For smallholder farmers in NTT, CSF vaccination is meant to be provided free from the government (Brandenburg & Sukobagyo, 2002). Although this is the case, farmers reported that AHWs had never come to their village. The farmers were unaware of any vaccination services and did not know that a vaccine was available. A vaccination trial on Alor island in NTT had identified that the locally distributed Indonesian CSF vaccine had a low efficacy rate in comparison to alternative international vaccines (Robertson et al., 2010b). Current data from Dinas Peternakan Propinsi (2011) shows that Sumba received the largest number of government distributed CSF vaccines during 2010: 301,353 vaccines distributed across the province. With a pig population of 3,266,750—this suggests that only 9.2% of the pig population is being vaccinated.

5.4.9 Constraints of the Survey

The sampling approach used was influenced by budget and logistical constraints. The overall objective of the survey was to obtain information that allowed a better understanding of pig movements across the province that would be able to inform a quantitative risk assessment and a social network analysis considering both formal and informal movements. The total interview number of 289 was distributed across regions of interest to acquire targeted information from purposively selected districts. A total of 32 interviews per subdistrict were conducted, with 16 per village. An alternative sampling approach would have been to interview more farmers in a village. However, this would have reduced the number of villages that could have been included in the study. This would have limited the extent of pig movements across the province that could have been captured in the survey.

5.5 Conclusion

This study has identified some key issues in the smallholder pig farming sector in NTT. The minimal use of biosecurity, consistent pig movements in and out of villages, on-farm herd management and limited knowledge and access to pig health information are just some of the key factors to be acknowledged when addressing CSF control in the province. The importance of live pig trade has been identified with minimal reports of pork sales.
Pig-farming practices have been found to be similar to the smallholder sector in other developing countries. As a result, we need to draw upon relevant and appropriate literature to combine with our results to determine the most appropriate pathways to assist farmers with CSF control and improved pig health.
Chapter 6: Social Network Analysis of Pig Movements Across Nusa Tenggara Timur Province

6.1 Introduction

Social network analysis (SNA) has become a recognised technique applied within the field of veterinary epidemiology to investigate disease spread across networks (Bigras-Poulin et al., 2007; Dubé et al., 2010; Kiss et al., 2006; Martinez-Lopez et al., 2009a; Natale et al., 2009; Noremark et al., 2011). This type of analysis enables complex networks to be conceptualised and modelled allowing multiple contact relationships to be considered (Christley et al., 2005). Traditional approaches, such as quantifying the frequency and volume of movements both on and off farms, has allowed a basic understanding of movement patterns. However the introduction of SNA has permitted more in-depth analysis leading to greater understanding of animal movements (Dubé et al., 2009).

Furthermore, following major disease outbreaks such as foot-and-mouth disease (FMD) and bovine spongiform encephalopathy (BSE), many countries have introduced livestock movement databases, enabling tracing (Dubé et al., 2009; Kao et al., 2007). This has further enhanced data accessibility and knowledge regarding network contacts.

Pig trade is imperative to meet the high demand of consumers in eastern Indonesia for live pigs for social, cultural and economic reasons (Johns et al., 2009). This has led to the development of both formal trade movements through markets and informal trade transactions directly between villages. The role of animal movement has long been recognised as a potential source of infectious disease dispersal (Bigras-Poulin et al., 2006; Noremark et al., 2011). The ability for infected animals to freely mix in a market or village setting represents a high risk factor for disease transmission (Robinson & Christley, 2007). Live animal markets are particularly vulnerable to disease due to their steady involvement in animal trade and direct contact between infected and susceptible animals (FAO, 2011). They play a crucial role as hubs within a network by linking pairs of livestock holdings and have the potential to infect large numbers of farms (Dubé et al., 2010; Rautureau et al., 2005).

Classical swine fever is a Pestivirus disease that is notifiable to the OIE (Moennig et al., 2003). Due to both direct and indirect transmission routes for this virus, locations such as
markets can play an important role in the dissemination of classical swine fever virus (CSFV) (FAO, 2010, 2011; Ribbens et al., 2004). Furthermore, the management practices used by smallholder pig farmers in South-East Asia, such as free roaming management systems, can further increase the spread of CSFV (Huynh et al., 2007). Direct contact, swill feeding, transportation vehicles and artificial insemination have all been identified as important transmission routes for CSF (Ribbens et al., 2004).

The contact structure of a network has the ability to influence the average size of an epidemic across primary starting nodes (Pautasso & Jeger, 2008). Investigation of animal movements through a network can determine the potential patterns and rates of spread for infectious diseases (Woolhouse et al., 2005). SNA can be used as a tool to quantify network characteristics that have the potential to influence disease spread which can aid control response planning (Aznar et al., 2005). Understanding about the extent of connectedness and the spatial structure of a network will identify the points with the greatest potential and need for targeted surveillance or alternative mitigation strategies (Christley et al., 2005; Natale et al., 2009). Locations with characteristics such as high throughput of animals, high in- and out-degree values, and premises sending animals greater distances indicated through network diameter should be targeted. A network composed of small disconnected subgroups has the potential to limit disease spread. In contrast, a network composed of larger subgroups with high connectivity represents a network with greater risk (Dubé et al., 2008). The geography of a region also needs to be considered when addressing a network (Heath et al., 2008). The extent of movement between nodes may be hindered by mountainous terrain, poor road infrastructure and other environmental factors (Webb, 2006).

The use of SNA to analyse the questionnaire data from markets and villages will enable a more detailed understanding of pig movement at village, subdistrict and district levels. This is necessary in order to establish a pig movement network for Nusa Tenggara Timur (NTT) province, which will then assist in guiding the development and implementation of mitigation strategies (Bigras-Poulin et al., 2007).

The objective of this analysis was to investigate the movement patterns of pigs both formally (village to market) and informally (village to village) across NTT province in eastern Indonesia. We aimed to use SNA to:
• Describe the network contacts and topology (refer to Glossary) between villages and markets through both formal and informal trade movements of live pigs involving market sellers, market buyers and smallholder farmers.

• Identify key village and market locations that are of a greater risk for spreading CSFV through the market chain.

• Determine the proportion of movement types across the network for each island and the overall province.

6.2 Methods

6.2.1 Study Population

Nusa Tenggara Timur province is divided into 21 districts. The islands incorporated in the study, West Timor, Flores and Sumba, make up 17 of those districts. Data were collected from both the repeated market survey and farmer survey (refer to Chapters 3 and 5, respectively). For the market study, the eligible population was anyone in the marketplace on the day of interviewing, either selling or buying pigs, available and willing to be interviewed. Respondents were divided into two categories: sellers, defined as individuals in the marketplace who were selling a pig/s on day of interviewing; and buyers, defined as individuals in the marketplace buying a pig/s on day of interviewing. For the pig farmer survey, those interviewed had been pre-selected from a sampling frame of pig raising households in the selected villages (refer to Methodology in Chapter 5).

6.2.2 Questionnaire Data

Questionnaires conducted during these two studies incorporated questions regarding both the formal and informal movement of live pigs. Data on individuals interviewed at markets were evaluated based on pig-source locations and destination locations (down to the village level), the number of pigs being moved to and from market and the number of sources utilised to obtain pigs. These movements were classified as formal movements, defined as ‘movement of pigs between villages involving sale/purchase at a market and movement of pigs between islands entering and exiting via formal ferry ports’. Data on farmers were evaluated based on pig source and destination locations (village locations), number of pigs entering and leaving their herd and the event/reason for a pig entering or exiting their herd. Reasons for pig exit from a herd included whether the pig was sold, given as a gift or given to relatives/family members. For pig entering a herd, this was classified as purchased pigs.
and those received as gifts. These movements were classified as informal, defined as ‘movement of pigs between villages not involving sale/purchase at a market and movement of pigs between islands not entering and exiting via formal ferry ports’. It should be noted that different time periods surround the data collected. Market interviews consisted of pig movements recorded across two different functional market days (representing a high- and low-demand period, September and November 2009, respectively). Farmer interviews represent pig movements events across a 12-month period (2009–2010).

6.2.3 Data Management and Analysis

Data from the repeated market survey (Chapter 3) and the farmer survey (Chapter 5) were initially entered into databases designed using the computer program Epi Info™ Software (Version 3.5.1, CDC, www.cdc.gov/epiinfo, Atlanta, Georgia, U.S). Data were then exported to Microsoft Excel (version 12.0, Microsoft Corporation, Redmond, WA) where purpose-built spreadsheets were developed to establish data and attribute tables (characteristics of a node such as number of animals, geographical information) for each data set including:

A. Seller Network
B. Buyer Network
C. Market Network: Seller and buyer data combined (i.e. A+B)
D. Farmer Network
E. Province Network: Market and farmer data combined (A+B+D).

A movement event was defined as the transportation of one or more pigs from an origin premises (village or market) to a destination premises (village or market). Contacts were defined based on the direction of their movement:

- Seller: Source village to market destination
- Buyer: Source market to village destination
- Farmer: Source village to destination village.

To improve reporting accuracy for village locations, each respondent was required to state the district, subdistrict and village name for pig source and destination locations. These were then subsequently verified using the Dinas Peternakan Propinsi Village List, a complete list of villages in NTT Province from 2008 and checked for consistent punctuation and spelling. During 2008–2009 some changes in village names and borders had occurred. This then required additional verification with local Dinas Peternakan
veterinarians with the DLS to determine the correct village locations reported. Furthermore, some village locations had multiple names, their official title and colloquial names used by locals, hence further consultation with interview team members and Dinas staff was necessary to identify the correct locations reported during the interview process.

On completion of cleaning, data were then exported into a social network analysis program, UCINET (v6.137 Analytic Technologies Inc., Harvard, Massachusetts, USA), which allowed construction and analysis of the pig-movement networks. Subsequently NetDraw (Version 2.091, Graph Visualization Software, Harvard, Analysis Technologies), a social network visualisation software was used to develop graphic representations of the pig-movement networks.

Within the constructed networks, markets and villages were designated as nodes. These nodes were then connected by edges. The edges represented the relationship between two nodes where the weight of the relation was quantified on the basis of the volume of animals being moved. This was visually represented using a tie strength method in NetDraw allowing identification of source or destination locations with exiting or entering pig volumes. The volume of pigs was selected as an edge weighting as data on the frequency of pig movement was not available from market interviews and was limited from farmer interview data. All edges in these networks were directed allowing the movement of pigs through the market chain to be identified.

The market network was considered as a 2-mode network as market and village locations were treated distinctly where villages were not directly linked and pigs were required to move through a market node. Where appropriate 2-mode normalised degree and density calculations were based on Borgatti and Everett (1997). The farmer and province networks were considered as 1-mode networks as pigs could move between either villages and/or markets. A common list of villages and markets was established among the three datasets by combining all villages reported to allow a complete network of the province to be developed. This was done by providing a unique identification to every village and market reported across the networks. As such, this allowed all ties to be treated as directional based on their information source. Correlation was investigated between in- and out-degree values by calculating the Spearman rank correlation coefficient (refer to Equation 6.1). This is a non-parametric measure to investigate associations between two variables.
(Altman, 1991). It can determine and compare rankings of vertices for different characteristics (Nooy et al., 2005).

\[ r^2 = 1 - \frac{6\sum d^2}{n^3 - n} \]  

Equation 6.1

Where: \( r^2 \) = Spearman rank correlation coefficient
\( d \) = difference between two ranks associated with each point
\( n \) = number of pairs in the sample data.

As only a proportion of markets and villages present in NTT province have been included in this SNA out of the entire province network, this had implications for the analysis of some network parameters shown in Table 6.1. With source and destination data for nine major markets in the province, the calculation of in- and out-degree was highly informative, identifying connections between villages and other markets while also recognising the presence of hubs within the networks. Furthermore, it provided information on the overall cohesion and integration of villages and markets within the network (Christley et al., 2010). As it was crucial to compare node degree values across different island networks, it was necessary to normalise this value (Christley et al., 2010).

In addition, the set-up of the market network was such that villages were directly connected to a market location. As a result, village in- and out-degree values for this network could only range from one to nine according to market contact. To further assess this, the volume of pigs and individuals entering the market were used. Geodesic distance and network diameter calculations were also influenced by the sampling approaches used. The geodesic distance value provided a minimum value with farmers potentially having a higher level of closeness within the network. Results of these network analyses provided us with an indication of the extent of movement events occurring across the province; however, their limitations due to the network being incomplete need to be taken into consideration.

6.2.4 Analysis Limitations

Limitations due to the sampling approaches used for the market and farmer surveys (Chapters 3 and 5, respectively) prevented the calculation of several SNA parameters: betweeness, closeness, clustering coefficient, reachability and small world network analysis (more details in Discussion section 6.4.5).
It also needs to be recognised that the market and village locations selected for inclusion in the study have biased the villages being reported. This may be providing results that are not representative of the entire network.

The timescale represented by the market and farmer networks needs to be considered. The data obtained for the market network are representative of two different market days (across a high- and low-demand period). The farmer network represented a year of pig trade movements by smallholder farmers. The purpose of combining the two networks was to create an overall province network to identify the extent of movement being captured by these studies and to further identify locations of importance for disease spread. It is not intended to represent comprehensively pig movement over a similar time period for all network nodes.
Table 6.1
Definitions of social network analysis parameters included in the analysis of pig movement data between markets and villages in Nusa Tenggara Timur.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Definitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
<td>The total number of network members, the unit of interest in a network (Aznar et al., 2005; Dubé et al., 2009). For this network markets and villages were considered as nodes.</td>
</tr>
<tr>
<td>Density (directed)</td>
<td>The proportion of all contacts that could be present that actually are (Aznar et al., 2005).</td>
</tr>
<tr>
<td>Number directed links</td>
<td>The total number of connections between nodes (Aznar et al., 2005).</td>
</tr>
<tr>
<td>In-degree</td>
<td>The count of contacts a node receives (Martínez-López et al., 2009b). For this network, the contact refers to the number of villages that pigs entering a particular market or village location have originated from.</td>
</tr>
<tr>
<td>Out-degree</td>
<td>The count of individual recipients obtaining animals from a particular market or village location (Dubé et al., 2009). For this network, the contact refers to the total number of villages receiving the pigs exiting from a market or a village.</td>
</tr>
<tr>
<td>Normalised in- and out-degree</td>
<td>In order for comparisons to be made across networks, it is necessary for the normalisation of the in- and out-degree values (Christley et al., 2010).</td>
</tr>
<tr>
<td>In-degree centralisation</td>
<td>An estimate of the deviation of the largest values of in-degree from the value computed for all other nodes in the network (Aznar et al., 2005).</td>
</tr>
<tr>
<td>Out-degree centralisation</td>
<td>An estimate of the deviation of the largest values of out-degree from the value computed for all other nodes in the network (Aznar et al., 2005).</td>
</tr>
<tr>
<td>Network diameter</td>
<td>The total number of links in the longest pathway between two nodes (Aznar et al., 2005).</td>
</tr>
<tr>
<td>Geodesic distance</td>
<td>The geodesic distance is the shortest path length between two nodes (Christley et al., 2010; Dubé et al., 2009).</td>
</tr>
<tr>
<td>Geodesic distribution</td>
<td>The distribution of frequencies of geodesic distances (Christley et al., 2010).</td>
</tr>
</tbody>
</table>
6.3 Results

6.3.1 Market and Farmer Data Sources

6.3.1.1 Market Respondent Information

The total number of individuals interviewed for the market study was 573 (refer to Chapter 3). Respondents who did not provide complete location information, data including village name, were excluded from analysis. For seller respondents, a total of 260 individuals and for buyers a total of 262 individuals were included in the SNA. The removal of 51 (8.9%) respondents from analysis (19 for sellers and 32 for buyers) allowed complete location data to be analysed.

6.3.1.2 Market Details

Nine live pig markets were included in the study for analysis. The locations were those utilised in the market survey and can be viewed in Figure 3.1 (refer to Chapter 3). Similar numbers of villages were reported as source and destination locations by both seller and buyer respondents through market interviews (Table 6.2). A number of common villages were reported by respondents.

Table 6.2
The number of villages reported by pig sellers and pig buyers at live pig markets to be directly involved in the pig market chain across West Timor, Flores and Sumba in Nusa Tenggara Timur province, eastern Indonesia, 2009.

<table>
<thead>
<tr>
<th>Person Type</th>
<th>Island</th>
<th>Number Villages Reported</th>
<th>Number Villages on Island</th>
<th>Proportion of Villages Reported (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sellers (source village)</td>
<td>West Timor</td>
<td>61</td>
<td>911</td>
<td>6.70</td>
</tr>
<tr>
<td></td>
<td>Flores</td>
<td>56</td>
<td>1178</td>
<td>4.75</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>57</td>
<td>348</td>
<td>16.38</td>
</tr>
<tr>
<td>Buyer (destination village)</td>
<td>West Timor</td>
<td>58</td>
<td>911</td>
<td>6.37</td>
</tr>
<tr>
<td></td>
<td>Flores</td>
<td>55</td>
<td>1178</td>
<td>4.67</td>
</tr>
<tr>
<td></td>
<td>Sumba</td>
<td>51</td>
<td>348</td>
<td>14.66</td>
</tr>
</tbody>
</table>

6.3.1.3 Farmer Respondent Information

A total of 289 farmers were interviewed during the farmer survey (refer to Chapter 5). Respondents were asked to provide details regarding pigs exiting or entering their herds during 2009–2010. A total of 133 farmers reported pigs exiting their herds and 111
reported pigs entering with only 32 (11.1%) farmers reporting two or more transactions during 2009–2010 and 64 farmers (22.1%) who performed both actions. Ultimately, 180 (62.3%) farmers contributed pig source and/or destination location information to the SNA with 109 farmers not providing location information because there were no entries and/or exits to their herd.

### 6.3.2 Social Network Analysis of Formal Movements

The overall market network representing formal pig movements was comprised of 307 nodes (Table 6.3; Figure 6.2), nine of which were market locations, while the remaining 298 nodes were reported village locations. When the seller and buyer networks were combined, there were 47 common villages identified. Sumba was identified as having the smallest overall network size. However, this network had the greatest number of directed links, highlighting a high level of connectivity across Sumba (Table 6.3).

The density of the market network as a whole was found to be 0.07%. To reduce the limitations of this value it was classified as 2-mode. If density was calculated using a 1-mode method, there are limitations as the network is unable to be completely dense due to the structure in which villages need to bypass a market; thus no villages are directly linked. The diameter of the market network was calculated to be eight (Table 6.3). West Timor was found to have the highest diameter in comparison to the other islands (Table 6.3). This value is providing a minimum figure for movement pathways across the network. The geodesic distribution was the same across all market networks (Table 6.3). Hence, for these networks, the majority of pigs were moved between two sequential nodes. The highest average geodesic distance was seen in West Timor with an average of three consecutive nodes (Table 6.3). A total of 366 directed links were identified for the overall market network highlighting the potential for pigs to move to different districts of the province.

Figures 6.2 and 6.3 visually display market and village locations across the province and their connections within the market network.

The in- and out-degree values demonstrated that Detusoko and Mbay Market on Flores and Waikabubak Market on Sumba had the highest 2-mode normalised out-degree, representing a high-risk potential to spread disease (Table 6.4 and Figure 6.1). Pigs sold at Detusoko and Mataloko markets were found to travel to Sumba (Figure 6.3 and Figure 6.10). A positive correlation was detected between normalised in- and out-degree values for market locations (Spearman rank: $r_2 = 0.948$, $P < 0.001$, $n = 9$). In addition, Weta...
Market on Sumba had the largest volume of pigs entering and exiting a marketplace (Table 6.4). This corresponded with the finding that pig sellers and pig buyers present at Wetabula Market had the highest average number of pigs per seller coming to the markets (refer to Chapter 3).

Halulik and Niki Niki markets had equivalent out-degree values and were the highest for the West Timor region, indicating their risk to spread infection through the market network (Table 6.4). Camplong and Niki Niki Market had equivalent in-degree values, which were the highest for West Timor, suggesting these market locations have greater potential to become infected.

This analysis also allowed identification of key villages within the formal pig-market network to be identified for their level of involvement in pig-movement events. The villages of Lumbukori and Rada Mata located in Kab. Sumba Timur and Kab. Sumba Barat Daya respectively, were identified as having contact with all three Sumba markets.

Comparisons were made regarding the two different interview rounds in which the market study was conducted, where round 1 represented a high-demand period (September) and round 2 a low-demand (November) period (Table 6.6). Taking into account degree values, a higher-demand period did not necessarily result in contact with a larger number of villages. However, higher pig volumes were seen to move through the marketplace during this period across West Timor, Sumba (with the exception of Wetabula Market) and Detusoko Market in Flores. Round 1 saw the highest out-degree values at Niki Niki and Mbay Market on West Timor and Flores respectively, and Melolo and Camplong Market on Sumba and West Timor respectively having the highest in-degree values (Table 6.6). This demonstrates the extent to which markets across the province can be equivalent in terms of connectedness.
Table 6.3
SNA calculated parameters for formal movements (village-to-market network) for pig movements across Nusa Tenggara Timur province, eastern Indonesia, 2009 (2-mode normalised degree calculations based on island networks for West Timor Flores and Sumba with overall market network based on entire network across 2 market days).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>Overall Market</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network Size</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Number of villages nodes&lt;sup&gt;a&lt;/sup&gt;</td>
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<td>98</td>
<td>91</td>
<td>298</td>
</tr>
<tr>
<td>Number of markets nodes&lt;sup&gt;b&lt;/sup&gt;</td>
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<td>5</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Number of directed links&lt;sup&gt;c&lt;/sup&gt;</td>
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<td>116</td>
<td>127</td>
<td>366</td>
</tr>
<tr>
<td>Size&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>600</td>
<td>558</td>
<td>5364</td>
</tr>
<tr>
<td>Diameter&lt;sup&gt;e&lt;/sup&gt;</td>
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<td>4</td>
<td>4</td>
<td>8</td>
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<td><strong>Measures of Centrality</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean in-degree (range)</td>
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<td>1.13 (0–23)</td>
<td>1.32 (0–23)</td>
<td>1.92 (0–24)</td>
</tr>
<tr>
<td>Mean out-degree (range)</td>
<td>1.11 (0–21)</td>
<td>1.13 (0–23)</td>
<td>1.32 (0–23)</td>
<td>1.92 (0–23)</td>
</tr>
<tr>
<td>2m Normalised in-degree (range)&lt;sup&gt;f&lt;/sup&gt;</td>
<td>0.37 (0–8.0)</td>
<td>0.23 (0–4.6)</td>
<td>0.26 (0–4.6)</td>
<td>0.21 (0–2.7)</td>
</tr>
<tr>
<td>2m Normalised out-degree (range)&lt;sup&gt;g&lt;/sup&gt;</td>
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<td>0.23 (0–4.6)</td>
<td>0.26 (0–4.6)</td>
<td>0.21 (0–2.6)</td>
</tr>
<tr>
<td>In-degree centralisation&lt;sup&gt;i&lt;/sup&gt;</td>
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<td>21.66</td>
<td>23.06</td>
<td>7.48</td>
</tr>
<tr>
<td>Out-degree centralisation&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>21.66</td>
<td>23.06</td>
<td>7.15</td>
</tr>
<tr>
<td><strong>Measures of cohesion</strong></td>
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<td></td>
<td></td>
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</tr>
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<td>2m Density&lt;sup&gt;k&lt;/sup&gt;</td>
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<td>0.19</td>
<td>0.23</td>
<td>0.07</td>
</tr>
<tr>
<td>Average geodesic distance&lt;sup&gt;l&lt;/sup&gt;</td>
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</tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mean entering volume (range)</td>
<td>2.15 (1–95)</td>
<td>1.49 (1–84)</td>
<td>2.40 (1–140)</td>
<td>2.06 (1–140)</td>
</tr>
<tr>
<td>Mean exiting volume (range)</td>
<td>2.05 (1–81)</td>
<td>1.22 (1–24)</td>
<td>3.56 (1–166)</td>
<td>2.18 (1–166)</td>
</tr>
</tbody>
</table>

<sup>a</sup>Number of nodes: The total number of network member; <sup>b</sup>Number of directed links: The total number of connections made between nodes; <sup>c</sup>Size: The total number of possible unique node pairs; <sup>d</sup>Diameter: The number of links in the largest possible pathway between two nodes; <sup>e</sup>Mean in-degree: The count of contacts a node receives (movements to a location); <sup>f</sup>Average out-degree: The number of contacts from a node (movements from a location); <sup>g</sup>Normalised in-degree: the number of contacts to a node divided by the maximum number of possible contacts (2-mode normalised in-degree is calculated by in-degree divided by number of markets in network, Borgatti & Everett, 1997); <sup>h</sup>Normalised out-degree: the number of contacts from a node divided by the maximum number of possible contacts (2-mode normalised out-degree is calculated by out-degree divided by number of markets in network, Borgatti & Everett, 1997); <sup>i</sup>In-degree centralisation: An estimate of the deviation of the largest values of in-degree from the value computed for all
other nodes in the network; ¹Out-degree centralisation: An estimate of the deviation of the largest values of out-degree from the value computed for all other nodes in the network; ²2m Density: The proportion of all contacts that could be present that actually are (2-mode is calculated by no. directed links divided by network size, Borgatti & Everett, 1997); ¹Average geodesic distance: The shortest path length between two nodes; ³Geodesic distribution: The distribution of frequencies of geodesic distances
Table 6.4
Market rankings according to in- and out-degree and volume of pigs entering and exiting a market node across West Timor, Flores and Sumba, Nusa Tenggara Timur Province, eastern Indonesia, 2009 (2-mode normalised degree calculation based on entire network, therefore calculated by degree divided by total number of markets in network).

<table>
<thead>
<tr>
<th>Island</th>
<th>Market</th>
<th>Out-Degree</th>
<th>In-Degree</th>
<th>2m Normalised Out-degree</th>
<th>2m Normalised In-Degree</th>
<th>People Volume Out</th>
<th>People Volume In</th>
<th>Pig Volume Out</th>
<th>Pig Volume In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flores</td>
<td>Detusoko</td>
<td>23</td>
<td>13</td>
<td>2.56</td>
<td>1.44</td>
<td>35</td>
<td>23</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>Sumba</td>
<td>Waikabubak</td>
<td>23</td>
<td>20</td>
<td>2.56</td>
<td>2.22</td>
<td>34</td>
<td>40</td>
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<td>2.56</td>
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<td>40</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
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<td>Melolo</td>
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<td>21</td>
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<td>2.33</td>
<td>29</td>
<td>51</td>
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<td>Niki Niki</td>
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<td>2.67</td>
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<td>34</td>
<td>47</td>
<td>59</td>
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<td>West Timor</td>
<td>Halulik</td>
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<td>1.78</td>
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<td>32</td>
<td>40</td>
<td>64</td>
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<td>2.56</td>
<td>35</td>
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<td>36</td>
<td>81</td>
<td>95</td>
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<td>2.56</td>
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<td>30</td>
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<td>84</td>
</tr>
</tbody>
</table>
Figure 6.1
2-mode normalised in and out-degree values for formal pig movements between villages and live pig markets across Nusa Tenggara Timur province, eastern Indonesia, 2009 (45° dashed line; 2-mode normalised degree calculation based on market network).
Table 6.5
Most commonly reported villages with market contacts in the pig market chain for high involvement in formal movements to and from live pig markets across West Timor, Flores and Sumba, eastern Indonesia, 2009 (C: Camplong Market; H: Halulik Market; Mb: Mbay Market; D: Detusoko Market; Wt: Watabula Market; Wk: Waikabubak Market; M: Melolo Market; 2-mode normalised degree calculation based on entire network, therefore calculated by degree divided by total number of markets in network.

<table>
<thead>
<tr>
<th>Island</th>
<th>Village</th>
<th>Out-degree</th>
<th>In-degree</th>
<th>2m Normalised Out-degree</th>
<th>2m Normalised In-degree</th>
<th>People Volume Out</th>
<th>People Volume In</th>
<th>Pig Volume Out</th>
<th>Pig Volume In</th>
<th>Market Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumba</td>
<td>Lumbukori</td>
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<td>0.33</td>
<td>0.00</td>
<td>18</td>
<td>0</td>
<td>37</td>
<td>0</td>
<td>Wt, Wk, M</td>
</tr>
<tr>
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<td>Rada Mata</td>
<td>1</td>
<td>2</td>
<td>0.11</td>
<td>0.22</td>
<td>1</td>
<td>11</td>
<td>3</td>
<td>54</td>
<td>Wt, Wk, M</td>
</tr>
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<td>Omba Rade</td>
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<td>0.00</td>
<td>0.33</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>8</td>
<td>Wt, Wk, M</td>
</tr>
<tr>
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<tr>
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<td>5</td>
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</tr>
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Table 6.6
In- and out-degree values for markets stratified by interview rounds (round 1: September, high-demand period; round 2: November, low-demand period) across West Timor, Flores and Sumba, Nusa Tenggara Timur Province, eastern Indonesia, 2009 (2-mode normalised degree calculation based on entire network, therefore calculated by degree divided by total number of markets).

<table>
<thead>
<tr>
<th>Island</th>
<th>Market</th>
<th>Round</th>
<th>Out-degree</th>
<th>In-degree</th>
<th>2m Normalised Out-Degree</th>
<th>2m Normalised In-Degree</th>
<th>People Volume Out</th>
<th>People Volume In</th>
<th>Pig Volume Out</th>
<th>Pig Volume In</th>
</tr>
</thead>
<tbody>
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<td>17</td>
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<td>Wetabula</td>
<td>1</td>
<td>12</td>
<td>6</td>
<td>1.33</td>
<td>0.67</td>
<td>14</td>
<td>9</td>
<td>99</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>10</td>
<td>16</td>
<td>1.11</td>
<td>1.78</td>
<td>21</td>
<td>20</td>
<td>67</td>
<td>104</td>
</tr>
<tr>
<td></td>
<td>Waikabubak</td>
<td>1</td>
<td>11</td>
<td>7</td>
<td>1.22</td>
<td>0.78</td>
<td>18</td>
<td>27</td>
<td>70</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>11</td>
<td>12</td>
<td>1.22</td>
<td>1.33</td>
<td>16</td>
<td>22</td>
<td>29</td>
<td>33</td>
</tr>
</tbody>
</table>
Figure 6.2
Market network for formal pig movements across West Timor, Flores and Sumba in eastern Indonesia, 2009 (Purple: West Timor; Blue: Flores; Orange: Sumba; Circle: Village; Square: Market; Line thickness represents the volume of pigs moving between two nodes).
Figure 6.3
Formal pig movements through nine major pig markets across Nusa Tenggara Timur province, eastern Indonesia, 2009. Location reports from pig sellers and pig buyers during interviews in market locations.
6.3.3 Social Network Analysis of Informal Movements

For informal movements of pigs by farmers between villages, there was much more fragmentation across the network with more localised movement (Figures 6.4 and 6.5). It can be seen from Figure 6.5 that minimal between-island movement was detected within the informal network. Observing Figure 6.4, both Sumba and Flores islands had fragmented networks. For Sumba, Rindi and Kayuri villages (located within Kab. Sumba Timur) reported trading only with villages within that district. On the western region of the island, it can be seen that the two districts involved in the study, Kab. Sumba Barat and Kab. Sumba Barat Daya were connected by only one village: Rada Mata. This identified the more localised movement pathways present on Sumba in contrast to the market network. Similarly, in Flores a separation in the network can be observed between the eastern and western regions. For the eastern part of the island, interviews were performed in Kab. Flores Timur and Kab. Sikka and only Pruda village was identified as connecting these regions. Furthermore, the western region of the island was very segregated and had no reported connection to adjacent districts on the eastern end of the island. West Timor displayed different visual network characteristics with all interview locations having some connectivity with movement events entering all five districts (Figure 6.4 and Figure 6.5).

The farmer network was made up of a total of 95 nodes, with Sumba having the largest network size (Table 6.7). Flores was found to have the smallest network size, which corresponded to a network diameter of only 4 (Table 6.7). A 2-node difference was detected between other island networks with a diameter of 6 detected for West Timor and Sumba. A greater level of fragmentation was identified on Flores in comparison to Sumba and West Timor. As diameter is only calculated among reachable pairs (nodes that are connected) the increased fragmentation can reduce network diameter. These data represent a one-year period of pigs entering and exiting village locations, which needs to be considered when comparing results. A positive correlation was detected when comparing between in- and out-degree values within the informal network (Spearman rank: $r_s = 0.976; P < 0.001, n = 95$). For Flores, the geodesic distribution was found to be 1. This supported a greater level of localised movement on this island with pigs often only moving from one village to another, commonly a neighbouring village within the same subdistrict. Pig volumes varied between islands, with Sumba having the greatest overall range (Table 6.7). Rindi village was found to have the highest exiting pig volume.
For Flores there was the presence of two network components, one of size 17 and one of size 9. The larger component was weak with only one village connecting to an additional subdistrict, and being uni-directional this limits its level of connectivity within the network (Figure 6.4). This can be referred to as a cut-point within the network, that is, a node whose deletion will increase the number of components in the network (Christley et al., 2010). Ultimately this cut-point creates a bridge between the two components connecting them and hence removing such bridges increases the number of components.

Across the West Timor informal network, no fragmentation of the network was identified. Only three villages in Kab. TTU were identified to be involved in the network, with pigs moved to Kota Kupang. The informal network detected across Sumba was found to have a regional trend. In contrast to the market network with high connectivity between the districts, this network was more fragmented with a divide between the western and eastern regions of the island. Only one reported movement from Kab. Sumba Timur to Kab. Sumba Barat was identified. Furthermore, there was very limited between-island movement, with only one recorded ferry movement off Sumba (Figure 6.5).
Table 6.7
SNA-calculated parameters for informal movements (village-to-village network) for pig movements across Nusa Tenggara Timur Province in eastern Indonesia, representing one year of pigs entering and exiting a village 2009–2010 (Refer to footnotes on Table 6.3).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>Overall Farmer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network Size</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of village nodes(^a)</td>
<td>33</td>
<td>26</td>
<td>36</td>
<td>95</td>
</tr>
<tr>
<td>Number of directed links(^b)</td>
<td>51</td>
<td>44</td>
<td>64</td>
<td>135</td>
</tr>
<tr>
<td>Size(^c)</td>
<td>1,056</td>
<td>650</td>
<td>1,260</td>
<td>9,120</td>
</tr>
<tr>
<td>Diameter(^d)</td>
<td>6</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Measures of Centrality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean in-degree (range)(^e)</td>
<td>1.55 (0–13)</td>
<td>1.69 (0–11)</td>
<td>1.78 (0–11)</td>
<td>1.42 (0–13)</td>
</tr>
<tr>
<td>Mean out-degree (range)(^f)</td>
<td>1.55 (0–7)</td>
<td>1.69 (0–7)</td>
<td>1.78 (0–11)</td>
<td>1.42 (0–9)</td>
</tr>
<tr>
<td>Normalised in-degree (range)(^g)</td>
<td>2.34 (0–19.7)</td>
<td>2.17 (0–14.10)</td>
<td>2.47 (0–15.28)</td>
<td>0.75 (0–6.84)</td>
</tr>
<tr>
<td>Normalised out-degree (range)(^h)</td>
<td>2.34 (0–10.6)</td>
<td>2.17 (0–8.97)</td>
<td>2.47 (0–15.28)</td>
<td>0.75 (0–4.74)</td>
</tr>
<tr>
<td>In-degree centralisation(^i)</td>
<td>18.46</td>
<td>12.91</td>
<td>13.55</td>
<td>6.23</td>
</tr>
<tr>
<td>Out-degree centralisation(^j)</td>
<td>8.79</td>
<td>7.36</td>
<td>13.55</td>
<td>4.07</td>
</tr>
<tr>
<td><strong>Measures of cohesion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density(^k)</td>
<td>0.043</td>
<td>0.045</td>
<td>0.041</td>
<td>0.013</td>
</tr>
<tr>
<td>Average geodesic distance(^l)</td>
<td>2.55</td>
<td>1.86</td>
<td>2.63</td>
<td>2.52</td>
</tr>
<tr>
<td>Geodesic distribution(^m)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td><strong>Pig Volumes</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean entering volume (range)</td>
<td>4.57 (1–33)</td>
<td>10.17 (1–39)</td>
<td>9.47 (1–56)</td>
<td>7.29 (1–56)</td>
</tr>
<tr>
<td>Mean exiting volume (range)</td>
<td>8.71 (1–39)</td>
<td>8.50 (1–48)</td>
<td>8.64 (1–78)</td>
<td>8.12 (1–78)</td>
</tr>
</tbody>
</table>
Table 6.8
Top 20 villages with the highest in- and out-degree for pig movements across the informal village-to-village network across Nusa Tenggara Timur Province, eastern Indonesia, 2009–2010.

<table>
<thead>
<tr>
<th>Island</th>
<th>Village</th>
<th>Out-Degree</th>
<th>In-Degree</th>
<th>Normalised Out-Degree</th>
<th>Normalised In-Degree</th>
<th>People Volume Out</th>
<th>People Volume In</th>
<th>Pig Volume Out</th>
<th>Pig Volume In</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sumba</td>
<td>Waikarara</td>
<td>9</td>
<td>4</td>
<td>4.74</td>
<td>2.11</td>
<td>16</td>
<td>9</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>West Timor</td>
<td>Manutapen</td>
<td>6</td>
<td>7</td>
<td>3.16</td>
<td>3.68</td>
<td>15</td>
<td>15</td>
<td>39</td>
<td>23</td>
</tr>
<tr>
<td>Sumba</td>
<td>Waekrau</td>
<td>6</td>
<td>4</td>
<td>3.16</td>
<td>2.11</td>
<td>11</td>
<td>9</td>
<td>25</td>
<td>21</td>
</tr>
<tr>
<td>Sumba</td>
<td>Walla Ndimu</td>
<td>6</td>
<td>7</td>
<td>3.16</td>
<td>3.68</td>
<td>10</td>
<td>12</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>Flores</td>
<td>Nampar Macing</td>
<td>5</td>
<td>3</td>
<td>2.63</td>
<td>1.58</td>
<td>22</td>
<td>18</td>
<td>48</td>
<td>39</td>
</tr>
<tr>
<td>West Timor</td>
<td>Benlutu</td>
<td>5</td>
<td>5</td>
<td>2.63</td>
<td>2.63</td>
<td>14</td>
<td>15</td>
<td>22</td>
<td>29</td>
</tr>
<tr>
<td>Sumba</td>
<td>Rindi</td>
<td>4</td>
<td>5</td>
<td>2.11</td>
<td>2.63</td>
<td>21</td>
<td>15</td>
<td>78</td>
<td>49</td>
</tr>
<tr>
<td>Sumba</td>
<td>Kayuri</td>
<td>4</td>
<td>5</td>
<td>2.11</td>
<td>2.63</td>
<td>16</td>
<td>20</td>
<td>31</td>
<td>61</td>
</tr>
<tr>
<td>Flores</td>
<td>Nurri</td>
<td>4</td>
<td>2</td>
<td>2.11</td>
<td>1.05</td>
<td>11</td>
<td>8</td>
<td>19</td>
<td>15</td>
</tr>
<tr>
<td>Sumba</td>
<td>Sobawawi</td>
<td>4</td>
<td>10</td>
<td>2.11</td>
<td>5.26</td>
<td>10</td>
<td>19</td>
<td>41</td>
<td>53</td>
</tr>
<tr>
<td>West Timor</td>
<td>Boentuka</td>
<td>3</td>
<td>6</td>
<td>1.58</td>
<td>3.16</td>
<td>6</td>
<td>9</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Flores</td>
<td>Pruda</td>
<td>2</td>
<td>3</td>
<td>1.05</td>
<td>1.58</td>
<td>12</td>
<td>13</td>
<td>31</td>
<td>32</td>
</tr>
<tr>
<td>West Timor</td>
<td>Duabesi</td>
<td>2</td>
<td>2</td>
<td>1.05</td>
<td>1.05</td>
<td>10</td>
<td>2</td>
<td>18</td>
<td>3</td>
</tr>
<tr>
<td>Flores</td>
<td>Golo Mbu</td>
<td>2</td>
<td>4</td>
<td>1.05</td>
<td>2.11</td>
<td>10</td>
<td>11</td>
<td>33</td>
<td>37</td>
</tr>
<tr>
<td>West Timor</td>
<td>Nanaet</td>
<td>2</td>
<td>3</td>
<td>1.05</td>
<td>1.58</td>
<td>10</td>
<td>3</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Flores</td>
<td>Ilinmedo</td>
<td>2</td>
<td>3</td>
<td>1.05</td>
<td>1.58</td>
<td>9</td>
<td>12</td>
<td>17</td>
<td>20</td>
</tr>
<tr>
<td>Flores</td>
<td>Riangburra</td>
<td>1</td>
<td>10</td>
<td>0.53</td>
<td>5.26</td>
<td>4</td>
<td>13</td>
<td>5</td>
<td>22</td>
</tr>
<tr>
<td>West Timor</td>
<td>Nunbaun Delha</td>
<td>0</td>
<td>13</td>
<td>0</td>
<td>6.84</td>
<td>0</td>
<td>18</td>
<td>0</td>
<td>33</td>
</tr>
</tbody>
</table>
Figure 6.4
Farmer network for informal pig movements across West Timor, Flores and Sumba, eastern Indonesia, 2009–2010 (Purple: West Timor; Blue: Flores; Orange: Sumba; Triangle: Village where interviews conducted; Circle: Villages connecting interview locations; Line thickness represents the volume of pigs moving between two nodes).
Figure 6.5
Informal movements of pigs from village to village across Nusa Tenggara Timur province, eastern Indonesia 2009–2010; Yellow Circle: Village locations reported by pig sellers, buyer and farmers. Nodes that are connected represent the informal pathways, those villages not connected to the network, represent those villages involved in formal movement through markets.
6.3.4 Province Social Network Analysis

The overall province network combining both formal and informal movement events was made up of 369 nodes (Table 6.9). West Timor was found to have the greatest overall size and the greatest number of nodes. Sumba had the smallest size overall; however, it had the highest number of directed links identifying a pattern of high connectivity within the network. No overall increase in diameter was achieved by combining the market and farmer networks, with the maximum diameter remaining at 8. This further reiterates the implications of our sampling technique leading to selection bias. A geodesic distribution of 2 was achieved for the province level. This suggests that although the diameter reached 8, the majority of trade movements occur across a 2-node pathway. A positive correlation was detected between in- and out-degree values (Spearman rank: $r^2 = 0.975; P < 0.001, n = 369$).

On average a village to market movement involved the transportation of five animals per market day whereas a farm-to-farm movement event involved an average of seven pigs per year. For single movement events for farmers during that year, a mean of $2 \pm 1.53$ pigs was calculated (range: 1–20; n = 153). The volume of pigs moving through the province network tended to be higher at the market level, as expected. There were some villages that had equivalent pig volumes moving through their region over 2009–2010, including Kayuri and Rindi village in Kab. Sumba Timur and Sobawawi village in Kab. Sumba Barat. These villages reported the highest entering and exiting pig volumes.

Several cut-points were identified on all three islands. All market locations were classified as cut-points. For Flores, five markets were connected across the network, three from Flores in addition to Wetabula and Waikabubak Market in Sumba (Figure 6.10). There were nine additional cut-point villages in the Flores network, the majority of those being villages involved in the farmer survey with the exception of Golo Ronggot village in Kab. Manggarai Barat and Madawat village in Kab. Sikka. Within the Sumba network, only one village connected the Flores market Detusoko with Wetabula Market in Sumba, which was Nuamuri village located in Kab. Ende. For the West Timor and Sumba networks, nine and ten cut-points were identified, respectively. These locations were all sites selected for inclusion in the market and farmer survey.

The integration of the formal and informal networks on Sumba demonstrated a high level of overall connectivity (Figure 6.11). Both the market and village networks linked all four districts. By combining networks there was an increase in geodesic distribution. Reaching a
value of 4 with other islands possessing a geodesic distribution of only 2, this suggests that pigs in Sumba have a greater potential to move a higher number of sequential locations.

Regarding between-island movements, there were 14 villages connecting Flores and Sumba. The majority of these villages were located in the western districts of Flores. Only 1.8% of movement events recorded were between islands with the majority of movements unidirectional from Flores to Sumba, with only one movement recorded from Sumba to Flores (Figure 6.8 and Table 6.10). Only one report was given of a pig taken from Wetabula Market back to Aimere in Flores. Regarding movement direction across Flores, it was interesting to note that from the western districts, all pigs were moved from west to east; there were no reports of pigs moving in the opposite direction. Sumba had the highest level of across-district movement, which is predominantly seen within the market network (Table 6.10). West Timor had the highest level of between-subdistrict movement when analysing the entire province network. However, it should be noted that for informal movements, West Timor had the highest level of between-district movement. Furthermore, Flores was reported to have the highest level of within-subdistrict movement, from village to village (Table 6.10). Supported by Figure 6.6 it can also be observed that, overall, markets had a greater level of connectivity within the network with regards to in- and out-degrees. The nine market locations had higher normalised degree values with more localised movement associated with the informal network.
Table 6.9
Province social network analysis results for informal and formal pig movements across Nusa Tenggara Timur province, eastern Indonesia, 2009–2010 (Refer to footnotes on Table 6.3).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>Overall Province</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Network Size</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of village nodes</td>
<td>130</td>
<td>123</td>
<td>106</td>
<td>360</td>
</tr>
<tr>
<td>Number of market nodes</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td>Number of directed links</td>
<td>165</td>
<td>143</td>
<td>167</td>
<td>501</td>
</tr>
<tr>
<td>Size</td>
<td>17,556</td>
<td>16,256</td>
<td>12,210</td>
<td>135,792</td>
</tr>
<tr>
<td>Diameter</td>
<td>8</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td><strong>Measures of Centrality</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean in-degree (range)</td>
<td>1.24 (0–24)</td>
<td>1.12 (0–23)</td>
<td>1.51 (0–23)</td>
<td>1.36 (0–24)</td>
</tr>
<tr>
<td>Mean out-degree (range)</td>
<td>1.24 (0–21)</td>
<td>1.12 (0–23)</td>
<td>1.51 (0–23)</td>
<td>1.36 (0–23)</td>
</tr>
<tr>
<td>Normalised in-degree (range)</td>
<td>0.93 (0–18.18)</td>
<td>0.87 (0–18.11)</td>
<td>0.68 (0–19.01)</td>
<td>0.18 (0–6.52)</td>
</tr>
<tr>
<td>Normalised out-degree (range)</td>
<td>0.93 (0–15.91)</td>
<td>0.87 (0–18.11)</td>
<td>0.68 (0–19.01)</td>
<td>0.18 (0–6.25)</td>
</tr>
<tr>
<td>In-degree centralisation</td>
<td>17.38</td>
<td>17.37</td>
<td>8.94</td>
<td>3.09</td>
</tr>
<tr>
<td>Out-degree centralisation</td>
<td>15.09</td>
<td>17.37</td>
<td>8.94</td>
<td>2.95</td>
</tr>
<tr>
<td><strong>Measures of cohesion</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>0.0092</td>
<td>0.0110</td>
<td>0.0139</td>
<td>0.0036</td>
</tr>
<tr>
<td>Average geodesic distance</td>
<td>3.59</td>
<td>2.74</td>
<td>3.02</td>
<td>3.65</td>
</tr>
<tr>
<td>Geodesic distribution</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>
Figure 6.6
The normalised in- and out-degree values for village and market locations reported (360 villages and nine markets) for involvement in live pig movement across Nusa Tenggara Timur province, eastern Indonesia, 2009–2010 (West Timor: Blue; Flores: Red; Sumba: Green; 45º dashed line; C: Campling Market, N: Niki Niki Market; H: Halulik Market; Mt: Mataloko Market; D: Detusoko Market; Mb: Mbay Market; M: Melolo Market; Wk: Waikabubak Market; Wt: Wetabula Market).

Table 6.10
Province movement data: Number and proportion of movement types stratified by island, district, subdistrict and within subdistrict movement including both formal and informal movement across West Timor, Flores and Sumba, Nusa Tenggara Timur Province, Eastern Indonesia, 2009–2010.

<table>
<thead>
<tr>
<th>Province of origin</th>
<th>West Timor</th>
<th>Flores</th>
<th>Sumba</th>
<th>Total</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Between Island</td>
<td>0</td>
<td>16</td>
<td>1</td>
<td>17</td>
<td>1.80</td>
</tr>
<tr>
<td>District</td>
<td>63</td>
<td>61</td>
<td>134</td>
<td>258</td>
<td>27.33</td>
</tr>
<tr>
<td>Subdistrict</td>
<td>138</td>
<td>99</td>
<td>122</td>
<td>359</td>
<td>38.03</td>
</tr>
<tr>
<td>Within Subdistrict</td>
<td>77</td>
<td>127</td>
<td>106</td>
<td>310</td>
<td>32.84</td>
</tr>
<tr>
<td>TOTAL</td>
<td>278</td>
<td>303</td>
<td>363</td>
<td>944</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Figure 6.7
Live pig movements across Nusa Tenggara Timur province, eastern Indonesia 2009–2010; Red circle: Live pig market; yellow circle: Village; blue line: Formal movements through markets; purple line: Informal movements between villages.
Figure 6.8
West Timor live pig movement network including formal and informal movements, eastern Indonesia, 2009–2010; green square: selected market; purple circle: reported village; orange triangle: villages included in the farmer survey.
Figure 6.9
Flores live pig movement network including formal and informal movements, eastern Indonesia, 2009–2010; purple nodes: Flores; orange nodes: Sumba; red node: Flores ferry port at Aimere Village; square: selected market; circle: reported villages; triangle: villages included in farmer survey.
Figure 6.10
Sumba live pig movement network including formal and informal movements, eastern Indonesia, 2009–2010; purple nodes: Sumba; yellow nodes: Flores; square: market; circle: reported villages; triangle: villages included in farmer survey.
6.4 Discussion

6.4.1 Social Network Analysis Application

In this chapter, it has been demonstrated that pig movement pathways enable the circulation of pigs around NTT province, both between and across islands. Animal movements present a major risk for the dispersal of transboundary animal diseases, particularly between animal holdings (Fevre et al., 2006; Noremark et al., 2011; Rautureau et al., 2011). This analysis has taken all movement pathways into account, including pigs traded for slaughter. Other literature, such as the research findings of Noremark et al. (2011), removed movement events for cattle going to slaughter, as this was considered an end point. For this network; however, these movements were relevant as animals destined for backyard slaughter may mix with other pigs prior to slaughter and for onward transmission via swill feeding post slaughter (Edwards, 2000; Fritzemeier et al., 2000; Kira & Kasman, 2011). Furthermore, similar to Webb (2006), we were able to gather data regarding the motives behind these movement events such as sellers being driven by large highly utilised marketplaces, convenience (favouring markets close to their residence), and farmers trading out of necessity to obtain a secondary income source or for traditional ceremonies and celebratory occasions (refer to Chapters 3 and 5).

In contrast to a number of other studies (Aznar et al., 2005; Bigras-Poulin et al., 2007; Kiss et al., 2006) in which regional or national databases are utilised as data sources, this SNA is based on data obtained through interviews. No previous investigations have been performed on pig-movement networks across this area of Indonesia. Furthermore, in the absence of any movement recording type system and identification system for pigs, this was the most appropriate technique to adopt. Literature has been published with this method adopted in different countries. A study by Martin et al. (2011) utilised questionnaire data to investigate the contact structure of the poultry market chain in South China. In addition, Webb (2005) utilised questionnaire data to investigate sheep movements in Britain.

The geography of a location needs to be considered as it can have a significant impact on a network (Heath et al., 2008). Sumba has a low-lying landscape with areas of rainforest (Asih et al., 2009). West Timor has both lowlands, which are dominated by rice production, and highlands that focus on maize production (Dalgliesh et al., 2008). In contrast, Flores is a mountainous island with volcanoes and dense rainforest.
The road network across the province is quite limiting with isolated villages having minimal road access, influencing pig-trade patterns. Seasonal influences, particularly during the rainy season have a great impact on animal movement. It is more difficult to transport pigs during the wet season with enhanced road degradation making long distance travel challenging (World Bank, 2006b). As a result, a reduction in market usage for pig trade was identified during the wet season, with a clear peak during the dry season (refer to Chapter 3). During the late dry season, September to October, West Timor can become extremely dry, leading to food shortages (Dalgliesh et al., 2008). This can result in the need for farmers to sell their pigs in order to obtain money for food. For informal movement patterns, trade occurred throughout the year, regardless of the season (refer to Chapter 5).

This network analysis included the movement of live pigs only. The movement of pig products was not incorporated due to the minimal reporting of pork product purchases by consumers in this research and the focus on live pig trade common throughout NTT (Geong M. pers comm, 2011). This is supported by the information collected during the repeated market survey (Chapter 3) and farmer survey (Chapter 5) and discussions with Dinas Peternakan veterinarians. No sellers or buyers reported purchasing pig meat at selected markets. Among the interviewed sellers with pigs at home, when backyard slaughtering does occur, 94.7% of households stated that this was for home consumption only, with a further 98.5% of individuals reporting that they did not sell pork. This is mainly due to the limited cold chain across the province restricting the extent of the pork product trade. Pork is generally not consumed on a daily basis, but for celebratory events, for which live pigs are the preferred trade product choice (Chapters 3 and 5; Kira and Kasman, 2011). The only locations in which pork is consumed more regularly is in more urbanised areas such as Kota Kupang where s’ei restaurants are becoming established (Johns et al., 2009).

Although it has been quantitatively shown that markets have a significant influence on the dissemination of infectious agents through a network, their role within the social and cultural structures across NTT needs to be considered (Dubé et al., 2010; Johns et al., 2009). The ability of smallholder farmers to trade pigs through both markets and directly between farms continues to allow for a convenient and fast monetary source where pigs can be sold while also allowing the high demand during cultural events to be fulfilled. By developing communication with villages and markets and providing knowledge regarding
biosecurity and CSF, this has the potential to instigate community awareness and involvement to assist in preventing potential disease spread (Dubre et al., 2010).

6.4.2 Formal Market Networks
Livestock markets play a central role in animal movements. Markets have greater connectivity with external locations thus having a significant influence on the potential flow of virus through a network (Christley et al., 2010; Noremark et al., 2011). As identified by Dube et al. (2010) when analysing animal movement events through markets, there are two conceptual factors to consider: the level of mixing, and the level of dispersal. This study has addressed the level of dispersal (referring to the calculation of the out-degree) and the level of assortment (referring to the in-degree). Furthermore, Shirley and Rushton (2005b) reiterated that it is essential to understand contact patterns of susceptible populations before strategic control measures can be implemented. Hubs within a network, such as markets, need to be a focus for strategic control (Shirley & Rushton, 2005b).

6.4.2.1 West Timor Market Network
It was identified that West Timor had the greatest number of nodes within the market network (111 nodes; Table 6.3). However, the two additional islands also had similar figures, which is mainly due to the sampling approach used and the number of individuals interviewed for the study.

There is one major road from Kab. Kupang to Kota Atambua, the border city to East Timor. Halulik and Niki Niki markets are along that trade route, making them common transit locations for the pig trade (Barlow & Gondowarsito, 2007). Several studies have confirmed that major roads are risk factors for disease spread (Fang et al., 2008; Ward et al., 2008). Camplong Market is located in Kab. Kupang and is a major live animal market for the southern region of West Timor as it is on the outskirts of Kota Kupang. Thus it is utilised by those from the city and surrounding villages to trade live pigs. This market had connections with both Halulik and Niki Niki, showing the great distances pigs are moved: from Kota Kupang to Kab. Belu. Strong components were identified across the network with all districts being connected within this network structure (Figure 6.8). Pig movement across the border between West Timor and East Timor has been confirmed by Do Karmo (2011, pers comm.), who is the head of the animal health department for East Timor. Pig movements from East Timor to West Timor have been suggested as an introduction source of CSF infection with reports of CSF from Dili first recorded in July–August 1997.
This study did not capture any movement events across the border.

6.4.2.2 Flores Market Network

Markets are a driving force for pig movements and with the absence of pig markets in the western districts of Manggarai Timur and Manggarai Barat, sellers are required to travel greater distance to locate markets, if a reasonable return on pig sales is to be achieved (Kira & Kasman, 2011) (refer to Market List, Appendix 1). The extent of pig movement by ferry between Flores and Sumba, the majority uni-directional towards Sumba, highlights the drive for sellers to obtain better prices for their pigs in Sumba. This is supported by findings in the Greater Mekong Subregion where livestock movements were financially driven with movement pathways from low-to high price areas (Cocks et al., 2009).

The locations of markets on Flores were also a factor to acknowledge regarding usage and influence in disease spread. It is important to consider the spatial distribution of villages and farms. Geographical proximity of premises of interest can control the extent of mixing, in turn influencing the degree to which disease dispersal can occur through a network (Heath et al., 2008). Mataloko Market, due to its central location, was a common market for those bringing pigs from western districts. This market is one of the closest accessible larger markets for farmers from these western regions. Farmers from villages close together have been known to congregate their pigs in one vehicle to reduce rental costs for transportation (Kira & Kasman, 2011).

The greatest distance travelled identified from this data set was a farmer transporting pigs from west to east: from Labuan Bajo village in Manggarai Barat to Mataloko Market, approximately 140km. Focus groups in Flores reported that if a farmer is unable or does not want to travel to the market, they will often seek the assistance of a pig trader who will purchase a large number of pigs from neighbouring villages and transport them to market. Some have been known to transport up to 30–50 pigs in one trip from a village to Mataloko Market (Kira & Kasman, 2011). The mixing of pigs during transportation is another source of CSF infection (Moennig et al., 2003). The most efficient transmission route is direct contact between susceptible and infected pigs (Klinkenberg et al., 2002a). The incubation period for CSF, the time period between infection and the development of clinical signs (Thrusfield, 2007), is 7–10 days (De Vos et al., 2004; Moennig et al., 2003). Moreover, the latent period for CSF is 2–8 days (Durand et al., 2009; Laevens et al.,
1999), depending on the virus strain. Thus, pigs appearing healthy may still be infectious. Furthermore, the potential transmission through fomites is another risk (Ribbens et al., 2007). The use of rented vehicles that may be contaminated may further assist in disease spread (Boklund et al., 2008; Dewulf et al., 2002b).

6.4.2.3 Sumba Market Network

It was on Sumba island that the largest volumes of pigs were seen to enter and exit market locations. Wetaabula had the highest overall entering and exiting volume of pigs for a market location and this market site is in close proximity to the ferry port in Kab. Sumba Timur. For the Sumba market network there were many reports of between-district movements, and common sellers attending different markets (Table 6.10; refer to Chapter 3). This is possible due to the weekly schedule for many markets operating 1–2 days a week, allowing sellers to move from market to market until the correct price or appropriate sale is achieved.

The ferry terminal in Aimere also acts as an informal purchasing area for pigs. Pig sellers from Sumba will travel to Flores, wait at the terminal and purchase pigs directly before transporting them back to Sumba for trade (Kira & Kasman, 2011). The villages of Lumbukori and Lewa Paku were identified as having the highest volume of exiting pigs while Rada Mata village had the largest volume of pigs entering a village. Their close proximity to the Sumba ferry terminal in Kota Waingapu provides an additional outlet in which to trade their pigs. Ferry movement has long been acknowledged as a transportation method capable of moving infected products or animals in different parts of the world (Klassen et al., 2005). The direct contact through mixing and extended time period during transportation can lead to disease transmission (Boklund et al., 2008; Cockram, 2007). Ferry transportation in the province can take several hours, with trip length and frequency influenced by destination and season. The high waves and strong winds occurring in January and February during the wet season have been found to reduce the frequency of ferry crossings by up to 65% in a month (Patunru et al., 2010). With Indonesia being an archipelago, ferry movement is an important method for product movement (De Glanville et al., 2009). De Glanville et al. (2009) further suggested that the presence and density of ferry ports are risk factors for disease spread.
6.4.3 Informal Farmer Networks

It was demonstrated by Lindstrom et al. (2009) that between holding contacts (farm-to-farm) are more common across short distances. This was seen across the informal networks, with an increase in localised village movement and a reduction in across-district movement. By trading in localised areas, transportation issues such as distance and poor road infrastructure may be overcome, and seasonal influences will have a minimal impact on trade patterns. A report by Patunru et al. (2010) investigating the transportation of goods around NTT province, identified that national highways are generally in good condition. However, road quality and coverage of regional and community roads is still poor (World Bank, 2006). Robinson and Christley (2007) further determined that distances travelled by cattle were significantly shorter when directly between animal holdings as opposed to movements via a market. Brennan et al. (2008) supported that the potential for disease transmission is increased with the number of contacts. Thus, markets and those villages with equivalent levels of contact are high risk. It should be noted that a large number of farmer respondents had not traded any pigs over the previous 12 months. These individuals were removed from analysis. This represents some selection bias, as only 62.3% of respondents provided location information for informal pig trade movements. These results therefore have the potential to underestimate the number of village contacts.

6.4.3.1 West Timor Farmer Network

The informal movements recorded for West Timor were found to be unique in comparison to those on Flores and Sumba islands. A much higher level of connectivity was detected with a large proportion of between-district movements. This suggests that even through informal movement events, pigs are still moving the same distances as they would in comparison to the market network.

6.4.3.2 Flores Farmer Network

Informal movement events across Flores were found mostly to be localised. Movements from the villages in Manggarai Barat remained within district and the eastern villages traded between districts of that region. In Kab. Flores Timur, the most eastern district in Flores, a movement event was recorded from Nurri village to Nobo village on the island of Adonara. This island is located between the eastern coast of Flores and Lembata. This has identified an illegal trade movement event, with a pig being taken from an infected area to a non-infected area. Technically, Adonara is part of Kab. Flores Timur, which is a
confirmed CSF-infected district. However, there have been no confirmed cases of CSF on Adonara (Dinas Peternakan Propinsi, 2011). Focus group interviews conducted across Flores determined that a large proportion of farmers are aware that movement restrictions are in place not allowing pigs from an infected area to be moved to a non-infected area (Kira & Kasman, 2011). Despite these restrictions, farmers stated that they would still move pigs to restricted areas (Kira & Kasman, 2011). Improved knowledge regarding CSF and disease spread may help to improve the situation.

6.4.3.3 Sumba Farmer Network
With an extremely high number of traditional ceremonies and cultural events requiring pigs, consumer demand for pigs needs to be met (Johns et al., 2009). There are two major ferry ports on Sumba, one located in Kab. Sumba Timur, and the other in Kab. Sumba Barat Daya (Patunru et al., 2010). The large influx of pigs through these ports allows farmers to purchase pigs from a variety of different sources, maintaining the high quantity needed. One recorded between-island movement was detected from the informal network, from Sumba to Kab. Sikka in Flores. This is an illegal movement as this is from an infected area to a suspect region of infection.

6.4.4 Island Networks
It needs to be recognised that although this SNA has only captured between-island movement for Flores and Sumba, ferry movements between West Timor and Flores and other islands occur weekly. In addition, those that have been detected are formal ferry routes with registered transportation. Informal ferry movement with smaller boats does occur but the extent is not currently known, with only one movement detected to Adonara island.

Control strategies need to be implemented on a provincial basis due to the high level of connectivity of the network. Identifying key players in the network and targeting animal movement management has the potential to decrease the size of an epidemic (Bigras-Poulin et al., 2006). It was demonstrated by Shirley and Rushton (2005a) that if movement restrictions had been implemented just two days earlier during the FMD outbreak in Britain, the size of the epidemic would have been halved. The timing of implementation is a factor to consider when trying to reduce disease spread through a network. The use of strategies including the closure of livestock markets and the prohibition of animal transport has been applied in various outbreak events (Pluimers et al., 1999; Robinson et al., 2007;
Shirley & Rushton, 2005a). However, their application as mitigation strategies across NTT province is limited. The movement restrictions currently in place have had only a limited effect. A recent CSF outbreak on Lembata from April 2011 (Diarmita, 2012; Dinas Peternakan Propinsi, 2011), which was previously a CSF-free district has demonstrated that significant losses occur when movement restrictions are not followed.

Current legislation states that permits are required when formally moving pigs. The most expensive route for pig trade is to transport a pig and sell it at a market on a different island. This requires the seller to obtain health and quarantine certificates from the DLS in addition to paying for ferry transport and market entry tax. Although higher pig prices can be obtained on Sumba, only 1.8% of respondents reported moving pigs between islands. Likely this is due to constraints related to funds and to the distances that pigs can easily be transported. Within-district movement had the highest reported movement levels for both formal and informal pathways (38.0%). Within-district movement only has additional costs when a pig is taken to a market to trade, which requires a health certificate and market entry tax. Between-district movement on the same island involves a similar process to within-district movement requiring a health certificate and market entry tax payment. Informal movements occur throughout the province from the village to island level. Although this movement type removes the need for health or quarantine certificates, informal checkpoints can often be encountered between districts. Payments of up to one million Rupiah or more have been reported for movements between Belu and East Timor (Roland-Holst & Frielink, 2009).

**6.4.4.1 West Timor**

The West Timor network was found to be highly connected. All five districts were reachable using both formal and informal trade routes. Shirley and Rushton (2005b) identified that it is the edges by which nodes are connected that allow disease spread through an entire population. Between-subdistrict movement was the most common movement type for West Timor (Table 6.10). In Figure 6.8 a hub and spoke structure can be detected, similar to that in Stevenson (2008) who identified bird movements between markets in Bali. This is common for markets, as they play a key role as a central location for sellers and buyers to mix (Dubé et al., 2010).

Cut-points identified in this network will be influenced by bias related to the sampling of specific villages and the absence of the entire network (Christley et al., 2005). Nine
different cut-points were identified in West Timor including the three markets and six villages from the farmer survey.

**6.4.4.2 Flores**

At this stage, there is no official list of live pig markets across the province. The most complete information regarding this is the list presented in Appendix 1, which was developed by directly contacting each DLS office within the province to collate these data. Accordingly, DLS in Flores stated that there are no markets located in Kab. Manggarai Barat and Manggarai Timur with the presence of only 10 smaller markets in Kab. Manggarai. Focus group information reported the presence of at least three additional pig markets located in the central regions of Flores in Kab. Nagakeo (Kira & Kasman, 2011). DLS of Flores further stated that in June 2011, a new market was opened in Kab. Manggarai, Woang Market. This is a weekly market for cattle with a small number of pigs sold, approximately 10, on market day (Wednesday) (refer to Appendix 1, Market List). As a result, there is a drive for pig farmers to transport animals from the western districts to at least Kab. Ngada to improve sale price by being in closer proximity to Aimere ferry terminal and the influence of buyers from Sumba on sale price.

It can be observed in Figure 6.9 that the formal and informal networks, when integrated, show a high level of dispersal and weak connections between components. Markets were linked with minimal involvement with reported villages to the extent that the village study sites in the east formed a new component of the network. Interestingly, the villages located in the western region were the only villages with linkages to a marketplace on Flores (Figure 6.9). The lone village connecting Nampar Macing village to the market network was Golo Ronggot village located in Kab. Manggarai Barat. Considering that the farmer survey only included a small proportion of villages across the western districts, there is still the potential for a higher level of connectivity.

When observing the overall movement patterns in Flores, within-subdistrict movement was reported as the most common movement type (Table 6.10). In addition, there was identified movement from Mataloko and Detusoko markets to Sumba (Figure 6.9). Focus group information provided evidence that traders would bring pigs from Manggarai Districts to Mataloko Market, depending on demand, or directly to the Aimere ferry port for transportation to Sumba. Ferry movements are seasonally influenced as the monsoonal rains can influence sea conditions. This can result in a high number of ferry cancellations
Focus group information from Flores identified that the highest pig volumes moving by ferry occurred from March to October. Furthermore, in the event of a ferry cancellation, pigs would remain at market until the next ferry departed. Three major ferry ports on Flores that transport pigs to Sumba are Aimere (Ngada), Labuan Bajo (Manggarai Barat) and Ende (Ende).

Smaller community ferry ports serve many coastal towns. A primary location is Larantuka in Kab. Flores Timur, which sends ferries to Lembata, Kupang, Sumba and Alor islands (Kira & Kasman, 2011; Patunru et al., 2010). Although not detected in our networks, there is evidence that ferries transit in neighbouring Nusa Tenggara Barat (NTB) province such as the ferry from Labuan Bajo to Sumba Barat with a transit stop in Sape on Sumbawa island in NTB (Patunru et al., 2010). As there is a concentration of Muslims on Sumbawa island it is unlikely that pigs would exit the ferry at this stop; instead continuing on to Sumba (Kira & Kasman, 2011).

6.4.4.3 Sumba

On Sumba, Nuamuri village was the only connection between Detusoko Market in Flores and Wetabula Market in Sumba. This is a key finding as it demonstrates that pig movements between Flores and Sumba are not only between the western districts, but also reach further east to the village located in Kab. Ende. Furthermore, this was an informal trade movement (Figure 6.10). The drive to sell pigs in Sumba due to the higher profit margins that can be gained is a significant factor to consider. By selling a pig in Sumba, individuals can receive up to double the price paid in Flores (Kira & Kasman, 2011).

6.4.5 Social Network Analysis Limitations

Although diameter, geodesic distance, size and density have been affected by the sampling approaches used during study conduction, these values can provide an indication of movements captured across the networks from the selected locations. The parameters displayed are tending towards their minimum values. However, they are still informative and provide base information regarding a network structure that has never been studied. In addition, the in- and out-degree values have provided some vital information regarding key locations for potential disease spread and infection. It also needs to be considered that these values in part are influenced by the number of people interviewed. The volume of pigs was selected as an edge weighting for the networks as the frequency of pig movement was not available from market interviews. Obtaining information on the frequency of pig
movements could provide additional support in identifying high risk locations for disease spread and should be considered in future investigations.

A biased representation of contacts within the network has been displayed due to the sampling techniques. Purposive selection of markets and the random selection of villages has meant that those locations being reported on have a greater tendency to be located close to each other, particularly for the informal network. Markets were selected across different districts in an attempt to remove some of the limitations of reported localised movement events. For the farmer network, there was a greater propensity for villages within the same subdistrict to be connected. Initially selecting districts for the farmer survey based on occurrence of reported CSF cases and high numbers of pig movements targeted particular regions of greater disease risk (refer to Chapter 5). It should further be noted that the number of reported villages was restricted to an extent by the number of individuals that were interviewed. For farmers, they were able to provide all locations in which they purchased or sold a pig or gave/received a pig as a gift. For the market interviews; however, the major question was the source and destination used on the day of interview. Some individuals provided more than one village location; however, this was not common.

This study could be extended by conducting a study focused on the individuals transporting pigs in the network. Identifying central individuals within the population involved in pig movements has the potential to inform surveillance and points for other control strategies (Christley et al., 2005). Furthermore, this study could be improved by incorporating a larger sample size of markets and villages across a wider regional base.

6.5 Conclusion

This study has enabled the identification of key villages and markets representing higher risk locations for disease spread. The key findings included the high level of connectivity across West Timor demonstrating the extent of movement from the southern end of the region to the border with East Timor. Pigs were found to move between a higher number of sequential nodes (locations) across Sumba in comparison to other islands. Due to the central location of larger pig markets on Flores, farmers were required to travel long distances and the cultural and economic drivers for pigs to be transported from Flores to Sumba was clearly identified. By generating this knowledge, future research can now
incorporate this new information to assist in the development and application of mitigation strategies. With limited resources available within the province, having targeted locations where mitigation measures can be pilot tested will provide the most effective feedback for future activities to reduce the impacts of CSF.
Chapter 7: Quantitative Risk Assessment of Classical Swine Fever Spread through the Live Pig Market Chain in Nusa Tenggara Timur Province

7.1 Introduction

Classical swine fever is a disease affecting pigs, which leads to substantial production and economic losses (Boklund et al., 2009). Due to its highly contagious nature, it is classified as a transboundary animal disease and is notifiable to the OIE (Moennig et al., 2003). Consequently, many countries have implemented control strategies to reduce the potential impacts caused by CSF including animal movement databases (Noremark et al., 2011), movement control strategies, pig slaughtering policies, vaccination and the development of eradication plans (Edwards et al., 2000).

Results from risk assessments can assist in guiding decision making for the development of appropriate control measures. To date, risk assessments have been used to assist decision making to improve surveillance and control strategies for CSF (De Vos et al., 2006; Karsten et al., 2005), African swine fever (Weiland et al., 2011), brucellosis (Jones et al., 2004) and foot-and-mouth disease (Schley et al., 2009). An example can be seen in a study by Jones et al. (2004) where a quantitative risk assessment was used to estimate the risk of importing brucellosis-infected breeding cattle into Great Britain from Northern Ireland and the Republic of Ireland. By taking into account the probability that an animal was infected, the number of animals being imported and the probability that pre-export testing did not detect an infected animal, the model was able to estimate that Great Britain could expect to import brucellosis from Northern Ireland every 2.63 years and from the Republic of Ireland every 3.23 years. As a result of this assessment, the government introduced compulsory post-calving testing for all breeding cattle imported into Britain to reduce the risk of importing brucellosis-infected breeding cattle.

Market chains for food products and/or food animals often experience changes in the product unit along a pathway with mixing or segregation occurring (Clough et al., 2009). In contrast, when developing a scenario tree model to examine exposure pathways for different hazards, a unit of interest that remains consistent through a pathway is required. As a result of these differences in approach, it was recognised that to assess the risk of
disease spread along a live animal market chain, a modular approach would be more appropriate because it allows a pathway to be divided into modules and permits separate evaluation of transmission for the product unit as it is constituted at each process stage. In the case of pig movements along a market chain, there are points along the pathway where infected and susceptible animals may mix, such as during transportation and within villages and markets. At points where mixing occurs, product units are integrated to create larger product units (Nauta, 2001). Within villages, the minimal use of biosecurity and pig housing systems such as tethering and free roaming that allow pigs to come in contact with other local village pigs presents opportunities for mixing and CSF transmission (refer to Chapters 3 and 5). Transportation to a market or another village represents an additional stage along the market chain where mixing of pigs can occur. With up to 30 pigs on an individual vehicle in NTT, contact between susceptible and infected pigs can occur (Kira & Kasman, 2011). At a live pig market, direct contact between pigs from villages in different districts and subdistricts can facilitate potential CSF transmission. By identifying these key locations along the market chain at which the risk of CSF transmission is increased due to mixing, a modular model was developed to assess the impact of mitigation strategies to control CSF.

The use of modular risk models was initially developed by Nauta (2001) for application in the food safety sector. This method has been applied to various animal product processes (Clough et al., 2009; Hope et al., 2002; Nauta et al., 2007), with a series of modules representing steps in the process that a product unit undergoes from start to finish, such as farm to slaughter, and each module describing likelihood of microbial hazard transmission to the product unit at that point. This structure allow the product unit to vary in size and composition across modules as occurs, for example, when milk leaves a farm as one unit and is then distributed into smaller units when packaged for distribution or pooled together for transportation purposes (Nauta, 2001, 2008). This model structure means it can be adapted to the movement of live animals from source to destination. For each module there is an input–output relationship, which enables the proportion of contaminated product units to be calculated at the end of each module (Nauta, 2001). By combining a modular risk model with a stochastic Monte Carlo simulation, the model is able to address variability and uncertainty through the use of probability distributions, and to investigate the influence of individual input parameters on outputs using sensitivity analysis (Nauta, 2008).
In this study, the market chain was divided into a series of modules and the likelihood of CSFV transmission along the live pig market chain in NTT was determined using an exposure assessment. Movements from village to market were considered in one model and movements from village to village were considered in an additional model. Two common scenarios were simulated, one for each model, and compared with the implementation of mitigation strategies including inspection and vaccination. The aims were to identify pathways presenting the greatest risk of pathogen transmission and to evaluate the effectiveness of risk mitigation measures on the transmission of CSFV along the market chain in NTT.

7.2 Overview of Models

7.2.1 Model Pathways

Two models were developed to describe the major movement pathways for pigs across NTT. The first was a model to investigate pig movements from village to market. The second model investigated pig movements directly between villages (informal movements), without the presence of a market. This considered animals entering or exiting a village, not only animals sold. Only live pig movement was considered in both models due to results from the market and farmer surveys demonstrating that trade is predominately live pigs (Chapters 3 and 5).

Along both pathways the unit of interest changed as pigs were grouped into consignments for the purpose of transportation and sale. This was to account for the impact of aggregation and mixing of animals and the change in volume of pigs at different points along the market chain. Both models took into account differences in CSF prevalence across the province. The segregated regions are shown in Figure 7.1 and were based on seroprevalence data obtained from a survey conducted through ACIAR (Project AH/2006/156) during 2010. Region 5 and 3 required the consolidation of several data sources, which is discussed in relation to input parameters in section 7.3.1.2 (part b).
Figure 7.1
Regions considered across Nusa Tenggara Timur province for inclusion in an exposure assessment risk model. Regions were assumed to have different prevalence levels for classical swine fever (West Timor, Flores and Sumba).

The time period that the models represented varied. The village to market model structure represented one functional market day at a live pig market. The village to village model represented a single month. Several assumptions applied to the modelling of the probability that the market or destination village was infected and the number of infected pigs. These were:

1) The vehicle used to transport pigs to market or another village was not contaminated with CSFV when pigs were collected, therefore infection could not occur due to fomite contact during transportation.
2) There was no transmission of CSF during transport if infected pigs entered the truck (i.e. different to fomite spread).
3) Prior to the entry of pigs to the market, or destination village, the location was free of CSFV.
4) Pigs were not vaccinated for CSF.
5) All pigs were equally susceptible to infection, irrespective of age and breed.
6) The CSFV strain considered in the model was the moderately virulent Paderborn 2.1 strain. Evidence suggests that in Indonesia there are two subgroups of CSFV: the Paderborn 2.1 strain and a highly virulent 1.1 strain (refer to Chapter 2). A more conservative approach was taken by using the moderately virulent strain to assess the effectiveness of inspection.
7) The latent period for CSF virus was greater than or equal to two days.
8) The clinical course of CSFV infection was the same across all age groups and breeds.
9) Infected pigs remained clinical during the entire infectious period.
10) Vaccine efficacy was the same across all age groups and breeds.
11) Vaccination coverage was assumed to be conducted on a regional level.
12) No pigs recovered from infection.

To account for variability and uncertainty, probability distributions were used for some input parameters. Sensitivity analysis was used to investigate the impacts of changing individual input parameters on the output. The quantitative models were constructed in Microsoft Excel using the @Risk Software (©Risk 5.0, Palisade Corporation, USA). Each scenario consisted of 10,000 iterations that were sampled using the Latin Hypercube method and with the seed selection set to random.

7.2.2 Data Sources

The data sources utilised for this exposure assessment included: the repeated market survey (Chapter 3), the farmer survey (Chapter 5), the focus groups and seroprevalence survey conducted by ACIAR (Project AH/2006/156). These studies provided data regarding pig numbers, herd sizes, pig seller and buyer numbers at market, and prevalence information. In addition expert opinion was sought to guide the determination of assumptions and input parameters related to the following issues. Dr Chris Morrissy from the Australian Animal Health Laboratory (AAHL) provided verification of information on the Paderborn 2.1 moderately virulent virus and its disease process in pigs, particularly in Asia. Dr Ian Robertson from Murdoch University, Western Australia, provided information on vaccination efficacy and details from the ACIAR Alor project. Associate Professor Jenny-Ann Toribio from the University of Sydney and Dr Maria Geong from Dinas Peternakan Propinsi, Kupang, NTT, provided expert opinion on CSF distribution in Flores. The scientific literature was also consulted for information regarding CSFV genetic typing, processes of infection, transmission and virulence.
7.3 Model 1: Village-to-Market

7.3.1 Baseline Model

The baseline village-to-market model comprised four modules: region, village, farm and market (Figure 7.2). Based on data obtained through the market and farmer surveys, a scenario was developed to represent one operational market day of pigs entering a typical live pig market in NTT. In the baseline model no risk mitigation measures were considered. The structure of the model incorporated stages of movement from the village to market level. The spread of CSF within villages was not modelled. However, variations in between-herd prevalence were accounted for. Due to the pig production systems used and high level of contact of pigs within villages, farms within a village were considered to have the same CSF infection status. In the scenario pigs were sourced from 20 villages and within each village pigs were sourced from three different farms. That is, the pigs in the market had come from a total of 60 different farms. These values were calculated based on data obtained from the market survey (Chapter 3). The value 20 was the average number of villages that were reported to be present at each of the nine market sites. The value three was calculated based on the average number of pig sellers from one particular village present at a market site.

The province was divided into regions based on CSF prevalence. Figure 7.1 shows the districts present in each region. The current CSF infection status allocation for each region was also taken into consideration. As a result, region 5 represents those districts that are classified as CSF ‘free’ (refer to Chapter 2).

For each iteration of the model three outputs were produced:

1) The number of infected pigs present at market.
2) The number of infected pigs displaying clinical signs of CSF infection at market.
3) The probability that one or more infected pigs were present in the market (i.e. the probability that the market was infected).
Baseline village-to-market model structure (formal movements) with modules for an exposure assessment, likelihood of classical swine fever virus transmission through the live pig market chain in Nusa Tenggara Timur Province, eastern Indonesia.

### 7.3.1.1 Description of Modules

**a. Region Module**

Across the province, different prevalence levels for CSF have been found through seroprevalence investigations (ACIAR Project AH/2006/156, 2010). Therefore, the likelihood a village had one or more pigs infected with CSFV varied between regions. Consequently, the first part of the model was to determine the probability that a village in each region was infected (refer to Figure 7.2, module 2). The probability that a village had pigs infected with CSFV was based on surveys of a small number of villages. Therefore, to
account for uncertainty in the prevalence of infected villages a beta distribution were used (refer to Table 7.1) This distribution was selected as it can be used to describe uncertainty regarding a binomial probability (Vose, 2008).

This model enabled pigs entering the market place to be sourced from all regions or a subset of regions. For example, in the iteration shown in Figure 7.3 the pigs were only sourced from regions 1 and 2 (i.e. the column \( P(\text{Animal From Region}) \) had zero for regions 3–5).

Table 7.1
Input values used to determine the probability a region was infected with classical swine fever from a seroprevalence survey conducted by ACIAR in 2010 (Project AH/2006/156) across Nusa Tenggara Timur Province, eastern Indonesia.

<table>
<thead>
<tr>
<th>Region</th>
<th>Districts</th>
<th>Number of Villages Sampled</th>
<th>Number of Villages Infected(^1)</th>
<th>Input Value(^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Southern West Timor (Kupang, TTU)</td>
<td>6</td>
<td>6</td>
<td>Beta (7,1)</td>
</tr>
<tr>
<td>2</td>
<td>Northern West Timor (TTS, Belu)</td>
<td>6</td>
<td>6</td>
<td>Beta (7,1)</td>
</tr>
<tr>
<td>3</td>
<td>Flores Timur</td>
<td>6</td>
<td>6</td>
<td>Beta (7,1)</td>
</tr>
<tr>
<td>4</td>
<td>Sikka</td>
<td>6</td>
<td>4</td>
<td>Beta (5,3)</td>
</tr>
<tr>
<td>5</td>
<td>Western Flores (MB(^3),M(^4), MT(^5), Ng(^6), Nk(^7), Ende)</td>
<td>6</td>
<td>3</td>
<td>Beta (1.5,6.5)(^8)</td>
</tr>
<tr>
<td>6</td>
<td>Sumba</td>
<td>6</td>
<td>6</td>
<td>Beta (7,1)</td>
</tr>
</tbody>
</table>

\(^1\)A village was considered infected when ≥ 1 pig with no history of vaccination was confirmed positive by a 2\(^{nd}\) generation ELISA test; \(^2\)Beta distribution (successes + 1, total number – successes + 1); \(^3\)MB is Manggarai Barat district; \(^4\)M is Manggarai district; \(^5\)MT is Manggarai Tengah district; \(^6\)Ng is Ngada district; \(^7\)Nk is Nagekeo district; \(^8\)The input value for region 5 was reduced to the number of infected villages = 0.5, based on several information sources including the seroprevalence survey, lack of reported CSF cases and expert opinion.

b. *Village Module*

The village module comprised of 20 different villages. For each village two values were simulated, the region and the village infection status. The region that a village came from could be one through to six. This was drawn from a discrete distribution where the relative frequency of the regions was equal to the value entered for the probability pigs were from a region [i.e. \( P(\text{Animal From Region}) \)] in the region module. The value could be altered according to the scenario being assessed. From the selection of the region, the infection status of the source village was determined by taking a random draw from a binomial distribution in which the number of trials was one and the relative frequency of infected
villages was a beta distribution of the value entered into the probability a village was infected [i.e. \( P(Villages \text{ Infected}) \)] column shown in Figure 7.3. The binomial distribution was used to account for variability of the input values. At the village level the infection status of the village was determined by a random draw from the Binomial (1, Village Infected), that is when the result was one the village was infected.

To illustrate, Figure 7.3 shows a single iteration of the region, village and farm modules. In this example the first village (Village/Farm ID), has come from region 2 and thus the probability that it is infected is 0.722 [based on a random draw from Beta (7,1)]. Given the high probability that the village in this iteration was infected, the random draw from Binomial (1, 0.722) was one. In contrast the ninth village, which is also in region 2, was not infected.

c. Farm Module

The farm module comprised of a total of 60 farms, three from each of the 20 villages (Figure 7.4). The inputs for this module are addressed in section 7.3.1.3: Inputs for baseline farm module. Region was obtained from the village module through a reference to the village number within its randomly allocated region. The baseline model sourced pig from West Timor (regions 1 and 2). The columns Village, Farm and Region, represented the source of the pigs to account for infection status. The number of pigs in a herd (column \# Pigs in Herd) was calculated using a discrete distribution; details of calculations are shown in section 7.3.1.3. The number of pigs being transported to market (column \# Pigs going to market) was calculated using equation 7.1.

\[
N_{\text{pigs in herd}} \times \text{Proportion of Herd Sold} \quad \text{Equation 7.1}
\]

Following these calculations, the farm module was then aggregated to the village level where the amalgamation of the three farmers from each village was combined into one village.
Region and Village Modules

<table>
<thead>
<tr>
<th>Region</th>
<th>P(Animal From Region)</th>
<th>P(Village Infected)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>0.814526844</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>0.722147342</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0.924050156</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0.5661994483</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
<td>0.204300206</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>0.985756061</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Village/Farm ID</th>
<th>Region</th>
<th>Village/Farm Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
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<tr>
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<td>1</td>
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<tr>
<td>19</td>
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<td>1</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 7.3
One iteration of the region and village modules showing the 6 regions that the province was divided into with pigs sourced only from West Timor (regions 1 and 2). A total of 20 villages are represented in the village module with a binomial distribution determining if a village was infected or not $P(Village\ Infected)$ considering the inputs.
### Farm module

| Event (Pigs in Herd)                  | 0.67 |

- **P(Pig +ive | Village+ive & no vac)**: 0.11
- **P(Pig +ive | Village+ive & vac)**: 0.0209
- Average number of pigs in herd: 5
- % Herd sold: 0.3
- **P(Clinical signs present | no vac)**: 0.67
- **P(Clinical signs present | vac)**: 0
- **P(Vacc_Eff)**: 0.81

<table>
<thead>
<tr>
<th>Region</th>
<th>P(Vaccination)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>6</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Village</th>
<th>Farm</th>
<th>Region</th>
<th>Vaccination</th>
<th>#Pigs in Herd</th>
<th>#Infected</th>
<th>#Pig going to market</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>2</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 7.4
One iteration of the farm module from the village-to-market model showing 6 out of 60 farmers present in the model from 20 different villages transporting pigs to market.
7.3.1.2 Inputs for Baseline Region and Village Modules

a. Region Module
This input parameter was the probability an animal was from one of the six regions (Figure 7.1) and varied according to the particular scenario being simulated. This allowed targeted source locations to be modelled and for baseline information to be obtained for region and island levels. For example when sourcing pigs from West Timor (baseline model), a value of 0.5 was allocated to region 1 and region 2 respectively as these two regions made up this area.

b. Village Module
The village module incorporated the probability that a village was infected. The values were determined by using the results of a seroprevalence survey conducted in 2010 by ACIAR (Project AH/2006/156) on West Timor, Flores, Sumba and Lembata islands. From the survey data, villages with at least one pig with no history of vaccination, confirmed positive by second generation ELISA, were considered infected. Region 5; however, was altered due to conflicting evidence. Several data sources were considered, including information from DLS and the seroprevalence results. Region 3 also required the consolidation of several data sources including a survey conducted by Santhia et al. (1999) and expert opinion from Dr Maria Geong. Input values for probability region infected had a beta distribution, which was selected to account for uncertainty (Table 7.1).

The ACIAR Project AH/2006/156 (2010) identified three out of six villages as infected in region 5 (Figure 7.5). In contrast, no clinical pigs (pigs displaying clinical signs) have ever been reported to animal health authorities from these districts since CSF was introduction into the province in 1998 (Dinas Peternakan Propinsi, 2011). Moreover, the districts within region 5 have retained their CSF-free classification since 1998 and vaccination has never been conducted in these areas.

During 2008, the Australian Quarantine and Inspection Service (AQIS) conducted a survey to assess the current situation of important production diseases in NTT, including CSF. The diagnostic test used was a PrioCHECK® CSFV Antibody ELISA. A sample size of only 10 pigs was taken from Manggarai Barat district in subdistrict Komodo. In the adjacent district of Manggarai an additional 13 pigs were sampled. All samples were negative for CSFV antibodies from those collected across both districts. In Ngada district,
a district located in region 5 for the purposes of this study, a 5% prevalence level was detected. Due to the disparity between different data sources, it was concluded that the most appropriate approach would be to use a lower prevalence estimate for region 5.

CSF prevalence levels in Kab. Flores Timur have undergone little investigation. Initial estimates were generated by Santhia et al. (1999) following a survey with 120 pigs across Kab. Kupang and Kab. Flores Timur. They determined a prevalence level of 30.9% (vaccination was not occurring at the time). More recent estimates provided by Dr Maria Geong (pers comm, 2011) suggested similar or slightly lower levels to Kab. Kupang. Taking this into consideration, it was concluded to base our estimate around the ACIAR Project AH/2006/156 survey using values slightly lower than Kab. Kupang.

Figure 7.5
Villages tested in Manggarai Barat and Sikka districts on Flores for a seroprevalence study conducted in 2010 by the Australian Centre for International Agricultural Research (ACIAR) Project AH/2006/156, Nusa Tenggara Timur, eastern Indonesia; red circles: at least one pig with no history of vaccination detected in a village with antibodies to classical swine fever virus (CSFV); green circle: no pigs tested positive to CSFV antibodies.

7.3.1.3 Inputs for Baseline Farm Module

Module 3 represented the farm module where the majority of input values were implemented. Variations at the farm level such as herd size were accounted for. The following input parameters were incorporated.

a. Probability Pig Infected with CSF

This parameter was calculated through data obtained from the ACIAR seroprevalence survey (ACIAR Project AH/2006/156, 2010). CSF prevalence levels were calculated for each region. Analysis was conducted using AusVet EpiTools (www.epitools.ausvet.com.au) in which the true prevalence with a 95% confidence level
and Rogan-Glanden approach was used (Appendix 10). A pert distribution was then fitted to the input values to account for uncertainty using the results displayed in Appendix 10 (Table 7.2). The seroprevalence survey provided data on seven districts. Region 3 (Flores Timur district) was not included in the sampling and as such an estimate was made based on previous clinical and serological reports. It was important to separate this district as an additional region in the model as it is the only district classified as CSF infected on Flores island. Prevalence levels have been estimated by Santhia et al. (1999) based on a serological survey of 120 pigs tested with a Creditest-ELISA for CSFV antibodies. The number of recently reported clinical cases has been similar to that of Kab. Kupang. For example, in 2010, 64 CSF cases were reported from Flores Timur and 99 from Kab. Kupang. As a result, an estimate was made ranging from 7% to 12%, slightly lower that the prevalence estimate of Kota Kupang (Appendix 10). For region 5, experts in the area supported a prevalence range of 1% to 9% (Geong M. pers comm, 2011; Toribio J-A. pers comm, 2011).

Table 7.2
Distributions used to determine the probability a pig was infected with classical swine fever from a seroprevalence survey conducted by ACIAR (Project AH/2006/156, 2010) across Nusa Tenggara Timur province, eastern Indonesia.

<table>
<thead>
<tr>
<th>Region</th>
<th>Location</th>
<th>Prevalence</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Southern West Timor (Kupang, TTU)</td>
<td>RiskPert(^1) (0.08, 0.12, 0.15)</td>
</tr>
<tr>
<td>2</td>
<td>Northern West Timor (TTS, Belu)</td>
<td>RiskPert (0.17, 0.21, 0.25)</td>
</tr>
<tr>
<td>3</td>
<td>Flores Timur</td>
<td>RiskPert (0.07, 0.10, 0.12)</td>
</tr>
<tr>
<td>4</td>
<td>Sikka</td>
<td>RiskPert (0.007, 0.02, 0.06)</td>
</tr>
<tr>
<td>5</td>
<td>Western Flores (MB, M, MT, Ng, Nk, Ende)</td>
<td>RiskPert (0.01, 0.05, 0.09)</td>
</tr>
<tr>
<td>6</td>
<td>Sumba</td>
<td>RiskPert (0.15, 0.23, 0.30)</td>
</tr>
</tbody>
</table>

\(^1\)RiskPert = Pert distribution (minimum, most likely, maximum)

b. Average Number of Pigs in Herd

The average number of pigs in a smallholder herd of marketable age (≥ 2 months) were considered using data obtained through the repeated market survey and farmer survey (refer to Chapters 3 and 5). Herd sizes of one up to 15 were considered. A discrete distribution was used to account for variability around these values (Figure 7.6).
Figure 7.6
Frequency distribution of the data used to define a discrete distribution for the number of pigs of marketable age (≥ 2 month) per herd in smallholder pig herds across Nusa Tenggara Timur province, eastern Indonesia.

c. The Proportion of Pigs Sold From a Herd

Using data obtained from the repeated market survey, estimates were made to determine the number of animals sold from a herd during a single transaction. It was estimated 30% of a herd was sold during a single transaction for pigs of a marketable age (≥ 2 month). This was a fixed value. It can be seen from Figure 7.7, generated from market survey data, that the majority of pig sellers sold between one and four pigs.

Figure 7.7
Frequency distribution of the number of pigs sold by pig sellers during a single market day, across Nusa Tenggara Timur, eastern Indonesia, 2009.
**d. Probability Clinical Signs Present Given No Vaccination**

For this input parameter, a review of current literature was used to generate an estimate. Estimates were based around the assumption of the Paderborn (2.1) moderately virulent strain being present. Expert opinion provided evidence to suggest that this strain produces more acute forms of the disease, thus this was accounted for by taking values on the lower end of the scale and being more conservative with the estimated value (Morrissy, pers comm., 2011). Weesendorp et al. (2010a) identified that the infectious period for pigs with a moderately virulent strain (Paderborn) excreting high levels of virus was 32.5 (21.2–51.8) days. For pigs excreting low levels of the virus, an infectious period of 14.7 (13.2–16.3) days was determined. For the incubation period, published literature provided evidence of a range of 7–10 days (Animal Health Australia, 2009; De Vos et al., 2006; Dewulf et al., 2002b). Equation 7.2 was used to calculate the probability an infected animal would show clinical signs.

\[ 1 - \frac{\text{incubation period}}{\text{infected period}} \]  

Equation 7.2

An initial estimate of 0.67 was generated (using 25.6 days for the infected period and 8.5 days for the incubation period) with this value being assessed using sensitivity analysis.

**7.3.2 Alternative Scenarios for the village-to-market model**

**7.3.2.1 Different Villages and Regions**

The model was able to simulate data for different regional scenarios. This was done by changing input values; specifying the proportion of pigs purchased from different regions. Initially, baseline information was generated for each region to identify higher risk regions. This was done by running the model with pigs being sourced only from one region at a time and completing this for each of the six different regions then comparing the output. For alternative scenario simulations and sensitivity analysis conducted on mitigation measures, pigs were sourced from regions 1 and 2 (West Timor). This region had high seroprevalence levels of CSFV and a highly connected pig movement network and as such was selected to model a high risk location.

**7.3.2.2 Pre-Transport Inspection or Pre-entry Market Inspection Module**

In this model, the use of an inspection strategy was simulated (Figure 7.8). This mitigation strategy was implemented by creating a new module that incorporated a detection
parameter to assess the impact of inspection. It was determined that the placement of this module could be either prior to transport from village or prior to market entry (refer to Figure 7.8). This module considered that if a clinically infected pig was detected, it would be discarded along with all other pigs in the consignment and thus not transported to market or refused entry to market. Following consideration of the pig market chain, it was decided to model inspection prior to market entry. Pre-transport inspection would be difficult to implement in the field, whereas inspection at market entry had the potential to be more regulated and feasible to enforce. Furthermore, as there are more pigs at markets compared to transportation vehicles, the mixing of infected and susceptible pigs at market has the potential to result in greater infection transmission. The probability of detection \[ P(Detection) \] was assessed with sensitivity analysis to observe its impacts as a mitigation strategy. A hyper-geometric distribution was used to account for the variability around the number of pigs entering the inspection module (where the number of clinical pigs was the number of infected pigs displaying clinical signs). The probability of detection prior to transport or prior to market entry was determined using equation 7.3 where the probability of detection was a value between zero and one.

\[
1-[1 - P(Detection)]^{no.\ clinical\ pigs} \quad \text{Equation 7.3}
\]

Figure 7.9 illustrates one iteration of the pre-entry market inspection module in which the probability of detection is 0.2. It can be seen that the 60 farmers have been aggregated into their 20 corresponding villages to allow consignments to be formed and inspection on market entry as a mitigation strategy to be assessed.

7.3.2.3 Vaccination Coverage and Efficacy

Vaccination was incorporated into the model as a mitigation strategy. This was done by altering the structure of the farm module, unlike the other mitigation strategies in which a new module was added. Vaccination could be incorporated into the simulation by adding values for vaccination coverage, which is represented by the column \( P(Vaccination) \) in Figure 7.4 and a value for vaccination efficacy.

The probability of clinical signs being present given vaccination was accounted for. A value of zero was used for this input parameter to model the worst-case scenario.
Figure 7.8
Village-to-market model structure (formal movements) with modules and mitigation strategies for an exposure assessment; likelihood of classical swine fever virus transmission through the live pig market chain in Nusa Tenggara Timur province, eastern Indonesia.
## Pre-Entry Market Inspection Module

<table>
<thead>
<tr>
<th>Village id</th>
<th>P(Detection)</th>
<th>#Infected</th>
<th>#Clinicals</th>
<th>#Pigs Sent to Market</th>
<th>P(infected after inspection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.360</td>
<td>3</td>
<td>2</td>
<td>5</td>
<td>0.519230769</td>
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<td>0</td>
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</tr>
<tr>
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<td>1</td>
<td>4</td>
<td>0.166666667</td>
</tr>
<tr>
<td>4</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
<td>4</td>
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<td>0.200</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0.166666667</td>
</tr>
<tr>
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<td>0.000</td>
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<tr>
<td>7</td>
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</tr>
<tr>
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<td>1</td>
<td>4</td>
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</tr>
<tr>
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<tr>
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<tr>
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</tr>
<tr>
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<td>5</td>
<td>0</td>
</tr>
<tr>
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</tr>
<tr>
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<td>0</td>
<td>0</td>
<td>6</td>
<td>0</td>
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<td>0.200</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>0.166666667</td>
</tr>
<tr>
<td>19</td>
<td>0.000</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>0.360</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>0.519230769</td>
</tr>
</tbody>
</table>

**Figure 7.9**

One iteration of the pre-entry market inspection module with the probability of detection [P(Detection)] of 0.2 and calculation of the number of infected and clinical pigs on arrival at market.
7.3.3 Sensitivity Analysis

Sensitivity analysis was conducted to investigate relationships between the input parameters and model outputs. This aimed to determine the level of impact various inputs had on the model outputs and to confirm that the model was performing correctly.

The following parameters were assessed with sensitivity analysis for this model:
1) Probability pigs were from different regional locations – different scenarios were simulated with pigs being sourced from 1 to 6 regions.
2) Vaccination coverage \([P(Vaccination)]\) – this parameter was investigated with values from 0 to 1.
3) Vaccination efficacy \([P(Vacc_Eff)]\) – this parameter was assessed using efficacy values from 0.6 to 1 (taking into consideration expert opinion).
4) Probability of infected pigs being detected on entry to market \([P(Detecting infected pig)]\) – this parameter was investigated with values from 0 to 1.
5) Probability of infected pigs displaying clinical signs \([P(Clinical signs present|no vac)]\) – this parameter was investigated with values ranging from 0.5 to 0.8.

To determine any significant differences when altering input values, a Kruskal-Wallis test was used on all parameters assessed with sensitivity analysis. This test is a non-parametric one-way analysis of variance that can identify differences between two or more independent samples. It does not assume data normality nor does it identify which groups are significantly different (Altman, 1991). Analysis and box plots were produced using R Software (Version 2.11.1, R Development Core Team, Vienna, Austria, 2011) with a 0.05 level of significance applied.

7.3.3.1 Justification for Values Used in Sensitivity Analysis for Vaccination

Sensitivity analysis was conducted on vaccination coverage from 0% to 100% while considering the use of the currently distributed Hogsivet (Pusvetma) vaccine, a modified live vaccine distributed across Indonesia. Expert opinion was used to inform vaccine efficacy that was set as a pert distribution with a minimum of 60%, most likely of 75% and a maximum value of 85% was used. Literature on vaccination efficacy was limited for this type of vaccine, thus a pert distribution was used to account for uncertainty. Efficacy was considered as field efficacy.
Sensitivity analysis was also conducted on vaccine efficacy. Vaccination coverage was considered as 100%, while efficacy was varied from 60% to 100% to observe the impact on the output parameters and effectiveness as a mitigation strategy.

7.3.4 Results

7.3.4.1 Baseline Results
The village-to-market model was initially run to obtain baseline information on typical live pig market in West Timor. Results were also generated at the regional and island level. Markets on all islands had a high probability of being infected on one operational market day (Table 7.3). Figure 7.10 and Figure 7.11 show that the number of infected and clinical pigs simulated at market at the regional level were similar across regions 1 (Kupang and TTU), 2 (TTS and Belu), 3 (Flores Timur) and 6 (Sumba). A significant difference ($P < 0.001$) was detected for regions 4 (Sikka) and 5 (Western Flores), which had lower numbers of infected and clinical pigs at market. The number of clinical pigs varied when sensitivity analysis was conducted on the probability a pig displayed clinical signs ($P < 0.001$; Figure 7.12). With increasing probability that clinical signs were displayed, a greater number of clinical pigs were present at market. However, no significant difference was detected for the number of infected pigs at market or the probability a market was infected ($P = 0.99$ and $P = 0.38$, respectively).

7.3.4.2 Pre-Entry Inspection at Market
Sensitivity analysis demonstrated that pre-entry market inspection was found to significantly reduce the probability of a marketplace being infected ($P < 0.001$; Figure 7.13). For this mitigation strategy to be effective, it needed to be executed very strictly. Only when the probability of detection was $> 75\%$ was a notable reduction seen in the probability of a marketplace being infected.

7.3.4.3 Vaccination Coverage
By increasing vaccination coverage across the province, a significant reduction ($P < 0.001$) was observed in the number of infected and clinical pigs present at market (Figure 7.14 and Figure 7.15, respectively). Despite a reduction in the number of clinical and infected pigs, the proportion of all iterations in which the market place was infected was 97.85%. This was due to the impact of vaccination only reducing, not excluding, the presence of infected pigs at the market.
7.3.4.4 Vaccine Efficacy

By improving the efficacy of the vaccine used in the province, there was a significant reduction ($P < 0.001$) in the number of infected pigs present at market (Figure 7.16). At > 85% vaccine efficacy there was a significant ($P < 0.001$) reduction in the probability that a marketplace was infected (Figure 7.17).
Table 7.3
Descriptive statistics on island level (identifying the number of infected and clinical pigs present and the probability a marketplace was infected) from an exposure assessment simulation for a typical live pig market considering pig movements from village-to-market and the risk of classical swine fever infection across Nusa Tenggara Timur province, eastern Indonesia.

<table>
<thead>
<tr>
<th>Island</th>
<th>Regions¹</th>
<th>No. Infected</th>
<th>No. Clinical Signs</th>
<th>P(Market Infected)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median (25&lt;sup&gt;th&lt;/sup&gt; and 75&lt;sup&gt;th&lt;/sup&gt; percentile)</td>
<td>Min, Max</td>
<td>Mean (25&lt;sup&gt;th&lt;/sup&gt; and 75&lt;sup&gt;th&lt;/sup&gt; percentile)</td>
</tr>
<tr>
<td>West Timor</td>
<td>1, 2</td>
<td>12 (8,16)</td>
<td>0, 39</td>
<td>11 (7, 15)</td>
</tr>
<tr>
<td>Flores</td>
<td>3, 4, 5</td>
<td>9 (4, 10)</td>
<td>0, 32</td>
<td>7 (4,10)</td>
</tr>
<tr>
<td>Sumba</td>
<td>6</td>
<td>12 (8,16)</td>
<td>0, 37</td>
<td>11 (7,15)</td>
</tr>
</tbody>
</table>

¹Regions are categorised into the following districts, 1: Kupang and Timor Tengah Selatan; 2: Timor Tengah Utara and Belu; 3: Flores Timur; 4: Sikka; 5: Manggarai Barat, Manggarai, Manggarai Tengah, Ngada, Nagekeo, Ende; 6. Sumba island (Sumba Barat, Sumba Timur, Sumba Barat Daya, Sumba Tengah).
Figure 7.10
Box plots of simulation results showing the number of pigs infected with classical swine fever virus at a typical live pig market in different regions of Nusa Tenggara Timur Province, eastern Indonesia (FT: Flores Timur; K/TTU: Kupang and TTU; Sik: Sikka; Smb: Sumba island; TTS/B: TTS and Belu; WestFlo: Western Flores districts); (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.11
Box plots of simulation results showing the number of clinical pigs with classical swine fever at a typical live pig market in different regions of Nusa Tenggara Timur Province, eastern Indonesia (FT: Flores Timur; K/TTU: Kupang and TTU; Sik: Sikka; Smb: Sumba island; TTS/B: TTS and Belu; WestFlo: Western Flores districts); (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Figure 7.12
Box plots of the number of clinical pigs at market by the probability infected pigs are displaying clinical signs for classical swine fever. The model assumes that pigs were sourced from West Timor, Nusa Tenggara Timur Province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.13
Box plots of the probability a marketplace had one or more infected pigs with classical swine fever by the sensitivity of inspection for pigs prior to entry into the market to detect disease. The model assumes that pigs were sourced from West Timor, Nusa Tenggara Timur Province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Figure 7.14
Box plots of the number of infected pigs at a live pig market by the sensitivity of vaccination coverage for classical swine fever given vaccine efficacy is set with a pert (0.60,0.75,0.85) distribution. The model assumes that pigs were sourced from West Timor, Nusa Tenggara Timur Province; (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.15
Box plots of the number of clinical pigs at a live pig market by the sensitivity of vaccination coverage for classical swine fever, given vaccine efficacy set with a pert (0.60,0.75,0.85) distribution. The model assumes that pigs were sourced from West Timor, Nusa Tenggara Timur Province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Figure 7.16
Box plots of the number of infected pigs with classical swine fever at a live pig market by the sensitivity of vaccination efficacy, given 100% vaccination coverage. The model assumes that pigs were sourced from West Timor, Nusa Tenggara Timur Province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.17
Box plots of the probability a marketplace has one or more pigs infected with classical swine fever by the sensitivity of vaccination efficacy given 100% vaccination coverage. The model assumes that pigs were sourced from West Timor, Nusa Tenggara Timur Province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
7.4 Model 2: Village-to-Village Model

7.4.1 Baseline Model

The village-to-village model was comprised of four modules: region, village, farm, and destination village (Figure 7.18). Based on data obtained through the market and farmer surveys, a scenario was developed to represent one month of pigs entering a typical village in NTT via informal movements. This involved five smallholder farmers from five different source villages bringing pigs into one destination village. Based on prevalence levels, the province was divided into regions, the same used for the village-to-market model (Figure 7.1). The model was able to account for the aggregation and mixing of animals and the change in volume of pigs at different points along the market chain.

From these processes, we were able to produce three outputs for the destination village:

1) The number of infected pigs entering the village.
2) The number of infected pigs displaying clinical signs of CSF.
3) The probability the village is infected based on the presence of one or more infected pigs.
7.4.1.1 Description of Modules

a. Region and Village Module

This model enabled pigs to be sourced from different regional levels from 1 through to 6. For example if we look at Figure 7.19, column $P(Purchased)$, pigs are only being sourced from region 6 (Sumba island). This parameter was able to be altered according to the scenario being simulated. The input parameters $P(Village Infected)$ and $P(Pig infected)$ were calculated using the same method as the village-to-market model (refer to section
7.3.1.1). For baseline simulations the vaccination coverage parameter, column $P(Vaccination)$, was not activated and will be addressed in section 7.4.2.3.

**Region and Village Module**

<table>
<thead>
<tr>
<th>Region</th>
<th>$P($Purchased$)$</th>
<th>$P($Village infected$)$</th>
<th>$P($Vaccination$)$</th>
<th>$P($Pig infected$)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0.791977545</td>
<td>0</td>
<td>0.13</td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>0.973561752</td>
<td>0</td>
<td>0.21</td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>0.790817383</td>
<td>0</td>
<td>0.08</td>
</tr>
<tr>
<td>4</td>
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<td>0.682168245</td>
<td>0</td>
<td>0.01</td>
</tr>
<tr>
<td>5</td>
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<td>0</td>
<td>0.04</td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td>0.944240162</td>
<td>0</td>
<td>0.28</td>
</tr>
</tbody>
</table>

Figure 7.19
One iteration of the region and village module with farmers from 6 different regions purchasing pigs to transport to another farm. In this scenario only pigs from region 6 (Sumba island) are being sourced.

**b. Village Module**

The village module consisted of five different villages from one of six regions. For each village there were two values simulated: the region, and the village infection status. The region values were drawn from a discrete distribution where the relative frequency of the regions was equal to the value entered for probability pigs were purchased from the region [i.e. $P($Purchased$)$]. The value could be altered according to the scenario being assessed. From the selection of the region, the infection status of a source village was then determined by taking a random draw from a binomial distribution where the number of trials was one and the relative frequency of infected villages was a beta distribution of the value entered into the $P($Village Infected$)$ column shown in Figure 7.19. The binomial distribution was used to account for variability of the input values. This then determined the infection status of a village, shown in column Village Infected in Figure 7.20.
**Farm Module**

- Average number of pigs in herd: 2
- $P(\text{Pig +ve} | \text{Village +ve & no vac})$: 0.05
- $P(\text{Pig +ve} | \text{Village +ve & vac})$: 0.01
- Vaccine efficacy: 0.8
- $P(\text{infected Pig Clinical})$: 0.67
- $P(\text{clinical | no vac})$: 0.67
- $P(\text{clinical | vac})$: 0
- % of herd sold: 0.3

<table>
<thead>
<tr>
<th>Farm id</th>
<th>Region</th>
<th>Village Infected</th>
<th>Vaccination</th>
<th>#Pigs per Herd</th>
<th>#Infected</th>
<th>#Clinical</th>
<th>#Pigs Going to Farm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>0</td>
<td>2</td>
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<tr>
<td>5</td>
<td>6</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 7.20
One iteration of the farm module from the village-to-village model with 5 farmers from 5 different villages contributing 30% of their herd for transport to another farm. As only one farmer from each village is transporting pigs, the herd is equivalent to the number of pigs leaving a single village.
c. Farm Module

Referring to Figure 7.20, the Region column represented the region from which pigs were being sourced and this was done using a random draw from a discrete distribution from the region module. The baseline model sourced pigs from Sumba island (region 6). The column, Village Infected, represented whether a village from a selected region was infected. The farm module followed the village module and inputs are addressed in section 7.4.2. The number of pigs in a herd (column # Pigs per Herd) was calculated using a discrete distribution; details of calculation are shown in section 7.3.1.3, part b. The number of clinical pigs (column #Clinical) was calculated using equation 7.4. The number of pigs being transported to another farm (column #Pigs Going to Farm) was calculated using equation 7.5.

\[ N_{\text{Infected}} \times P(\text{Infected Pig Clinical}) \] ……………………Equation 7.4

\[ N_{\text{pigs per herd}} \times \text{Proportion of Herd Sold} \] ……………………Equation 7.5

7.4.2 Inputs for Baseline

7.4.2.1 Region Module

This value represented the probability of a pig being purchased was from one of six regions. These values varied according to the scenario being assessed, allowing targeted sourcing from different regions.

7.4.2.2 Region and Village Module

The region/village module was made up of five input parameters incorporating village and herd information obtained from several data sources.

a. Probability Village Infected: P(Village Infected)

These values were determined through use of results from the seroprevalence survey (ACIAR Project AH/2006/156, 2010). Villages with at least one infected pig were considered infected. A beta distribution was used and values were the same as used in the village-to-market model in Table 7.1.
**b. Probability Pig Infected: P(Pig Infected)**

This input parameter used the same calculations as the village-to-market model using a pert distribution (refer Table 7.2).

**c. Proportion of Herd Exit: (% of Herd Exit)**

This input parameter used the same calculations as the village-to-market model to identify the proportion of a herd exiting (refer to section 7.3.1.3, part c).

**d. Average Number of Pigs in Herd**

This input parameter used the same calculations as the village-to-market model using a discrete distribution (refer to section 7.3.1.3, part b).

### 7.4.3 Alternative Scenarios

#### 7.4.3.1 Different Villages and Regions

The model was able to simulate data for different regional scenarios. This was done by changing input values; specifying the proportions of pigs purchased from different regions. For alternative scenario simulations and sensitivity analysis conducted on mitigation measures, pigs were sourced only from region 6 (Sumba island). This region had the highest seroprevalence levels of CSFV and as such was selected to model the worst case scenario.

#### 7.4.3.2 Pre-Entry Village Inspection

The pre-entry village inspection module was incorporated to assess the impact of inspection of pigs on entry to a village as a mitigation strategy (Figure 7.21). It was incorporated into the model through the addition of a new module. The calculations were the same as those used for the pre-entry market inspection in the village-to-market model (refer to section 7.3.2.2). It considered that if an infected pig with clinical signs was detected in a consignment on village entry, the whole group would be rejected and not allowed into the village. The module was comprised of several input parameters including:

**a. Probability Clinical Signs were Present**

The same calculations as the village-to-market model were used with a value of 0.67 (refer to section 7.3.1.3, part d).
b. Probability Clinical Signs were Present Given Vaccination Occurring

A value of zero was used to model the worst case scenario, same as the village-market model.

c. The Probability of Detection of an Infected Pig on Village Entry

This input incorporated a detection parameter to assess the impact of inspection of pigs prior to village entry. This parameter considered that if a clinically infected pig was detected, the infected pig and remaining pigs in the consignment would be rejected and not permitted entry into the village. This value was assessed with sensitivity analysis to observe its impacts as a mitigation strategy.

7.4.3.3 Vaccination Coverage and Efficacy

This parameter was incorporated into the village module in the same manner as the village-to-market model in which sensitivity analysis was conducted on vaccination coverage and efficacy (section 7.3.2.3).

7.4.4 Sensitivity Analysis

Sensitivity analysis was conducted in the same manner as the village-to-market model (refer to section 7.3.3).

The following parameters were assessed with sensitivity analysis:

1) Probability pigs were from different regional locations – different scenarios were simulated with pigs being sourced from 1 to 6 regions.

2) Vaccination coverage \([P(\text{Vaccination})]\) – this parameter was investigated with values ranging from 0 to 1.

3) Vaccination efficacy \([\text{Vaccine Efficacy}]\) this parameter was assessed using efficacy values from 0.6 to 1 (taking into consideration expert opinion).

4) Probability of infected pigs detected on entry to village \([P(\text{Detecting infected pig})]\) – this parameter was investigated with values ranging from 0 to 1.

5) Probability infected pig displaying clinical signs \([P(\text{Clinical signs present})]\) – this parameter was investigated with values ranging from 0.5 to 0.8.
Figure 7.21
Village-to-village model structure (informal movements) with modules and mitigation strategies for an exposure assessment; likelihood of classical swine fever virus transmission through the live pig market chain in Nusa Tenggara Timur province, eastern Indonesia.
### Inspection Prior to Village Entry

<table>
<thead>
<tr>
<th>Farm id</th>
<th>#Infected/Herd</th>
<th>#Clinical/Herd</th>
<th>P(Detection)</th>
<th>P(Infect</th>
<th>#Transported</th>
<th>#Infected transported</th>
<th>#Clinical</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0.7</td>
<td>0.3</td>
<td>2</td>
<td>1</td>
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<tr>
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<td>0</td>
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<td>0</td>
<td>1</td>
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<td>0</td>
</tr>
<tr>
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<td>1</td>
<td>1</td>
<td>0.7</td>
<td>0.3</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>0</td>
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<td>1</td>
<td>0</td>
<td>0</td>
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<tr>
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<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Figure 7.22
One iteration of the pre-entry village inspection module from the village-to-village model with 5 farmers from villages transporting pigs to another farm where pigs displaying clinical signs were rejected.
7.4.5 Results

7.4.5.1 Baseline Results
The village-to-village model was run initially to generate baseline information on a typical village in Nusa Tenggara Timur province. Both island and region level information was obtained. It was found that a destination village in Sumba had a higher probability of being infected compared to one in Flores ($P < 0.001$). Moreover, a greater number of infected and clinical pigs were identified at a destination village in Sumba. Flores was found to have the lowest average values for all risk outputs (Table 7.4). At the regional level, region 2 (TTS and Belu) and 6 (Sumba) had the highest number of infected pigs entering a village (Figure 7.23). The number of clinical pigs did not vary when sensitivity analysis was conducted on the probability a pig displayed clinical signs ($P = 0.10$; Figure 7.24). Likewise with increasing probability that clinical signs were displayed, no significant difference was detected for the number of infected pigs entering a village or the probability that a village was infected ($P = 0.08$ and $P = 0.18$, respectively).

7.4.5.2 Pre-entry Inspection at the Village
When pigs were sourced only from typical villages in Sumba, it was found that pre-entry inspection at the village level significantly ($P < 0.001$) reduced the probability of a destination village being infected (Figure 7.25). This mitigation strategy also required a very strict procedure for it to be beneficial, similar to findings at the market level. With fewer pigs entering a village it would be possible to visually inspect all pigs.

7.4.5.3 Vaccination Coverage
With increased vaccination coverage, a reduction in the number of infected and clinical pigs was observed ($P > 0.001$; Figures 7.26 and 7.27). A significant reduction in the probability a village was infected was also detected ($P < 0.001$; Figure 7.28).

7.4.5.4 Vaccination Efficacy
Sensitivity analysis demonstrated that with improved vaccine efficacy, a significant ($P < 0.001$) reduction in the number of infected pigs entering a village was observed (Figure 7.29). With vaccination coverage at 100%, it was found that a vaccine efficacy $> 70\%$ was needed to notably reduce the probability that a village was infected (Figure 7.30).
Table 7.4
Descriptive statistics calculated from an exposure assessment simulation for typical villages in West Timor, Flores and Sumba (number of infected and clinical pigs present and the probability that a village was infected) considering pig movements from village-to-village and the risk of classical swine fever infection across Nusa Tenggara Timur province, eastern Indonesia.

<table>
<thead>
<tr>
<th>Island</th>
<th>Regions</th>
<th>No. Infected</th>
<th>No. Clinical</th>
<th>P(Village Infected)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Median (25th and 75th percentile)</td>
<td>Min, Max (25th and 75th percentile)</td>
<td>Median (25th and 75th percentile)</td>
</tr>
<tr>
<td>West Timor</td>
<td>1, 2</td>
<td>1.24 (0.2)</td>
<td>0.6</td>
<td>1.16 (0.2)</td>
</tr>
<tr>
<td>Flores</td>
<td>3, 4, 5</td>
<td>0.44 (0.1)</td>
<td>0.4</td>
<td>0.43 (0.1)</td>
</tr>
<tr>
<td>Sumba</td>
<td>6</td>
<td>2.06 (1,3)</td>
<td>0.7</td>
<td>1.84 (1,3)</td>
</tr>
</tbody>
</table>

1Regions are categorised with the following districts, 1: Kupang and Timor Tengah Selatan; 2: Timor Tengah Utara and Belu; 3: Flores Timur; 4: Sikka; 5: Manggarai Barat, Manggarai, Manggarai Tengah, Ngada, Nagekeo, Ende; 6. Sumba island (Sumba Barat, Sumba Timur, Sumba Barat Daya, Sumba Tengah).
Figure 7.23
Box plots of baseline simulation results showing the number of infected pigs, with classical swine fever, entering a village in different regions of Nusa Tenggara Timur province, eastern Indonesia (FT: Flores Timur; K/TTU: Kupang and TTU; Sik: Sikka; Smb: Sumba island; TTS/B: TTS and Belu; WestFlo: Western Flores districts); (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.24
Box plots of the number of clinical pigs entering a village by the probability an infected pig with classical swine fever is displaying clinical signs. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Figure 7.25
Box plots of the probability a village was infected with classical swine fever by the sensitivity of pre-entry village inspection for pigs. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.26
Box plots of the number of infected pigs entering a village by the sensitivity of vaccination coverage for classical swine fever given vaccine efficacy is set with a pert(0.60,0.75,0.85) distribution. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Figure 7.27
Box plots of the number of clinical pigs entering a village by the sensitivity of vaccination coverage for classical swine fever given vaccine efficacy is set with a pert (0.60,0.75,0.85) distribution. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.28
Box plots of the probability a village was infected with classical swine fever by the sensitivity of vaccination coverage given vaccine efficacy is set with a pert (0.60,0.75,0.85) distribution. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Figure 7.29
Box plots of the number of infected pigs entering a village with classical swine fever by the sensitivity of vaccination efficacy given 100% vaccination coverage. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).

Figure 7.30
Box plots of the probability a village was infected with classical swine fever by the sensitivity of vaccination efficacy given 100% vaccination coverage. The model assumes that pigs were sourced from Sumba island, Nusa Tenggara Timur province, eastern Indonesia; (box representing range from the 25th and 75th percentiles with the bold line representing the median).
Modular structured models were constructed to assess the effects of mitigation strategies on classical swine fever infection using common scenarios occurring along the live pig market chain in NTT. These models also enabled the generation of estimates and baseline information for markets and villages within NTT province.

For the village-to-market model, baseline risk estimates were found to be high both at the regional and island levels. Similarly baseline risk estimates from the village-to-village model were high at regional and island levels. By conducting sensitivity analyses on the mitigation measures being assessed, pre-entry inspection and vaccination, we were able to gain some insight into appropriate risk management strategies for CSF within NTT province.

7.5.1 Pre-Entry Inspection

Pre-entry inspection, when strictly implemented with rejection of the whole consignment on detection of one infected pig with clinical signs, was the most effective strategy to reduce the likelihood of market infection and of village infection. Due to the highly contagious nature of this disease, stringent regulations are needed for this approach to be most effective. However there would be challenges with implementation. Inspection for clinical signs to detect CSF will at best, based on the evaluation of clinical signs as a diagnostic tool during an epidemic by Elbers et al. (2002), achieve sensitivity of 72.0% and specificity of 52.7%. With this level of specificity, the issue of false positives particularly needs to be considered as pigs displaying clinical signs that are rejected will not necessarily have CSF. The potential benefit in this case will be to reduce spread of other infectious diseases that cause clinical signs similar to CSF. While inspection alone can lead to improvements in the health of animals presented, as reported for poultry exhibited at fairs and shows in Colorado following the introduction of poultry health inspectors (Bradley, 2007), for markets in NTT compliance with inspection could be aided by higher sale prices paid in the market based on presentation of healthy pigs for sale. Further research is needed in this area to identify techniques that would be appropriate in this cultural setting.

From the observational study it is known that sellers trade pigs at sites outside the marketplace, thus rejected consignments with clinical pigs will likely still be traded and
CSFV spread along the market chain proceed despite inspection. In this context, farmer education is imperative to sustain benefit for buyers purchasing pigs in the market at a premium price. To reduce the chance of infection on route when leaving the market, buyers should be encouraged to use transportation that minimises mixing with other pigs, such as ojeks. The large numbers of pigs entering a market per day poses a logistic challenge for inspection as does the present physical structure of most markets that allows access via multiple points at any time day and night. Infrastructure changes will be needed to permit examination of pigs at the market entrance to determine health status before entry. The fact that no sick pigs and only one dead pig were recorded during the market observational study (Chapter 4) indicates that visual inspection of the large number of pigs present at a market is not easy. In this work the observer (E.E.C.L.) was only able to undertake a brief external observation of pigs due to the relatively quick movement of sellers and buyers exiting market sites quickly after a trade transaction.

For a village, the smaller numbers of pigs arriving provides opportunity for village-level biosecurity including inspection to be implemented. Inspection with rejection of consignments that have a clinical pig will require a procedure to deal with infected consignments such as slaughter of the pig/s outside the village and no swill feeding. Furthermore during months when traditional ceremonies or events take place, large numbers of pigs may be entering a village and procedures will need to be able to accommodate higher numbers. For this mitigation approach, the role of farmer education is evident. Through the implementation of education programs, significant improvements in farmer knowledge and attitudes to animal health and biosecurity has been demonstrated for village poultry in Tanzania (Msoffe et al., 2010) and cattle raising in Cambodia (Nampanya et al., 2011). By providing education on a community level and involving pig farmers directly, the development of village-level biosecurity is possible and the higher risk periods when larger pig numbers are present could be targeted for education activities to raise awareness and to ensure appropriate procedures are in place.

7.5.2 Vaccination

For each of the two models, increased vaccination coverage and increased vaccine efficacy separately led to a reduction in the probability of a market or village being infected. The trends seen in the village-to-market model in response to different assumed vaccination coverage levels and vaccine efficacies are more useful for decision making compared to the village-to-village model. This is due to limitations of smaller pig numbers being
modelled in the village-to-village model making parameters very sensitive to change. For countries where CSF is endemic, control based on the use of vaccination and mitigation measures such as movement control are recommended to avoid serious losses (Edwards et al., 2000; Moennig, 2000). In order to eradicate CSF from a pig population, transmission of the virus needs to be reduced to an extent where it can no longer survive and be maintained within the population (Schnyder et al., 2002; Weesendorp et al., 2010a). Results from the Alor project (Robertson et al., 2010b) have suggested that high levels of vaccination coverage with an efficacious vaccine can be a successful component of a control program in the province combined with farmer education and animal movement management. The finding of the vaccine trial on Alor that identified lower efficacy for government distributed Hogsivet vaccine directed the decision of the district government to purchase an internationally produced vaccine for control on Alor (Robertson et al., 2010b). The model assumption that the market or village location was initially free of CSFV is not likely to be the case in the field. Moving forward with the implementation of a control program under these circumstances requires a combination of strategies to be put in place involving both education and biosecurity. A vaccination program will require involvement by various parties including DLS and NGOs to ensure adequate personnel to meet cold chain requirements and high coverage levels. Moreover, the use of vaccination does not eliminate infection, with clinical signs in vaccinated pigs often becoming less pronounced (Uttenthal et al., 2001). The assumption of no clinical signs in vaccinated pigs in this model was to reflect the worst case scenario of complete inability to detect infected, vaccinated pigs due to absence of any clinical signs.

Cold chain issues can affect the efficacy of live vaccines, such as the CSF vaccine. In countries that have hot climates with inadequate cooling equipment (often the case in developing countries), vaccine potency can be compromised (Wirkas et al., 2007). The lack of thermostability for many vaccines can also result in high recurrent costs during vaccination campaigns. This arises from issues such as refrigeration and temperature maintenance during transport, as was seen during the 1990s with the Rinderpest vaccination campaigns (Mariner et al., 1990). Vaccination can further hinder alternative mitigation strategies such as inspection. Clinical signs in pigs vaccinated for CSF are often less pronounced, making detection more difficult (Backer et al., 2009).
7.5.3 CSF Prevalence

CSF prevalence is an important factor in the two models. For this work, NTT province was divided into prevalence regions based on results from the seroprevalence survey (ACIAR Project AH/2006/156, 2010). The exceptions to this were region 3 and region 5. For region 3, the lower prevalence estimate used based on expert opinion, in comparison to Santhia et al. (1999), will have lowered the number of infected pigs and the probability of being infected. The lower prevalence for region 5 western Flores has influenced the results with market and village locations drawing pigs from this region having lower numbers of infected pigs and a lower probability of being infected. The reasons for some samples testing positive for CSFV antibodies in Kab. Manggarai Barat obtained by the ACIAR Project AH/2006/156 (2010) are still under investigation. Re-testing with the 2nd generation ELISA should have eliminated the potential for false positives due to cross-reaction with antibodies to other pestiviruses. As the level of positives for Kab. Manggarai Barat conflicted with prior knowledge, it was considered appropriate to reduce the prevalence for region 5 at this stage. When more information is available to inform parameterisation of regional prevalence the model can be re-run with new prevalence input values. Moreover, the small sample size of 4–6 villages per district over seven districts may limit the accuracy of the results.

Consideration of CSF prevalence at a region level does not reflect differences between districts and subdistricts; however this model structure allowed for the development of targeted mitigation strategies. Due to the limited resources in NTT, it may not be possible to apply mitigation measures across the entire province thus information on areas that may be higher risk is useful to guide decision making on control strategies and where best to implement them.

7.5.4 Model Evaluation and Limitations

There are limitations to simulation modelling due to the uncertainty surrounding input parameters and the factors considered in a model (Clifford et al., 2011; Harvey et al., 2007; Jones et al., 2004). Results from simulation models should be incorporated with other data and information sources to guide decision making and ensure the development of the most effective control strategies for a given context. When evaluating model outputs focus should be placed on the trends observed within results rather than specific values to give an indication of baseline levels and the effectiveness of mitigation measures (Clifford et al., 2011). For these models, we purposely investigated the worst case scenario in which
pigs are transported from different districts and considered as a consignment on arrival at the market or village. This will help to direct thinking about the formation of CSF control planning.

In addition to the mitigation strategies assessed, it needs to be acknowledged that there are alternative strategies to reduce CSFV transmission among pigs that were not investigated. Minimal biosecurity is practised both at the market and village level in NTT (refer to Chapters 3 and 5: market and farmer surveys). There are a variety of different biosecurity measures that can be used on the farm and at the market in addition to inspection (FAO, 2010). The models focussed on the introduction of CSF to a location, therefore the most pertinent biosecurity measure in this context was prevention of infected pig entry. Other biosecurity measures often relate more to reducing virus levels once a premise is infected.

Farmer education has been used as a mitigation strategy to assist in disease control. However, farmer education levels are difficult to quantify; and improved knowledge may not equate to implementation of biosecurity actions thus it is challenging to produce an appropriate input value. For example, Caro III et al. (2010) found that for some farmers in the Greater Mekong, although they recognised the need to control and eradicate transboundary diseases, they did not see this to be an urgent need. Development programs have supported the need for improved farmer education regarding biosecurity and animal health to achieve improvements in public health and animal disease control (Bagust, 1994; Nampanya et al., 2011; Thorpe & Jemaneh, 2008).

The model assumed that the latent period was ≥ 2 day, based on a conservative estimate from the literature and expert opinion. Therefore, it was decided a Susceptible-Infected-Recovered (SIR) model to simulate transmission occurring among pigs in a consignment would not be incorporated in either model. For the majority of pig movements by farmers, transportation was estimated to occur across a maximum 24–36 hour period. This was based on SNA results identifying pig movement distances (Chapter 6) and data from Patunru et al. (2010) taking into account waiting time at the port and on ferry, the time it would take for the sea crossing and for additional land travel. With transportation time being less than two days (less than the latent period), CSFV transmission amongst pigs during transportation was not considered in the model because it would not increase the number of clinical pigs arriving at a village or market. It should be noted; however, that due to this decision, both models underestimate the number of infected pigs.
It also needs to be noted that these models have only addressed live pig movement. It has been confirmed through many studies that CSFV can be spread through indirect routes including swill feeding (Dewulf et al., 2000), artificial insemination (De Smit et al., 1999; Floegel et al., 2000) and contaminated fomites (Boklund et al., 2008). From the market and farmer surveys it was determined that inter- and intra-island movement are driven by a high demand for live pigs. Direct contact between live pigs has been shown to be the most effective transmission route for CSFV (Weesendorp et al., 2010a). Live animal markets and free roaming housing systems are important risk factors for disease spread in the smallholder sector (Costard et al., 2009a; FAO, 2011). As the risk of CSFV transmission through the live pig market chain has not been investigated previously in NTT, the decision to model only live pig movement aligned with the aim to obtain information on the highest risk pathways to enable comparisons and support decision making on control strategies. Further, although an annual pattern for pig movements in NTT is known (Chapter 3), these models did not consider seasonal variation in pig movements.

The assumption that pigs were equally susceptible to CSFV has meant that breed and age variations were not accounted for. The parameters used within the models to estimate the infectious, latent and clinical periods of pigs were derived from current literature, which may not replicate field conditions in NTT. To date, no studies have been conducted on the indigenous pig breeds in Indonesia for CSF infection. Blacksell et al. (2006), Depner et al. (1997), Artois et al. (2002) and Everett et al. (2011) have investigated the pathogenesis and clinical course of CSF in indigenous pig breeds from Lao PDR, white pig breeds, wild European boar and native South African pigs, respectively. It was determined that the indigenous Lao PDR breeds infected with CSF experienced longer survival rates (Blacksell et al., 2006). It should also be considered that less virulent strains often produce mild disease or asymptomatic infection, with the potential to delay disease detection (Boklund et al., 2008). Age group variations for CSF infection and disease progression have been confirmed in the literature, with younger pigs often experiencing the acute form of disease and clinical signs being less obvious and death less frequent in old pigs (Artois et al., 2002; Moennig et al., 2003). This model could be modified to assess differences between each age group; however, due to time constraints, pigs were considered equally susceptible to CSFV. Moreover, only the acute form of CSF has been recorded in wild pigs and what is known regarding the processes of CSF infection in wild pigs for different age groups is limited (Artois et al., 2002).
As NTT province is an archipelago and pigs are in such high demand, live pig movements will continue to play a major role in disease transmission until effective control measures can be implemented. Control of CSF can be assisted through the establishment of village-level biosecurity programs incorporating pig inspection, vaccination and animal movement management. Training and capacity building involving local village leaders and addressing issues faced by local smallholder farmers will increase the chances of success of animal health programs (Msoffe et al., 2010). This exposure assessment has identified mitigation strategies for potential implementation at various stages along the market chain to reduce CSF transmission. Future investigations need to be conducted to trial these strategies and to assess whether it is feasible to effectively implement them in Nusa Tenggara Timur province.
Chapter 8: Effective Surveillance Strategies
Following a Potential Classical Swine Fever Incursion in a Remote Wild Pig Population in Northwestern Australia

8.2 Introduction

The choice of surveillance and control strategies can substantially influence the outcome of an infectious disease incursion (Klinkenberg et al., 2005). The ability to detect infection and to prove disease freedom influences decision making. Factors such as domestic and international trade, economic and social loss, and public health need to be considered (Boklund et al., 2008; Domenech et al., 2006; Thulke et al., 2009). Surveillance methods can be evaluated and improved by the use of disease spread models. Such models, which incorporate important disease spread parameters, can be used to map potential outbreaks and evaluate the effectiveness of surveillance and control strategies (Willeberg et al., 2011). Models have been developed to simulate outbreaks of important transboundary animal diseases (TADs) – such as foot-and-mouth disease (FMD) and classical swine fever (CSF) – to assist in preparedness planning for policy formulation, decision making and economic impact assessments (Harvey et al., 2007). Garner et al. (2007) suggested that models are most useful prior to an outbreak to allow for contingency and resource planning, risk assessment and appropriate training in anticipation of such a disease incursion event.

More than 60 countries have reported one or more outbreaks of CSF to the World Animal Health Association (OIE) during the last 15 years (Donahue et al., 2011). The highly contagious nature of the CSF virus and its ability to spread rapidly within both domestic swine and wild pig (Sus scrofa; both feral pigs and wild boar) populations has substantial economic and social impacts (Donahue et al., 2011; Meuwissen et al., 1999). Since its eradication in 1961, Australia has maintained its CSF-free status through the establishment of biosecurity policies implemented by organisations such as the Australian Quarantine and Inspection Service and its Northern Australia Quarantine Strategy (AQIS, 2005). An outbreak of CSF in Australia would have devastating impacts on the pig industry with serious productivity effects and trade impacts through local movement restrictions and loss...
of export markets (Animal Health Australia, 2009). The close vicinity of countries in south east Asia where CSF is endemic poses a risk for the reintroduction of the disease into Australia. The Indonesian islands in Nusa Tenggara Timur (NTT) province represent the closest area to Australia (Western Australia) where CSF occurs, with parts of NTT being endemically infected with CSFV. To support emergency preparedness, an Australian Veterinary Emergency Plan Disease Strategy for Classical Swine Fever has been prepared and provides guidelines for control and post-outbreak surveillance in the event of an outbreak (Animal Health Australia, 2009).

A variety of diagnostic tests are available for CSF. Virus isolation in cell culture is considered the ‘gold standard’ diagnostic tool for CSFV (Moennig, 2000). Alternative detection methods including enzyme-linked immunosorbent assays (ELISAs) (Greiser-Wilke et al., 2007; Koppel et al., 2007) and polymerase chain reaction (PCR) assays (Greiser-Wilke et al., 2007) have been developed. Serosurveillance has been used as a diagnostic tool for monitoring both wild boar and domestic pig populations (Elbers et al., 2000; Suradhat et al., 2007). However, for early detection of CSF in previously disease-free populations, Crauwels et al. (1999) found that the probability of detecting an epidemic in its early stages (within forty days of introduction) was low using an antibody ELISA test.

CSF in wild pigs has been a recognised source of infection for many domestic pig outbreaks (Fritzemeier et al., 2000; Lipowski, 2003). For example, in Germany during the 1990s Fritzemier et al. (2000) determined that 59% of CSF-index cases were a result of infected wild boar populations. The wild pig is an invasive species in Australia that impacts on agricultural land and the environment while also competing with native and domestic animals for food and water (Cowled et al., 2008; Spencer et al., 2005). Their actual and potential role as a disease reservoir for infections such as CSF, brucellosis, swine vesicular disease and porcine reproductive and respiratory syndrome (PRRS) has been recognised (Montagnaro et al., 2010; Wyckoff et al., 2009). In Australia, the wild pig population is predominantly distributed throughout the eastern and northern regions of the country (West, 2008). Studies have suggested that wild pig group structures consist of female groups and solitary boars (Spencer et al., 2005). This social organisation will influence disease transmission between groups. Population connectivity is also important in influencing both disease spread and the persistence of CSFV in a region (Cowled et al., 2012; Siembieda et al., 2011).
Recognising the role that wild pigs in northern Australia might play in a potential incursion of CSF, this study was undertaken to explore appropriate surveillance strategies in the event of a potential CSF incursion involving wild pigs. Specifically the aim was to analyse simulated CSF outbreaks in a wild pig population in the Kimberley region of northwestern Australia to determine the effectiveness and efficiency of different surveillance strategies – including random surveillance and two targeted methods of surveillance – to detect and delineate infection.

### 8.3 Methods

#### 8.3.1 Model Description

A model developed by Cowled *et al.* (2012) was used to simulate wild pig inter-group CSF spread in time and space following an incursion in the Kimberley region, located within the state of Western Australia in northwestern Australia (Figure 8.1). This region is located approximately 900 km southeast of NTT province, Indonesia. Within the Kimberley region, the Fitzroy River area was selected as a representative wild pig population for potential disease introduction (Cowled *et al.*, 2012). The disease spread model was coded in MapBasic® and output data was generated in MapInfo® Professional Version 10.5 (Release Build 15, Pitney Bowes Software, Inc). It has been described previously (Cowled *et al.*, 2012).

The population data set used in the model was derived from the wild pig biology and ecology literature. The total number of functional pig groups simulated in the model was 5,304. This number was generated using several data sources. Questionnaire surveys conducted by Cowled *et al.* (2009) and Woolnough *et al.* (2004) obtained information on pig distribution and densities. Results demonstrated that pigs were found across approximately 26,000 km² of the Kimberley region. A ‘core’ habitat of 16,701km² was then identified and divided into polygons, classified as having low, medium or high pig densities. Published literature was then used to extract density and population parameters to use in the model, providing an estimate for the number of pig groups present within the region (see Cowled *et al.* 2012 for details).

The model included factors likely to be important in disease spread, including pig density and movements, group, age, social structure and the population distribution and habitat connectivity (Cowled *et al.*, 2012). The epidemiological unit is the herd, and all parameters used are herd parameters. This inter-herd model explicitly includes movements and
dispersal of herds (including individual boars – which are also a herd type). To parameterise this interherd CSF model we constructed an intra-herd model (Cowled et al., 2012) in which birth and natural mortality was explicitly included. By sampling these intraherd derived parameters as probability distributions we stochastically captured information on natural births and deaths in the interherd model.

Population parameters used in the model are shown in Table 8.1 – in which both group types (solitary boars and female groups) are considered. Each group in the model was allocated a point location and an annual home range. The model is dynamic with pig groups able to move within their annual home range. Where applicable, a Monte Carlo method was used to place probability distributions around input parameters to account for uncertainty and variability (Table 8.1). Specific details for these model distributions can be seen in Cowled et al. (2012). In brief, epidemiological and ecological parameters were derived mostly from the published literature. Latent and immune periods were incorporated as uniform distributions (5 to 9 and 88 to 475 days, respectively) and infectious period as a triangular distribution (low, estimate, high 15, 27 and 42 days, respectively). Herd size was represented as a beta-pert distribution (7, 45, 5). The remaining ecological parameters (home range, daily home range and daily home movements for both males and females) were represented as triangular distributions). For more details, see Cowled et al. (2012), Tables 8.1 and 8.2.

![Figure 8.1](image_url)

Figure 8.1
Wild pig group distribution in the Kimberley region Western Australia. Map obtained from Cowled et al. (2011). The inset identifies the location of the Kimberley region in Western Australia. Red dots represent pig groups simulated within known wild pig distributions. The green arrow identifies the introduction site for classical swine fever for all simulations.
The model was used to simulate CSF outbreaks based on a range of feasible scenarios. The spread of CSF could be investigated with or without surveillance or control strategies by altering model settings. A highly virulent CSF strain was assumed in the model. Several surveillance techniques including radial and leapfrog sampling (defined below) were incorporated in the model. In this extensive and remote region of Australia, aerial surveillance is the only feasible option for disease surveillance. To implement surveillance and control, a 10km x 10km grid was overlayed on the study area with surveillance and control targeted to grid cells. Individual grid cells contained a variable number of pig groups, depending on local population densities. The model included a lag period of three days following detection of infection before surveillance would begin to account for the time required to assemble resources and organise the response. Finally, control options were coded into the model whereby culling or vaccination could be implemented in the event of CSF being found. Control operations involved population reduction through shooting or aerial poison baiting (Animal Health Australia, 2009). If surveillance and control were both used in a simulation, surveillance was done first to delineate the affected area, and was followed by control. Parameter values were selected based on local knowledge of the authors of this unique study area. Key assumptions used for the modelling included:

- population size of the study area was 5,304 groups under the assumption of 1–3 pigs/km² (Cowled et al., 2012).
- three helicopters available for surveillance.
- four helicopters used for control.
- expected number of 40 pig groups to be surveyed per team per day.
- an infected group would have a minimum prevalence of 50%. A minimum of 5 pigs would be sampled per group which would provide 95% confidence of detecting disease in larger groups.

Important baseline outputs considered in this study include the number of susceptible, latent, infectious, immune and dead pig groups. It was assumed that once a group was classified as immune it no longer contributed to spread of infection. Epidemic length was used to compare different simulation scenarios. In addition, when surveillance was simulated, the number of days to complete the surveillance (i.e. to delineate the area containing affected pig groups) and the number of cells sampled were used as output metrics. Where disease control was included in a simulation the total area covered (km²)
from beginning of surveillance to completion of control was used to compare effectiveness of the surveillance strategies. For further model details refer to Cowled et al. (2012).
Table 8.1
Ecological parameter values and distributions used in a between-group model of classical swine fever spread in the Kimberley region of Western Australia.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
<th>High</th>
<th>Low</th>
<th>Probability Distribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group size(^2)</td>
<td></td>
<td>7</td>
<td>45</td>
<td>5</td>
</tr>
<tr>
<td>Pig density (km(^2))</td>
<td></td>
<td>1–3</td>
<td>...</td>
<td>3.7</td>
</tr>
<tr>
<td>Male home range (km(^2))</td>
<td></td>
<td>12</td>
<td>31.2</td>
<td>3.7</td>
</tr>
<tr>
<td>Female home range (km(^2))</td>
<td></td>
<td>7</td>
<td>19.4</td>
<td>2.5</td>
</tr>
<tr>
<td>Male daily home range (km(^2))</td>
<td></td>
<td>1.5</td>
<td>9.99</td>
<td>0.2</td>
</tr>
<tr>
<td>Female daily home range (km(^2))</td>
<td></td>
<td>0.9</td>
<td>3.6</td>
<td>0.06</td>
</tr>
<tr>
<td>Male daily linear movements (km(^2))</td>
<td></td>
<td>1</td>
<td>2</td>
<td>0.1</td>
</tr>
<tr>
<td>Female daily linear movements (km(^2))</td>
<td></td>
<td>0.7</td>
<td>1.8</td>
<td>0.1</td>
</tr>
</tbody>
</table>

\(^1\) Cowled et al. (2012); \(^2\) 12% of groups were assumed solitary male boars and the remaining distributed into female groups.
8.3.2 Model Application

An example of a typical simulated epidemic curve for CSF in the study region is shown in Figure 8.2. Using this model, two different approaches were taken to investigate disease surveillance. Approach 1 determined the minimum number of groups required to be sampled to detect disease following a CSF incursion. Approach 2 compared the effectiveness of three different surveillance techniques—simple random sampling (SRS), radial sampling and leapfrog sampling—in detecting and delineating CSF infection. For both approaches the probability of detection of infection was compared at day 42 (6 weeks), 168 (6 months) and 365 (1 year) post-incursion. These time points were selected to demonstrate the extent of a CSF outbreak following likely delays in disease detection.

Hone and Pech (1990), using a model to investigate FMD spread, estimated minimum time to detection of a FMD outbreak (sample size of 100) to be 35 days. Cowled et al. (2012) used similar estimates (minimum of 42 days for disease detection). For clarity, when a reference is made to infected pigs this should be interpreted as latent, infectious and immune groups of pigs. It was assumed that the detection of CSF index groups was via passive surveillance (clinical signs, which in the extensive study area might be seen as 'die-off' events observed and reported by land owners). Latently-infected and infectious groups could be detected via PCR assays (in conjunction with clinical signs in the latter case) and immune groups via serology (Greiser-Wilke et al., 2007).
Figure 8.2
An epidemic curve (without implementation of surveillance and control) for a simulated classical swine fever outbreak simulation in wild pigs in the Kimberley region, Western Australia.

8.3.3 Approach 1: Detecting Disease Following CSF Incursion

Approach 1 modelled a CSF outbreak assuming a single entry point in a high pig density area within the study region, with no control measures implemented (i.e. a baseline scenario). The model was simulated 100 times and surveillance was conducted at 42, 168 and 365 days post incursion within this set of 100 simulations to determine the extent of CSF spread. Comparisons were then made between these time points (42, 168 and 365 days) to determine the success of a random surveillance strategy to detect infection. The model was simulated at the group level. The number of groups were dependant on population densities and an assumed mean size of approximately seven pigs per group (Cowled et al., 2012). At each time point for each simulation, a simple random sample of 290 groups was selected according to a standard sample size calculation to detect disease with a 95% confidence level, assuming 1% group prevalence and a finite population (Thrusfield, 2007). Groups were selected using a random number generator (Hood, 2011). The same random group sample was used for all simulations and time points to allow comparisons to be made across the different sampling time points.

8.3.4 Approach 2: Comparisons between Surveillance Techniques

Approach 2 allowed the comparison of surveillance techniques – simple random sampling, radial sampling and leapfrog sampling – that could be implemented in the event of a CSF incursion. Simulations were run until the end of an outbreak (i.e. until the end of
surveillance and control, when no further latent or infectious groups were present). Comparisons were made for each surveillance technique implemented following disease detection at three time points (42, 168 and 365 days post-incursion) to determine their effectiveness in detecting and delineating disease in a control response based on output metrics of surveillance length, number of cells sampled during surveillance, epidemic length and outbreak area (km$^2$). It was assumed that disease control, in the form of animal culling, would be applied in response to CSF detection. Culling was implemented following the completion of surveillance.

8.3.4.1 Simple Random Sampling (SRS)
A scenario was generated using SRS as the surveillance technique. The model was simulated 100 times and 15 simulations were randomly selected for comparisons between each time point. At each time point the spread of CSF within these simulations was mapped, taking into consideration latent, infectious, immune and dead pig groups. A total of 290 randomly selected groups (calculated based on 1% prevalence and 95% confidence) were identified on each map. It was then determined whether disease was detected and delineated during the outbreak based on locations of sampled and diseased groups. Disease detection in the population was assumed to have occurred if a single group that was infected was sampled using the surveillance strategy. Disease delineation was assessed assuming a 10 km radius buffer zone was established around all infected groups detected during surveillance as recommended by the Australian Veterinary Emergency Response Plan (AUSVETPLAN) (Animal Health Australia, 2009). Delineation was assumed to have occurred if the buffering of infected groups identified during surveillance was sufficient to include all other infected groups within the study population. Delineation was further assessed with the removal of the buffer zone to determine whether delineation was successful.

8.3.4.2 Radial Surveillance
Radial sampling is a surveillance technique that uses the first detection as the starting point. At the designated time period an infected pig group was randomly selected to be ‘found’ and the affected grid cell identified. All adjacent cells surrounding the index cell were then scheduled for surveillance, which was progressively done according to resource constraints. Within each surveyed cell, sufficient pigs were sampled to detect disease with 95% confidence, assuming 1% prevalence (Thrusfield, 2007) and the cell was categorised as infected or not. If an infected cell was found then the sampling area was increased to
include all the cells adjacent to the newly identified infected cell. For example, if a single infected cell was detected, surveillance would be conducted on the adjacent (nearest-neighbouring) 8 cells. The process was repeated until no new infected cells were detected. Surveillance stopped when all scheduled cells had been sampled. Sampling occurred day by day under realistic resource constraints, such as the number of helicopters and the number of wild pigs that can be shot each day (see Cowled et al., 2012).

8.3.4.3 Leapfrog Surveillance
Like radial sampling, leapfrog sampling began at the designated time period with random selection of an infected pig group and thus identification of one affected grid cell. Whereas the radial surveillance strategy then scheduled all adjacent (nearest neighbour) cells for surveillance, in leapfrog surveillance the next-to-adjacent (second nearest neighbour) cells were scheduled for surveillance. If an infected cell was found using the same sampling approach for radial sampling then the process was repeated. If no infected cells were found then the eight nearest neighbour cells were surveyed. Surveillance stopped when all scheduled cells had been sampled. The motivation for developing this surveillance method was the potential increased efficiency by sampling further afield to more quickly delineate the affected area. As with SRS and radial surveillance, the model was run 100 times with sampling to detect infection at time points of 42, 168 and 365 days.

8.3.5 Statistical Analysis
General descriptive analyses were conducted for each scenario output using Genstat 11th Edition (PC/Windows XP, 2006, VSN International Ltd., Hemel Hempsted, UK).

8.3.5.1 Approach 1
The infection status of 290 randomly selected groups was determined in each simulation at each time point (42, 168 and 365 days). A detected group was an infected group identified in the surveillance sample. A pre-determined ordered list of groups (designated by the random number generator) was used to consecutively identify, using a binary process (1 = yes or 0 = no), whether a group was infected. This process aimed to identify the minimum number of groups that needed to be sampled before the first case of infection was detected at each time point.

8.3.5.2 Approach 2
To assess the effectiveness of the different surveillance techniques, a $\chi^2$ test was performed to determine significant differences between group type (numbers of susceptible, latent,
infectious, immune or dead herds) at different time points (42, 168 and 365 days). A z-test using a Bonferroni adjustment was used to identify which of the group types and time points were significantly different, controlling for comparisons of multiple outcomes. Data were assessed for normality to fulfil the assumptions of the z-test and a type I error of 0.05 was used. Z-tests were also used to assess differences between the surveillance techniques in terms of the length of surveillance (days), number of cells sampled during surveillance, epidemic length (days) and outbreak area (km$^2$).

### 8.4 Results

#### 8.4.1 Approach 1

The model output obtained for Approach 1 demonstrated that in the early stages following an incursion (at 42 days post incursion) a minimum of 28 groups needed to be sampled to detect disease (Table 8.2). In the first few weeks, only latent and infectious groups were detected. Immune groups were not detected until later in the outbreak (day 168 or more).
Table 8.2
Disease model output\(^1\) following a typical incursion of classical swine fever among a population of 5304 wild pig groups in the Kimberley region, Western Australia, with random group selection to detect infection. Infected groups were those in a latently-infected, infectious or immune state.

<table>
<thead>
<tr>
<th>Day post incursion</th>
<th>Minimum number of groups sampled to detect disease</th>
<th>Minimum number of days sampling</th>
<th>Status of groups(^2)</th>
<th>Number of infected groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>42</td>
<td>28</td>
<td>4.8</td>
<td>L, I</td>
<td>75 ± 13.3(^3)</td>
</tr>
<tr>
<td>168</td>
<td>10</td>
<td>1.9</td>
<td>L, I, Im</td>
<td>259 ± 39.6</td>
</tr>
<tr>
<td>365</td>
<td>2</td>
<td>0.3</td>
<td>L, I, Im</td>
<td>525 ± 94.9</td>
</tr>
</tbody>
</table>

\(^1\) Output from a total of 100 simulations; \(^2\) L = latent, I = infectious, Im = immune; \(^3\) Mean ± SD.
8.4.2 Approach 2

8.4.2.1 Simple Random Sampling (SRS) of Groups

The number of susceptible, immune and dead pig groups differed significantly between time points for disease detection (days 42, 168 and 365; Table 3). The number of latent and infectious groups at these time points following the outbreak did not vary significantly (Table 8.3).

Using this disease spread model, the mean epidemic length (without surveillance) was found to be 759 (95% CI, 180–1424) days (Cowled et al, 2012). Among 15 randomly selected simulations, 13 (86.7%) simulated incursions were detected at each of the three time points (days 42, 168 and 365) through the use of SRS with a buffer zone around selected groups found to be infected. When a buffer zone was not applied, infection was detected; however, it was not delineated. For SRS with the application of a buffer, all infection was delineated when disease was detected at days 42 and 168. However using SRS it was not possible to delineate infection, even with the application of a buffer zone, when disease was detected at day 365.
Table 8.3
Number of pig groups by infection status following classical swine fever introduction at time points 42, 168 and 365 days post incursion among a population of 5304 wild pig groups in the Kimberley region, Western Australia.

<table>
<thead>
<tr>
<th>Days post incursion</th>
<th>Susceptible</th>
<th>Latent</th>
<th>Infectious</th>
<th>Immune</th>
<th>Dead</th>
<th>Mean (±SD) number of infected groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 (min, max)</td>
<td>5209 ± 13.8a</td>
<td>16 ± 6.2a</td>
<td>51 ± 9.0a</td>
<td>8 ± 2.4a</td>
<td>20 ± 4.5a</td>
<td>75 ± 13.3a</td>
</tr>
<tr>
<td></td>
<td>5168 – 5239</td>
<td>3 – 41</td>
<td>29 – 73</td>
<td>2 – 14</td>
<td>8 – 34</td>
<td></td>
</tr>
<tr>
<td>168 (min, max)</td>
<td>4891 ± 57.4ab</td>
<td>15 ± 6.5a</td>
<td>45 ± 16.6a</td>
<td>198 ± 28b</td>
<td>154 ± 21.3ab</td>
<td>259 ± 39.6ab</td>
</tr>
<tr>
<td></td>
<td>4763 – 5032</td>
<td>2 – 37</td>
<td>11 – 81</td>
<td>130 – 262</td>
<td>108 – 204</td>
<td></td>
</tr>
<tr>
<td>365 (min, max)</td>
<td>4378 ± 160.6b</td>
<td>14 ± 8.6a</td>
<td>53 ± 24.2a</td>
<td>458 ± 90.0c</td>
<td>400 ± 69.3b</td>
<td>525 ± 94.9b</td>
</tr>
<tr>
<td></td>
<td>4044 – 4708</td>
<td>0 – 43</td>
<td>8 – 125</td>
<td>279 – 630</td>
<td>251 – 536</td>
<td></td>
</tr>
</tbody>
</table>

a,b,c within a column, values without a common superscript letter differ significantly ($P < 0.05$); ¹ Output from 15 randomly selected simulations from a total of 100 simulation runs.
8.4.2.2 Surveillance Strategy Comparison

The performance of radial and leapfrog sampling was compared at day 42, 168 and 365 post incursion (Table 8.4). For the same day of disease detection, there was no significant difference between the two for surveillance length and cells sampled or for epidemic length and outbreak area. However surveillance length was slightly greater for leapfrog sampling at all 3 time points (although not significantly different), and epidemic length and outbreak area greater with leapfrog sampling for disease detection at day 42. In contrast leapfrog sampling resulted in a shorter epidemic length and smaller outbreak area compared to radial sampling when disease was detected at 168 and 365 days. For mean number of groups dead, infected and culled, there was likewise no statistically significant difference between radial and leapfrog sampling at the same day of disease detection.

As expected, for each sampling method there were increases in all but one model output with delayed days of disease detection when compared with detection at day 42. The one exception was the number of groups culled at 365 days, which decreased due to groups already dead. For radial and leapfrog sampling, mean increases were statistically different between the three days of detection for outbreak area. Across the three days of detection, there was no significant increase in surveillance length or number of groups culled for either radial or leapfrog sampling.
Table 8.4
Disease model output following classical swine fever detection at day 42, 168 and 365 with radial and leapfrog sampling for surveillance followed by control of disease by culling among a population of 5304 wild pig groups across the Kimberley region, Western Australia. Means and standard deviations are shown.

<table>
<thead>
<tr>
<th>Disease detection</th>
<th>Sampling type</th>
<th>Epidemic length (days)</th>
<th>Outbreak area (km(^2))</th>
<th>Groups dead from disease</th>
<th>Groups infected</th>
<th>Groups culled</th>
<th>Surveillance length (days)</th>
<th>Cells sampled</th>
</tr>
</thead>
<tbody>
<tr>
<td>42 days</td>
<td>Radial</td>
<td>159 ± 31.6(^{ac})</td>
<td>377 ± 103.5(^{ac})</td>
<td>74 ± 18.3(^{ac})</td>
<td>183 ± 40.8(^{ac})</td>
<td>411 ± 30.7(^{ac})</td>
<td>8 ± 0.6(^{ac})</td>
<td>38 ± 3.6(^{ac})</td>
</tr>
<tr>
<td></td>
<td>Leapfrog</td>
<td>166 ± 29.1(^{af})</td>
<td>414 ± 112.8(^{af})</td>
<td>80 ± 20.6(^{af})</td>
<td>199 ± 44.5(^{af})</td>
<td>419 ± 30.3(^{af})</td>
<td>9 ± 0.7(^{af})</td>
<td>39 ± 3.6(^{af})</td>
</tr>
<tr>
<td>168 days</td>
<td>Radial</td>
<td>321 ± 115.2(^{abcd})</td>
<td>1,522 ± 894.1(^{ad})</td>
<td>220 ± 60.0(^{abcd})</td>
<td>538 ± 144.1(^{abcd})</td>
<td>609 ± 31.5(^{ac})</td>
<td>13 ± 0.9(^{ac})</td>
<td>68 ± 5.6(^{ac})</td>
</tr>
<tr>
<td></td>
<td>Leapfrog</td>
<td>306 ± 39.3(^{af})</td>
<td>1,463 ± 397.9(^{ag})</td>
<td>218 ± 39.5(^{afg})</td>
<td>534 ± 92.8(^{afg})</td>
<td>609 ± 31.3(^{af})</td>
<td>14 ± 1.4(^{af})</td>
<td>68 ± 5.7(^{af})</td>
</tr>
<tr>
<td>365 days</td>
<td>Radial</td>
<td>500 ± 42.0(^{ad})</td>
<td>4,531 ± 1358.7(^{ae})</td>
<td>461 ± 77.0(^{ad})</td>
<td>1126 ± 185.5(^{ad})</td>
<td>510 ± 46.2(^{ac})</td>
<td>19 ± 2.1(^{ac})</td>
<td>106 ± 12.1(^{ad})</td>
</tr>
<tr>
<td></td>
<td>Leapfrog</td>
<td>498 ± 48.2(^{ag})</td>
<td>4,518 ± 1340.1(^{ah})</td>
<td>461 ± 75.4(^{ag})</td>
<td>1127 ± 183.2(^{ag})</td>
<td>502 ± 63.7(^{af})</td>
<td>21.4 ± 2.4(^{af})</td>
<td>105.9 ± 2.4(^{ag})</td>
</tr>
</tbody>
</table>

\(^{a,b}\) Within a column comparing sampling type for each time point, values without a common superscript letter differ significantly \((P < 0.05)\); \(^{c,d,e}\) Within a column comparing disease detection day for radial sampling, values without a common superscript letter differ significantly; \((P < 0.05)\) \(^{f,g,h}\) Within a column comparing disease detection day for leapfrog sampling, values without a common superscript letter differ significantly \((P < 0.05)\).
8.5 Discussion

8.5.1 Disease Detection
The earlier disease detection can occur, the more effective are control strategies in containing an outbreak (Klinkenberg et al., 2005). Early detection can also minimise costs by reducing the resources required for control (Nusser et al., 2008). At day 42 post-incursion it was found that sampling 28 groups using a simple random sampling approach would likely result in the detection of CSFV infection. Although this is a larger sample size compared to 10 groups at 168 days, and two groups at 365 days, by detecting and containing an outbreak in its early phases the impacts of the outbreak can be reduced. This was demonstrated by model outputs: when there was a delay in infection detection, an increase in the number of infected groups was predicted. On day 42 of detection, only 75 infected groups were present. By day 365, 525 groups were infected, demonstrating a much greater spread of disease.

Cowled et al. (2012) identified spatial structure and behaviour of wild pig populations as important factors that effects disease spread and thus need to be considered for disease control (Doran & Laffan, 2005; Ward et al., 2009). The potential for infectious disease spread is seen from research on pig movement with lone boars travelling up to 2km per day and having home ranges of up to 10km$^2$ (Cowled et al., 2012; Spencer et al., 2005). For FMD, Pech and Hone (1988) suggested that persistence among a flood plain population in a semi-arid Australian environment would require a threshold density of 2.3–14 pigs per km$^2$. For model simulations of CSF, we assumed a pig density of 1–3 pigs/km$^2$ and the model output predicted substantial numbers of infected groups among the population of 5403 pig groups. Within the context of such a CSF outbreak, given that surveillance and control activities can only reach a proportion of a given population, it is necessary to identify more efficient strategies that will help to maximise the use of resources (Thulke et al., 2009).

8.5.2 Surveillance Strategies
The use of an SRS surveillance approach was found to be effective across days 42, 168 and 365 post incursion for detection of infection. When a 10 km radius surveillance area (buffer zone) was implemented and surveyed following detection of an infected group, delineation of infection was successful following disease detection at days 42 and 168 in 13 of 15 simulations. By day 365 of an epidemic, a 10 km radius buffer zone for
surveillance around an infected group did not result in delineation of all infected herds, because of significant spatial dispersion of infection. Moreover, in the absence of a buffer zone, delineation of infection was not successful in any of the 15 simulations selected for assessment at any of the 3 time points. Although a SRS approach was effective in detecting infection, it was suboptimal in terms of resource allocation and time, supported by Nusser et al. (2008). Wildlife disease surveillance is more complex than the surveillance of domestic livestock diseases. There is limited knowledge on species populations at-risk, abundance, distribution and susceptibility, thereby necessitating the consideration of alternative sample designs as effective means of tracking disease spread (Thulke et al., 2009). Using a design similar to that of Nusser et al. (2008), a SRS approach was used to develop a baseline scenario, and alternative surveillance strategies were then compared to this standard. Subsequently we found that SRS was not a practical strategy for the effective allocation of resources for CSF detection in the simulated wild pig population. Mean epidemic length was found to be longer (although not statistically different) and the use of a buffer zone was unable to delineate all infection when an outbreak had a duration greater than 365 days.

The use of radial and leapfrog sampling allowed a more targeted approach to be utilised in the event of an outbreak. Adapting sampling techniques based on a specific epidemic event can assist in improving effectiveness of surveillance (Thulke et al., 2009). At day 42 post incursion, the most effective surveillance strategy to contain an outbreak was radial sampling, although parameters were not significantly different from leapfrog sampling. During the early stages of the modelled outbreak, disease dispersal was limited. Implementing a surveillance area around the index cell allowed delineation within an average of 8 days, and a total epidemic length of 159 days. Disease detection at days 168 and 365 demonstrated that further spread of disease had occurred through the population. For commencement of surveillance at these time points, our work suggests that the most appropriate sampling technique was leapfrog sampling. It provided a reduction on average in total outbreak area and length of the epidemic compared to radial sampling (although differences were not statistically significant). In terms of length of time required for surveillance at these time points, leapfrog sampling particularly at 365 days was slightly longer, but the difference was non-significant and in terms of achieving disease control was compensated for by the shorter outbreak duration. Therefore leapfrog sampling
appears a more suitable approach when an outbreak has not been detected for a lengthy period post incursion and there has been a greater amount of spread through a population.

Of course, at the time of disease detection a decision maker is unlikely to know how long an outbreak has been progressing. Modelling research on FMD incursions involving European wild boar suggests that disease detection via passive surveillance (hunters) would take between 13 and 39 weeks post-incursion, depending on season (European Food Safety Authority, 2012). Thus it would be likely that the disease has been spreading for at least several months by the time of reporting in an actual outbreak, and then a short period of time would be necessary to conduct some *ad hoc* sampling and collect supplementary information to confirm disease diagnosis and define the scope (district- or regional-level) of the outbreak. Only after these activities would a decision on the formal surveillance approach to adopt be made. Given this expected event sequence it is most likely that surveillance will be implemented a reasonable period into an outbreak – making a targeted approach, and leapfrog sampling in particular on the basis of this work, the preferred approach to support efficient disease control.

It has been recognised in domestic pigs that the process of CSF infection can be acute, subacute or chronic (Dahle & Liess, 1992; Floegel-Niesmann *et al.*, 2003). The presence of chronic CSF infection in wild pigs has yet to be documented (Artois *et al.*, 2002; Cowled *et al.*, 2012). Consequently, the model assumed only the presence of acute infection in wild pigs. The course of CSF infection is influenced by various factors including age, breed and environment (Floegel-Niesmann *et al.*, 2003). Literature has suggested the presence of both highly and moderately virulent strains of CSF in Indonesia which can both result in acute forms of CSF infection (Frias-Lepoureau & Greiser-Wilke, 2002; Paton & Greiser-Wilke, 2003; Paton *et al.*, 2000), supporting this model assumption. If a less virulent form was present, it may take longer to identify and there is the potential for more chronic forms of the disease. A further assumption about CSF epidemiology of the model was that an immune pig group no longer contributed to spread of infection. CSF outbreaks in wild pigs have predominately resulted from acute infection further supporting this assumption (Artois *et al.*, 2002; Cowled *et al.*, 2012).

Previous models investigating wild pig population distribution have identified water sources (watercourses and floodplains) as the primary environmental driver of distribution and activity (Choquenot *et al.*, 1996). The Kimberley region is a hot, dry area; however, the
Fitzroy River provides a vital water source in this catchment and has been identified as an area with high wild pig abundance (Woolnough et al., 2005). As highlighted by Cowled et al. (2012), Saunders and Kay (1991) estimated a daily home range of wild pigs to be approximately 2km. The model therefore assumed pigs to be located within 2km of a permanent water source, which provided their daily requirements for water access. It also needs to be mentioned that during the dry season some parts of the river system will be dry. This may lead to clustering of pigs along waterholes with the potential of reducing between herd contact. During the rainy season, flooding could either drive pig herds apart, restricting contact or could drive herds together, increasing contact if movement is limited due to the presence of changing river systems. These effects will impact surveillance approaches where a radial surveillance approach may be more appropriate to use when pigs are restricted in their movement whereas a leapfrog approach may be better when populations are more dispersed. The model only considered direct contact between live pigs for disease transmission due to the remote nature of the study site.

There are limitations to the conclusions that can be drawn from simulation modelling studies because of inherent variability and uncertainty in the system represented by input parameters and model structure. The results of disease model outputs need to be considered along with other information sources when making control decisions (Clifford et al., 2011). Rather than focusing on specific output values, the focus should be on the trends in the results (Clifford et al., 2011). Cowled et al. (2012) investigated available literature to determine input values and validate assumptions. Several limitations of this model need to be highlighted. The model assumed that infection was not spread through human movements of infected wild pigs or fomites, only simulating spread directly from pig-to-pig within wild pig populations. Therefore, depending on the population characteristics, model output might represent lower estimates for the potential spread of CSF. Human population density is extremely low in the Kimberley region (0.1 person/km²; ABS, 2011), which provides support for this assumption of limited CSF transmission via human movements.

Future research should be conducted on the use of radial and leapfrog sampling to investigate their effectiveness for CSF infection detection and delineation in wild pig populations in different environments across Australia. This is particularly important in north-eastern Australia where there are high numbers of wild pigs, a greater presence of
commercial pig herds and the close proximity to neighbouring islands presents a risk for disease incursion, transmission and persistence. Regions such as Cape York Peninsula have been identified as high-risk for the introduction of other diseases such as *Trichinella papuae* and H5N1 avian influenza (Cuttell *et al.*, 2012; East *et al.*, 2008). In Australia wild pig populations are most abundant in New South Wales and Queensland and these states also have substantial commercial pig production as well as smallholder pig herds. Thus, these areas are at risk for disease transmission between wild and domestic pigs (West, 2008) and wild pig disease surveillance approaches need to be investigated.

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### 8.6 Conclusions

Due to the complexity of wildlife population dynamics and group behaviour, a targeted approach to surveillance needs to be implemented for the effective use of resources and time. In the current simulation study, although disease was detected the use of simple random sampling was suboptimal. In comparison, radial and leapfrog sampling were demonstrated to improve the effectiveness of CSF detection at various stages of a disease outbreak and to support faster outbreak containment, with leapfrog sampling appearing to be preferable when detection occurs later in an outbreak. These results can be used to assist decision making on surveillance approach in the event of an exotic disease incursion among wild pigs in northwestern Australia.
Chapter 9: Discussion, Recommendations and Conclusions

9.1 Discussion

The limited literature available regarding the movement of pigs across eastern Indonesia suggested a gap in knowledge that needed investigation. Given that animal movements are a risk for disease transmission and spread along a market chain, improved knowledge of pig movements in this region can inform decision making processes and lead to more appropriate disease control and surveillance strategies for CSF (Martin et al., 2011; Noremark et al., 2011). CSF has been negatively impacting smallholder farmers in NTT since the disease was introduced in 1998 through the movement of pigs from East Timor and/or western Indonesia (Christie, 2007; Hutabarat & Santhia, 1999). The reported number of CSF cases has continued to increase to a total now over 100,000, with the high demand of pigs driving inter- and intra-island movement and resulting in newly infected islands as recently as 2011 (Dinas Peternakan Propinsi, 2011). Realistic, achievable, and economically sustainable mitigation strategies that can be implemented in this type of environment need to be developed.

The ACIAR Alor project demonstrated that the use of sustained vaccination coverage and farmer education regarding CSF and pig production can be successful in this region, evident from the substantial reduction in CSF cases from 2005 and no reported cases since 2008. On initiation of the current PhD project, little CSF prevalence information was available for the region and there was only broad unquantified knowledge of pig movement across the province. There was a need to investigate pig-raising and movement practices in other parts of NTT province to determine the applicability of the ACIAR Alor project’s findings to other areas of the province.

Resource limitations and minimal communication between villagers and the government has severely hindered CSF vaccination coverage. Moreover, the movement restrictions in place (movements banned from CSF-infected areas to non-infected areas) are extremely difficult to enforce (Brandenburg & Sukobagyo, 2002; Geong M. pers comm, 2011). As recognised by AQIS, Australia’s closest neighbours such as Indonesia represent a risk for disease introduction to Australia. Assisting in CSF control in NTT province, is a pre-
border biosecurity strategy for Australia, reducing the risk of CSF reintroduction. As suggested by Van Oirschot (2003), the most effective measures to control CSF in endemic countries are systematic vaccination campaigns and other measures (such as animal movement management, village and market biosecurity and farmer education) implemented with support from the local community.

To address this situation six studies were conducted. The research findings have highlighted issues affecting the potential risk of CSF spread. The major findings from each of these studies are summarised below with discussion of the current literature:

9.1.1 Live Pig Market Survey and Observational Study

As recognised by the FAO (2010), live animal markets represent high-risk locations for disease transmission. The market survey and observational study identified key issues influencing CSF spread across the province. It was found that live pigs dominate market trade, with minimal pork sales. This is a trend identified in other areas of the developing world due to limited cold chain facilities and preference for fresh meat (Lapar et al., 2009; Salin & Nayga, 2002). Pig movements peaked from July through to October, and were seen to be influenced by traditional ceremonies, monetary requirements and seasonal variations. Farmers were found to focus on cropping during the wet season (December to April) with pig raising and increased pig trade at markets identified during the dry season (May to November). Patunru et al. (2010) and World Bank (2006b) suggested that during the wet season, problems are often encountered with transportation hindering animal movement due to road degradation and ferry cancellations.

The importance of markets for pig trade in the province was highlighted in the market survey. In developing countries, the ability to trade livestock is a vital part of the economy and livelihood of rural households (Perry et al., 2005). This study found that pig farmers made direct use of markets, with 90% of sellers and 87% of buyers reporting that they were smallholder pig farmers. This study found a much lower level of involvement of pig collectors; the majority of those selling at market were the farmers themselves. The SNA demonstrated that markets could have pig sellers and buyers from over 20 different villages present on one market day. Thus there is potential for markets to be used as dissemination points for educational material. This could lead to a wider regional distribution of information to villages, assisting the role of AHWs.
The market survey and observational study identified a severe lack of biosecurity at live pig markets across the province with both sellers and buyers having minimal knowledge about CSF and biosecurity practices. Market management practices of concern included the direct contact between pigs of all age groups from a variety of different villages, unregulated pig entrances into markets, large pig volumes entering and exiting premises, absence of effective cleaning procedures and the reuse of uncleaned transportation vehicles. The use of biosecurity and surveillance at live animal markets such as inspection, cleaning, disinfection, and minimising the trade of sick pigs, has been suggested in the literature to assist in reducing disease transmission (FAO, 2010, 2011; Kiss et al., 2006; Pritchard et al., 2005; Webb, 2006).

The observational study was the first to document details of live pig markets in NTT. The identification of high-risk market management practices for disease spread and the trading practices documented provides baseline information that can be used to support decision making for the development of mitigation measures. Higher risk markets based on market observations and the SNA, and higher risk time periods (dry season) could be used to inform targeted surveillance. As suggested by Kiss et al. (2006), an epidemic that starts during an intensive trading period, when there is greater connectivity across a network and more animals are being traded, has the potential to be a more widespread epidemic that can reach multiple parts of a network. By implementing targeted control and surveillance measures with focus on higher risk locations or times, effectiveness can be improved.

9.1.2 Smallholder Farmers in NTT

The smallholder farmer survey identified several high risk practices performed by pig farmers, which had the potential to spread CSF. The use of both formal and informal trade patterns demonstrated the need to focus mitigation measures at both the market and village level. With over 85% of households owning at least one pig and factors such as traditional ceremonies and monetary requirements driving movement, the education of farmers is an important issue (FAO, 2010; Johns et al., 2009).

The severe lack of farmer knowledge about biosecurity and CSF is a concern. The ability of smallholder farmers to implement biosecurity on their farms is dependent on their production systems, knowledge of technical issues and availability of finances (FAO, 2010). Farmer education is vital to improve the uptake of appropriate on-farm practices for disease reduction. A study by Msoffee et al. (2010) in Tanzania investigated biosecurity
implementation at the village level for the poultry sector. They found that training and empowering local leaders and those that would implement the practices was the most effective approach for a successful intervention. Moreover, Mudita and Natonis (2008) found that to achieve the level of communication required for improved knowledge among smallholder farmers in NTT it was necessary to create farmer groups or for farmers to have regular contact with government or non-government organisations. Supporting Msoffee et al. (2010), Azhar et al. (2010) reports that a greater understanding of the origin, prevention and control of poultry disease (primarily HPAI) led to more active farmer participation in surveillance and control at the village level in Indonesia. For training purposes, Feder et al. (2003) and Azhar et al. (2010) supported the use of participatory approaches to engage farmers. A study by Waisbord et al. (2008) on avian influenza (AI) control in the Mekong found hands-on training to be more effective at demonstrating how to prevent transmission through implemented activities compared to basic AI information from the media (television and radio). Moreover, one important disease control factor identified by Mudita and Natonis (2008), in relation to plant product biosecurity, was enabling farmers to identify the disease in the field. This was considered important in the initial stages of a development program to allow farmers to recognise the problem and identify the risks posed by the disease. In the case of CSF, the absence of pathognomonic clinical signs and the occurrence of acute, subacute and chronic forms of disease can present a challenge for disease recognition. Consequently, this highlights the need to emphasise the use of regular biosecurity practices at the village level to reduce the risk of CSF introduction/reintroduction and transmission. Moreover, by identifying the strain/s and virulence of CSFV circulating in Indonesia, this will help to inform understanding on forms of disease expression leading to more effective education on disease recognition.

A study conducted by Elbers et al. (2002) reported that in Germany and the Netherlands 75% or more of CSF cases in the late 1990s were identified through detection of clinical signs observed by farmers and those working for veterinary authorities. This type of collaborative effort is important for enabling effective detection and coordinated response methods. Underreporting of CSF and limited access to animal health information and facilities in NTT has been caused by factors such as farmers’ mistrust of the government, lack of resources and minimal communication between villages and the government. Farmers’ mistrust of the government is not confined to developing countries; a study by Palmer et al. (2009) found that mistrust of the government existed among extensive sheep
and cattle farmers in Western Australia. These issues, highlighted by the ACIAR Alor project (Robertson et al., 2010b) need to be addressed in future work across NTT province. Robertson et al. (2010b) found that even when study participants had a high level of disease awareness, not all farmers reported suspect cases of disease. Economic impacts of reporting disease such as travel and transportation costs need to be reduced to improve reporting practices (Deveridge, 2008).

The application of different communication tools in developing countries to enhance disease reporting by farmers and AHWs has been investigated. The important findings from Azhar et al. (2010), which aim to develop sustainable community-based programs through participatory approaches, have the potential to be applied to other high-priority diseases. This study further identified the importance of minimising the lag time between disease detection and response activities and the importance of establishing links between veterinary services and villages to facilitate improved capacity building. An alternative approach reported by Robertson et al. (2010a) was the use of a mobile phone-based disease surveillance system in Sri Lanka. Supported by Sawford et al. (2011), this method is suitable for a lower-resource setting. In addition, investigations have been conducted on the integration of internet usage to aid animal disease surveillance (Shephard, 2006; Wilson & Brownstein, 2009). Shephard (2006) identified limitations for animal disease surveillance in remote cattle-producing regions in northern Australia due to reduced resource allocations for surveillance and limited contact with veterinary services in these isolated areas. As a result, the Bovine Syndromic Surveillance System (BOSS) was developed and trialed as a web-based reporting system, allowing observations by producers to be uploaded for analysis with a mapping component to record locations of reported cases. It was concluded that this approach would be useful alongside the existing surveillance system. This type of approach, although useful in some countries, may be of limited use in NTT province due to the limited availability of the internet and resources to set up such a system. However, a syndromic surveillance approach seems feasible due to the large proportion of respondents that could recognise clinical signs of a sick pig. Moreover, a more useful and efficient system for AHWs to report their observations should be investigated.

Additional high-risk on-farm practices identified included swill feeding and the introduction of a pig into a herd without quarantine. Focus groups in Flores reported that
some farmers would place a newly purchased pig directly in their herd for up to two days prior to slaughter for a traditional ceremony (Kira & Kasman, 2011). Practices such as these must be addressed through farmer education to improve knowledge on effective measures which might assist in disease control (Bradley, 2007).

9.1.3 Social Network Analysis

SNA of pig movements across this province identified both inter- and intra-island movement with the presence of both formal and informal trade pathways. The extent of connectedness and spatial structure of a network can indicate areas with the greatest potential for disease spread and need for targeted surveillance or alternative mitigation strategies (Christley et al., 2005; Natale et al., 2009). The market network was found to be highly connected, with all markets included in the study connected at an island level. Substantial pig movements were recorded from Flores to Sumba, fulfilling the high demand for pigs in traditional ceremonies and other cultural and social uses. This analysis was able to establish that pigs sold in Sumba, in relation to the entire province network, had a higher potential to move a greater number of sequential locations (nodes) compared to Flores and West Timor. The West Timor network demonstrated that pig movements were extensive, from Kota Kupang to the border with East Timor. Informal pig movements on Flores were found to be more localised, predominantly occurring within districts. Pigs being moved informally on West Timor and Sumba were more likely to move between a larger number of sequential villages.

Disinfecting market premises each day before the intake of livestock and poultry has been suggested to minimise disease transmission (FAO, 2010; Kiss et al., 2006; Thornton et al., 2008). The lack of such biosecurity measures across NTT means there is the potential for infection at the market and then in villages receiving pigs from market. The markets with the greatest potential to spread infection were Detusoko and Mbay markets in Flores and Waikabubak Market in Sumba, based on out-degree values. The markets with the greatest potential to become infected were Camplong and Niki Niki markets in West Timor, based on in-degree values. One additional high-risk market that should be noted is Wetabula Market. It had the largest volume of pigs entering and exiting of any market.

High risk villages for CSF spread were found to be those with high numbers of individuals trading outside the village (maximum reported to trade outside one village: 22 individuals; maximum reported to bring pigs into one village: 20 individuals) and with a high entry
and/or exit volume of pigs (maximum number of pigs taken outside the village for trade: 78 pigs per year; maximum number of pigs entering into a village: 61 pigs per year). The highest pig volumes being moved informally were identified in Sumba.

These study results have not captured all potential movement pathways because interviews were conducted at only nine markets and 18 villages. The usefulness of these results may be expanded by using a longitudinal study approach to capture a more extensive proportion of the network and also to quantify seasonal trends. Moreover, by including a larger number of markets, live pig markets in the region could be categorised by the level of risk they pose to disease distribution through the network.

9.1.4 Quantitative Risk Assessment

Simulation of the market model suggested that Sumba and West Timor had the highest number of infected pigs at market. The use of vaccination and pre-market inspection was found to significantly reduce the probability that a market was infected with CSFV. The application of these mitigation measures has the potential to reduce CSFV transmission along the market chain; however, it may present challenges for implementation. Currently Hogsivet (Pusvetma) is the primary vaccine type distributed in the province. The field-based vaccine trial from the ACIAR Alor project demonstrated that three internationally produced vaccines, Kitasato from Japan, Pestiffa (Meria), and Pestvac (Fort Dodge), were significantly more effective (based on antibody response) than the locally manufactured Hogsivet vaccine (Robertson et al., 2010b). Although CSF vaccination is free for smallholder farmers in Indonesia, results showed that farmers were unaware of the presence of a vaccine (29.1% of respondents). This presents a situation in which farmer education and vaccination coverage must to be improved in order to help control CSFV spread along the pig market chain.

The farm-to-farm model identified villages in Sumba as having the highest number of infected pigs entering a village during a month. The use of pre-entry village inspection was found to significantly reduce the probability that a village was infected. This type of practice could be incorporated into an education program for farmers.

This risk assessment has provided some preliminary findings to guide the next stage of development for mitigation strategies. The results highlight that for inspection to be successful, the process must be a strict procedure. Feasibly, the application of inspection
would most likely be more successful at the village level than at the market level because of a range of market management issues, including the lack of a market manager at some markets, high pig volumes and limited personnel to conduct inspection. In the village, the governance structure can assist in the implementation of mitigation strategies. Each village has an individual appointed as a Village Head whose official duties maintain the everyday running of a village. More importantly, they play a role in mediation between government and traditional activities (Bebbington et al., 2006). Villagers enable the implementation of regulations and activities in the village, however, the Village Head has the ‘final say’ (Bebbington et al., 2006). By utilising the relationship between these parties, mitigation strategies such as inspection could be achievable. Studies have shown that at the village level, by involving a community/village, animal health interventions can be more successful (Catley & Leyland, 2001; Msoffe et al., 2010). The use of vaccination would be effective in reducing CSF. However, its impacts on the effectiveness of inspection need to be considered. (Artois et al., 2002)

Results from Robertson et al. (2010b) have demonstrated that vaccination can be part of a successful program for CSF control in this region. Fitzgerald and Patrick (2012) further support these results following an economic analysis of a vaccination control program for NTT. They concluded that in order for a vaccination program to be successful in the province, it would need to be accompanied by education and extension activities to overcome the negative impacts from animal husbandry practices influencing CSF spread. Studies conducted in Thailand by Suradhat et al. (2007) found that CSF vaccination can be influenced by several factors including maternal immunity, the age of primary vaccination, the vaccination protocol and complications due to other pathogens. It was found that pigs with low levels of maternal derived antibodies at the time of vaccination required at least two vaccinations to induce clinical protection. Moreover, piglets at five weeks of age were able to develop a greater level of immunity compared to three week old piglets. These factors need to be considered in the development of a vaccination program with communication between all districts necessary to coordinate a successful program.

9.1.5 Surveillance Strategies for Australia

For effective surveillance of wild pig populations, a situation-based surveillance approach is often more appropriate than those adapted to domestic herds (Thulke et al., 2009). As shown by our simulation model study, the use of simple random sampling (SRS), radial
sampling, and leapfrog sampling were all successful in detecting CSF infection following an incursion. However, the use of radial and leapfrog sampling were more effective at delineating infection. The use of SRS has been suggested as suboptimal if applied to wildlife disease surveillance, necessitating the use of alternative approaches (Nusser et al., 2008; Thulke et al., 2009). This study suggested that the use of radial sampling should be implemented in the early stages of an outbreak; when infection was detected before six weeks. In contrast, if CSF was detected at a later stage (such as six months post incursion) the use of leapfrog sampling was found to be more efficient at delineating infection.

These alternative surveillance approaches could also be used for other emerging or TADs such as ASF and FMD. The rapid spread of such diseases means that surveillance approaches that can detect and delineate disease most rapidly to enable control with efficient use of available resources are favourable. Investigations should be considered with alternative diseases. Moreover, the application of these strategies in a real-life situation needs to be investigated.

9.2 Recommendations and Areas for Future Research

9.2.1 Farmer Education Programs and Village Level Biosecurity

Further research should be conducted on the development of a farmer education program for smallholder pig farmers across NTT, based on these findings and those from Alor (Robertson et al., 2010b). The program should focus on issues including:

- Classical swine fever and pig health information.
- Education to identify clinical signs and to classify healthy and sick pigs with the aim of enabling pig inspection on village entry.
- Pigs should be classified as pigs for raising (weaners and growers), pigs for slaughter (growers and fatteners), and pigs for breeding (sows and boars), to assist in the implementation of strategies for targeted age groups.
- Farmers should be taught to understand that as pigs get older, clinical signs of CSF become more subtle; thus careful observations should be conducted for pigs on entry. In addition, for breeding pigs only gilts and young boars should be permitted entry into the village.
• Combined inspection and quarantine: On arrival, all pigs should be inspected for clinical signs and placed in quarantine for a minimum period of 30 days, as recommended by FAO (2010). This is to allow time for any clinical signs to emerge. Newly introduced pigs of all ages should be kept in an isolated area separate from pigs already on the farm. If possible, pigs should be penned in a kandang or similar structure to limit contact with other village pigs. The use of free roaming herds and tethering of pigs should be discouraged within the village, due to the potential for disease transmission as a result of direct contact.

• With the potential for ‘carrier sows’, focus should be placed on recognising any reproductive loss or birth of sickly piglets showing clinical signs such as weakness and poor growth rate. Potentially infected sows should be isolated from other pigs and observed until confirmation of infection can be made.

• Pigs entering a village for slaughtering purposes should not come in contact with on-farm pigs even if only in the village for a short time period.

• No uncooked pork/offal should be permitted as feed due to its role in disease transmission.

• Cleaning practices should be addressed, teaching basic activities such as regular cleaning and use of disinfectants.

• It is essential that farmers be provided information on who they can report to and where to report cases of suspected disease. Further development of communication between animal health services and farmers at the village level will further facilitate this practice.

• Addressing the impact of biosecurity practices on-farm and how they can assist farmers economically is vital for adoption and to improve uptake by farmers.

• Socio-psychological research is also needed to obtain objective information about reasons for under reporting and for mistrust among farmers towards to government.

The locations for trialling this educational approach and biosecurity usage can be selected from locations considered to be higher risk from the SNA. Taking into consideration the level of contact a village had with other village and market locations and exiting and entering pig volumes, the following locations are recommended for trialling purposes:

West Timor
1. Nunbaun Delha Village (Kota Kupang)
2. Benlutu Village (TTS District)
Flores
1. Nampar Macing Village (Manggarai Barat District)
2. Riangburra Village (Flores Timur District)

Sumba
1. Rindi Village (Sumba Timur)
2. Sobawawi Village (Sumba Barat Daya)

9.2.2 Movement Regulations between Islands
Evidence from this research has shown that pig movement regulations within NTT are not being enforced as confirmed by both the SNA (Chapter 5) and focus group results (Kira & Kasman, 2011). Ferry transportation was found to be commonly used within the province to move pigs, particularly from Flores to Sumba. As a result, ferry ports could be targeted as locations for mitigation strategies. The major ferry port in Aimere, Ngada District in Flores, was identified as a key location for pig movements to Sumba. As there is only one entrance onto the boat, controlled inspections may be more easily conducted as opposed to market sites, which have multiple entrances. Potential groups that could be involved in implementing the inspection process could be Dinas veterinarians, quarantine and local NGOs. Regulation 51 (Ministry of Agriculture, 2006) could be used in this area to drive an increase in data recording for the frequency and volume of pigs leaving and entering this port. The scarcity of data for pig movements across the province needs to be addressed as it hinders further development and implementation of appropriate strategies and where they are needed most. Incentives could be offered to those farmers demonstrating the health status of their pig/s on presentation for sale at market or for transport on ferry. This avenue of research needs further investigation.

9.2.3 Vaccination Program
Results from Robertson et al. (2010b), Fitzgerald and Patrick (2012) and this study should be utilised to guide the development of a cost-effective and achievable vaccination program that can be applied across the province. Education and extension activities should be a necessary part of the program to ensure its longevity and viability. Discussions between the central, provincial and local governments need to be coordinated to determine the monetary resources available and establish an action plan to implement better CSF
control in the coming years. Implementing an identification scheme for vaccinated animals, such as ear notching, would also be important.

9.2.4 Information Distribution at Markets
In addition to developing a farmer education program, the distribution of CSF and pig health information at key live pig markets in the province should be investigated as an opportunity to directly reach farmers. AHWs have reported difficulties in reaching villages due to their isolated locations and lack of available transportation. This is an approach that can reach sellers and buyers from a large number of villages on one market day for example. The development of an accurate and complete province market list is also crucial. This gap in knowledge is limiting the ability to identify other key locations, which may play a role in disease dissemination through the pig movement network.

9.2.5 Seroprevalence Study on Flores
Results have suggested that the regional classifications for CSF infection are no longer accurate. Sikka district is not a suspect region, with CSF infection confirmed by Santhia et al. (2006), AQIS (2008) and ACIAR Project AH/2006/156 (2010). Moreover, the presence of CSF in western Flores has been suggested by recent results from the ACIAR Project AH/2006/156 (2010). The distribution of vaccines by Dinas Peternakan Propinsi is dictated by district infection classifications, with vaccine only allocated to endemic areas. Dinas Peternakan Propinsi needs to consider recent survey results and reclassify districts to ensure appropriate distribution of resources to assist farmers. No farmers in Flores reported having any knowledge of CSF. This is because no CSF information is distributed on CSF due to the ‘free’ classification. These results have highlighted an important area that needs further investigation and action. A more in-depth seroprevalence survey across Flores is needed, sampling pigs from a larger number of villages, with focus placed on the western districts to provide more information about the prevalence of CSF on the island. The survey needs to incorporate diagnostic testing for other pestiviruses such as BVDV and BDV to determine their prevalence and to clarify any cross-reaction problems when testing for CSF. Results can then assist in future decision making for CSF control.

9.2.6 Genotyping CSF in eastern Indonesia
As demonstrated throughout the thesis, the presence of a high and moderate virulent CSF strain has been suggested, with evidence gathered from pig movements and clinical reports
from farmers. Identification of CSF strain/s would foster a greater level of understanding to
guide the development of effective mitigation measures. Moreover, it can assist in farmer
education programs by informing farmers of the differences in clinical signs displayed in
association with acute, subacute and chronic forms of the disease. Farmers need to be
aware of more subtle signs if a moderately virulent strain is present. The study should
involve both West Timor and East Timor to provide information on the extent and nature
of CSFV across the two regions of Timor island.

9.2.7 Pig Movements between West Timor and East Timor

The SNA illustrated that pigs moved great distances across West Timor from Kota Kupang
to the border of East Timor. This study did not capture any cross-border movement.
However, future studies should be conducted in this area to investigate both formal and
informal movement patterns across the border. The entire island of Timor is infected with
CSF, highlighting a need to quantify animal movements and identify villages involved in
cross-border movement.

9.2.8 Allocation of Limited Resources

Due to the limited availability of resources in the province these study results suggest that
focusing on several geographical regions would more effectively utilise resources. Sumba
as a whole needs to remain a focus. The high volume and frequency of live pig movements
around the island and the greater influence of traditional ceremonies on the movement of
pigs to Sumba demonstrates a need for control strategies at an island level. Given that
Sumba is predominantly a destination for pigs rather than a source, more areas for pig
production are found in Flores and Timor. On Flores, focus should be placed on Flores
Timur and Sikka districts to minimise the potential for CSF to spread further to the western
end of the island. The SNA demonstrated that pig movements tended to be focused on
either the eastern or western regions of the island. The application of strategies in the
eastern districts would more appropriate at the current time, until further knowledge is
gained regarding the distribution of CSF in western Flores. Belu district in West Timor,
along the border with East Timor, should be the focus for resource allocation in this area.
High numbers of CSF cases have been reported from this district and the SNA
demonstrated a high level of connectivity among villages and markets in West Timor, with
markets from Kota Kupang reaching Belu. Its close proximity to East Timor leaves it
vulnerable to CSF entry from both ends of the island. The importance of addressing
disease threats at the source needs to be recognised as supported by FAO and OIE (Domenech et al., 2006).

9.2.9 Surveillance Strategies in Australia

Additional research should be conducted on the use of radial and leapfrog sampling to investigate their effectiveness for CSF infection detection and delineation in wild pig populations in different environments across Australia. This would be particularly important in north-eastern Australia where there are high numbers of wild and domestic pigs and the close proximity to neighbouring islands in eastern Indonesia presents a risk for disease transmission. Locations such as Cape York and islands in the Torres Strait that have been classified as high-risk areas for the introduction of other diseases (East et al., 2008; Jambrecina, 2010) should be a priority. Surveillance strategies need to be tailored to suit the local situation. These surveillance techniques could also be evaluated and used to investigate disease incursions involving other wildlife populations.

9.3 Conclusion

This study has highlighted the importance of the live pig trade across NTT province and the cultural-led demand for pigs driving inter- and intra-island movements. The development of control and surveillance strategies needs to incorporate identification of high-risk management practices on-farm and at live pig markets, and address the severe lack of biosecurity and CSF knowledge on the part of smallholder pig farmers. Educating farmers and implementing control strategies at a village community level can increase the sustainability and uptake of management practices that can improve pig health and production. Moreover, an improvement in communication between the Dinas, AHWs and farmers at the village level is needed to facilitate control and surveillance strategies, if they are to be effective. Allowing these results to guide decision making, combined with previous knowledge from the area, can lead to the development of appropriate mitigation strategies to control CSF that will improve the livelihoods of smallholder pig farmers in NTT. (Depner et al., 2001)

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Appendix 1: Markets on West Timor, Flores and Sumba that trade live pigs, information obtained from District Livestock Services (2011), Nusa Tenggara Timur, eastern Indonesia.

<table>
<thead>
<tr>
<th>No.</th>
<th>Island</th>
<th>Kabupaten/District</th>
<th>Kecamatan/Subdistrict</th>
<th>Market Name</th>
<th>Market Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>West Timor</td>
<td>Kab. Kupang</td>
<td>Fatuleu</td>
<td>Pasar Camplong/Lili</td>
<td>Fri, Sat</td>
</tr>
<tr>
<td>2</td>
<td>West Timor</td>
<td>Kab. Kupang</td>
<td>Amarasi Barat</td>
<td>Pasar Baun</td>
<td>Not recorded</td>
</tr>
<tr>
<td>3</td>
<td>West Timor</td>
<td>Kab. Kupang</td>
<td>Ambi Oefeto Timur</td>
<td>Pasar Oemofa</td>
<td>Not recorded</td>
</tr>
<tr>
<td>4</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kota Soe</td>
<td>Pasar Inpres Soe</td>
<td>Daily</td>
</tr>
<tr>
<td>5</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanuban Timur</td>
<td>Pasar Oe'Ekam</td>
<td>Thursday</td>
</tr>
<tr>
<td>6</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanuban Timur</td>
<td>Pasar Oeleon</td>
<td>Thursday</td>
</tr>
<tr>
<td>7</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanuban Timur</td>
<td>Pasar Sillu</td>
<td>Tuesday</td>
</tr>
<tr>
<td>8</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanuban Timur</td>
<td>Pasar Pisan</td>
<td>Friday</td>
</tr>
<tr>
<td>9</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kualin</td>
<td>Pasar Nunusunu</td>
<td>Wednesday</td>
</tr>
<tr>
<td>10</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanuban Tengah</td>
<td>Pasar Niki-Niki</td>
<td>Wednesday</td>
</tr>
<tr>
<td>11</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kolbano</td>
<td>Pasar Ofu</td>
<td>Monday</td>
</tr>
<tr>
<td>12</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kolbano</td>
<td>Pasar Se'i</td>
<td>Thursday</td>
</tr>
<tr>
<td>13</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kolbano</td>
<td>Pasar Kolbano</td>
<td>Friday</td>
</tr>
<tr>
<td>14</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanatun Selatan</td>
<td>Pasar Ayotupas</td>
<td>Thursday</td>
</tr>
<tr>
<td>15</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanatun Selatan</td>
<td>Pasar Oinlasi</td>
<td>Tuesday</td>
</tr>
<tr>
<td>16</td>
<td>West Timor</td>
<td>TTS</td>
<td>Batu Putih</td>
<td>Pasar Batu Putih</td>
<td>Monday</td>
</tr>
<tr>
<td>17</td>
<td>West Timor</td>
<td>TTS</td>
<td>Batu Putih</td>
<td>Pasar Hane</td>
<td>Saturday</td>
</tr>
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<td>18</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanatun Selatan</td>
<td>Pasar Panite</td>
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</tr>
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<td>19</td>
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<td>Amanatun Selatan</td>
<td>Pasar Toineke</td>
<td>Tuesday</td>
</tr>
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<td>20</td>
<td>West Timor</td>
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<td>Amanatun Selatan</td>
<td>Pasar Benasoka</td>
<td>Wednesday</td>
</tr>
<tr>
<td>21</td>
<td>West Timor</td>
<td>TTS</td>
<td>Amanatun Barat</td>
<td>Pasar Nusa</td>
<td>Saturday</td>
</tr>
<tr>
<td>22</td>
<td>West Timor</td>
<td>TTS</td>
<td>Boking</td>
<td>Pasar Boking</td>
<td>Saturday</td>
</tr>
<tr>
<td>23</td>
<td>West Timor</td>
<td>TTS</td>
<td>Noebeba</td>
<td>Pasar Popleu</td>
<td>Thursday</td>
</tr>
<tr>
<td>24</td>
<td>West Timor</td>
<td>TTS</td>
<td>Mollo Utara</td>
<td>Pasar Kapan</td>
<td>Thursday</td>
</tr>
<tr>
<td>25</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kuanfatu</td>
<td>Pasar Kuanfatu</td>
<td>Saturday</td>
</tr>
<tr>
<td>26</td>
<td>West Timor</td>
<td>TTS</td>
<td>Kuanfatu</td>
<td>Pasar Lasi</td>
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<td>Rua</td>
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<td>Kabu Karudi</td>
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<td>Laboya Barat</td>
<td>Gaura</td>
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<td>Katiku Tana</td>
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<td>Umalulu</td>
<td>Melolo Pasar</td>
<td>Thurs, Fri</td>
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</table>
Appendix 2: Seller Questionnaire used in Market Survey across Nusa Tenggara Timur province, eastern Indonesia, 2009.

Livestock Movement and Managing Disease in Eastern Indonesia and Eastern Australia  
Pig movements in Nusa Tenggara Timor

Pig Seller Questionnaire

Introduction to project: This questionnaire is aiming to improve our understanding of pig trade movements throughout NTT. The research is being conducted by the Australasian Centre for International Agricultural Research. You were selected as a respondent due to your involvement with pigs within NTT. All information provided will remain confidential and used for project purposes only. The questionnaire should take approximately 1 hour and you are free to pass on any question if you do not want to answer it or stop the interview at any time.

Participating is voluntary. However, your report is needed to make movement estimates as accurate as possible.

<table>
<thead>
<tr>
<th>Code Identification No:</th>
</tr>
</thead>
</table>

- * 01-03 for island = 01 for Timor, 02 for Flores and 03 for Sumba,  
- * 01-03 for Market No = 01 for Market 1, 02 for Market 2 and 03 for Market 3  
- * Respondent No. (3 digits)  
- * S (Seller), B (Buyer) or F (Farmer) at the end of each Code Identification No.

Example Code Identification No: 0101001 (Timor, Market 1, Respondent no. 1, Seller)

Name of Interviewer: ____________________________

Date of interview: ____________________________ (dd/mm/yyyy)

Round of interview: I [ ] OR II [ ]

Instruction for interviewing:

1) Please read out the "Introduction to project" at the commencement of each interview.
2) The questionnaire should be read to the respondent word for word to ensure consistency. The validity of the survey will depend on the truthfulness of responses so persuasion should not be used to gain the most desirable answers.
3) Interview questions should be stated clearly to each respondent with answer options repeated to assist respondents in their answer choice.
4) To answer each question, please tick all relevant boxes for each question, multiple answers are possible. In the case of a question not being answered, please circle the box with '99' on the right side of the page. If the respondent answers 'I do not know', please tick the 'Other' option box and write 'Not sure' in the 'please specify' textbox.
5) This questionnaire is a total of 14 pages. Please check before starting the interview that all pages are present.
6) All hard copies of the questionnaire need to be retained following the interview.

Please report any errors in data entry here: __________________________________________________________

-------------------------------------------------------------------------------------

<table>
<thead>
<tr>
<th>Part A: Respondent demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1 Name (not compulsory)</td>
</tr>
<tr>
<td>A.2 Year of birth: [ ] Male [ ] Female [ ] Unknown</td>
</tr>
<tr>
<td>A.3 Gender:</td>
</tr>
<tr>
<td>A.4 Address: District [ ] Subdistrict [ ] Village [ ]</td>
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</table>

<table>
<thead>
<tr>
<th>A.5 Education - Please circle the highest year of school completed:</th>
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<tbody>
<tr>
<td>[ ] School not attended or primary not completed [ ] High School</td>
</tr>
<tr>
<td>[ ] Primary School [ ] Secondary School [ ] Undergraduate University degree</td>
</tr>
<tr>
<td>[ ] Postgraduate University degree</td>
</tr>
</tbody>
</table>

| A.6 Religion: [ ] Christian [ ] Catholic [ ] Islam [ ] Other (please specify) |

| A.7 Primary Occupation: [ ] Secondary Occupation: [ ] |

<table>
<thead>
<tr>
<th>Part B: Respondent Background</th>
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<tbody>
<tr>
<td>B.1 What is your role with pigs at the market place?</td>
</tr>
<tr>
<td>[ ] Pig seller at the market [ ] Other (please specify)</td>
</tr>
</tbody>
</table>

If you DO NOT sell pigs at the market, terminate questionnaire here.

(i) As a PIG SELLER, please specify the following:
| [ ] You sell your own pigs at the market |
| [ ] You are a permanent seller at the market |
| [ ] You are a pig collector - please specify your role: |

If you are a pig trader - please specify your role: |

[ ] Other (please specify) |

B.2 How long have you been a pig seller at this market? (Please circle unit or tick) |
| [ ] days/weeks/months/years [ ] Not sure |

B.3 Why do you sell pigs? |
| [ ] Primary income |
| [ ] Extra income |
| [ ] Family tradition |
| [ ] Other (please specify) |

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C.1 What age group of pigs are you selling at the market today?

<table>
<thead>
<tr>
<th>Pig Age Group</th>
<th>No. pigs selling today</th>
<th>Pig Breed (Circle all relevant breeds)</th>
<th>Selling price of 1 pig</th>
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<tbody>
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<td>Rp</td>
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<tr>
<td></td>
<td></td>
<td>2. Crossbreed</td>
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<td></td>
<td>3. Duroc</td>
<td>Rp</td>
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<td></td>
<td></td>
<td>4. Other (specify)</td>
<td>Rp</td>
</tr>
<tr>
<td>Weaner</td>
<td></td>
<td>1. Local</td>
<td>Rp</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Crossbreed</td>
<td>Rp</td>
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<tr>
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<td></td>
<td>3. Duroc</td>
<td>Rp</td>
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<tr>
<td></td>
<td></td>
<td>4. Other (specify)</td>
<td>Rp</td>
</tr>
<tr>
<td>Grower</td>
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<td>1. Local</td>
<td>Rp</td>
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<tr>
<td></td>
<td></td>
<td>2. Crossbreed</td>
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<td>3. Duroc</td>
<td>Rp</td>
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<tr>
<td></td>
<td></td>
<td>4. Other (specify)</td>
<td>Rp</td>
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<td>Fattener</td>
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<td>1. Local</td>
<td>Rp</td>
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<td></td>
<td></td>
<td>2. Crossbreed</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>4. Other (specify)</td>
<td>Rp</td>
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<td>Sow</td>
<td></td>
<td>1. Local</td>
<td>Rp</td>
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<td></td>
<td>2. Crossbreed</td>
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<td></td>
<td>3. Duroc</td>
<td>Rp</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>4. Other (specify)</td>
<td>Rp</td>
</tr>
</tbody>
</table>

C.2 How are your pigs separated into different pens/groups at the market?

- [ ] They are not separated into groups
- [ ] Age
- [ ] Sex
- [ ] Sick and healthy
- [ ] Breed
- [ ] Other (please specify) 

C.3 Are your pigs fed while being kept at the market?

- [ ] Yes
- [ ] No

(i) If YES, please specify what they are fed from the options below

- Commercially prepared feed
- Table scraps from home
- Waste food from external sources (such as restaurants, markets)
- Rice bran mixed with water
- Local agriculture product (please specify) (such as sweet potato, cassava, coconut, tea)
- Other (please specify)

C.4 How often do you clean up animal waste and faeces while keeping pigs at the market?

(please circle appropriate unit or tick)

- [ ] per day/week/month
- [ ] Never

C.5 Which of these waste disposal methods do you most commonly use for removal of animal waste and faeces at the market?

- [ ] Bury (go to question C.7)
- [ ] Cover waste with soil, sand or ash (go to question C.7)
- [ ] Burn (go to question C.7)
- [ ] Compost (go to question C.7)
- [ ] Clean by hand
- [ ] Throw away (go to question C.7)
- [ ] Other (please specify) 

C.6 Are any products used for cleaning up animal waste and faeces?

- [ ] No
- [ ] Water
- [ ] Disinfectant (Karbol, Lysol, Creolin)
- [ ] Soap (Detergent)
- [ ] Other (please specify)

C.7 When there are unsold pigs at end of day, what do you do?

- [ ] Take them home
- [ ] Sell them at a cheaper price (go to question C.8)
- [ ] Transport them to another market (go to question C.8)
- [ ] Leave at market until sold (go to question C.8)
- [ ] Other (please specify) 

(i) If you answered 'Take them home' are these pigs mixed with other pigs that are already kept on your property?

- [ ] Yes
- [ ] No
C.8 Have you heard of the term biosecurity?
☐ Yes  ☐ No (go to section (ii) below)

(i) If YES, please specify what you believe biosecurity is:

☐ Other farmer (please specify location below)

☐ Yes  ☐ Not sure (go to Part D: Pattern of live pig selling)  ☐ No (go to Part D: Pattern of live pig selling)

(ii) If NO, are any management practices put in place to reduce the introduction of disease such as cleaning, vaccination or isolating new animals?

☐ Yes  ☐ Not sure

(iii) If YES, please specify the measures put in place at the market:

☐ Other (please specify)

D.1 Where did the pigs come from that you are selling today?

<table>
<thead>
<tr>
<th>Pig Age Group</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>District</td>
</tr>
<tr>
<td>Piglet</td>
<td></td>
</tr>
<tr>
<td>Weaners</td>
<td></td>
</tr>
<tr>
<td>Growers</td>
<td></td>
</tr>
<tr>
<td>Fatteners</td>
<td></td>
</tr>
<tr>
<td>Sows</td>
<td></td>
</tr>
<tr>
<td>Boars</td>
<td></td>
</tr>
</tbody>
</table>

D.2 The pigs you have sold at the market over the past year, where do they come from?

☐ Your own home raised pigs  ☐ Other market (please specify location below)

☐ Other farmer (please specify location below)

D.3 What months are the highest numbers of pigs sold? (Circle all relevant months or tick below)

Jan  Feb  March  April  Mei  Jun  Jul  Aug  Sept  Okt  Nov  Des

☐ Other farmer (please specify location below)

☐ Yes  ☐ Not sure (go to question D.4)

(i) Please explain why you think these months have higher demand for pigs:

☐ Other (please specify)

(ii) During these high demand months, how many pigs are sold per week?

☐ pig per week  ☐ Not sure

D.4 What months have the lowest demand for live pigs? (Circle all relevant months or tick below)

Jan  Feb  March  April  Mei  Jun  Jul  Aug  Sept  Okt  Nov  Des

☐ Other farmer (please specify location below)

☐ Yes  ☐ Not sure (go to question D.6)

(i) Please explain why you think these months have lower demand for pigs:

☐ Other (please specify)

D.5 During months of low demand for live pigs, how many are sold per week?

☐ pig per week  ☐ Not sure

D.6 What is the busiest time of day for selling live pigs at this market? (Select appropriate time period and enter time at market place for example: 2-10am)

☐ Morning  ☐ Lunch  ☐ Afternoon  ☐ Night
F.5 How do you house your pigs?
- A pen adjacent to your house
- Tethered next to your house
- Free range – pigs are free to roam
- Other (please specify)

F.6 What method do you use for selling your pigs produced at home?
- Private sale (directly from farm) (go to question F.7)
- Sell at the market (go to question F.7)
- Leas (go to question F.7)
- Sell to another individual who is involved in transportation or selling of your pig
- Other (please specify) (go to question F.7)

(i) Please specify the individual(s) involved
- Another farmer
- A pig collector
- A pig dealer
- A permanent seller at the market
- Other (please specify)

F.7 What are your pigs fed at home?
- Commercially prepared feed
- Table scraps from home
- Waste food from external sources (such as restaurants, markets)
- Local agriculture product (please specify) (such as sweet potato, cassava, coconut, taro)
- Mixed feed (combined commercial and home feed)
- Other (please specify)

F.8 What is your disposal method most commonly used for dead pigs?
- Bury them
- Burn them
- Sell for consumption
- Throw away
- Other (please specify)

F.9 Are any management practices put in place to reduce the introduction of disease such as cleaning, vaccination or isolating new animals?
- Yes
- Not sure (go to Part G: Pig Health)
- No (go to Part G: Pig Health)

(ii) If YES, please specify: (Please tick only what the respondent states, multiple answers are possible)
- Separate sick and healthy animals
- Clean pig transportation vehicles
- Clean equipment and cages in contact with pigs

Part G: Pig Health
G.1 Are there any symptoms you are aware of that indicate that a pig is sick?
- Yes
- No (go to question G.3)

(i) If YES, please specify from the options below (Please tick only what the respondent states, multiple answers are possible)
- Coughing
- Vomiting
- Minimal response to touch
- Loss of appetite
- Fever
- Red eyes
- Depression
- Diarrhea
- Drooping ears
- Other (please specify)

G.2 If a pig is sick, what is usually done?
- Nothing
- Treated with medicine
- Slaughtered and meat is sold
- Slaughtered and meat consumed by family
- Sold live for slaughter/consumption
- Leas
- Other (please specify)

G.3 How do you usually dispose of dead pigs at the market?
- Bury them
- Burn them
- Sell for consumption
- Throw away (please specify location)
- Other (please specify)

G.4 Are dead or sick pigs at the market reported to anyone?

<table>
<thead>
<tr>
<th>Pig status</th>
<th>Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sick pig</td>
<td>(Yes, Sometimes, Not sure OR No)</td>
</tr>
<tr>
<td>Dead pig</td>
<td></td>
</tr>
</tbody>
</table>

If NO, go to section (ii) below

(ii) Please specify who this information is reported to:
- Local Veterinary
- Market Manager
- Government Officer
Part H: Transportation of Live Pigs

H.1 How do you transport live pigs?
- Car
- Truck
- Motorcycle
- Bus
- Boat
- Animal (please circle): Horse/Buffalo/Other (go to question H.3)
- By foot (go to question H.3)
- Other (please specify)

(i) Please specify the owner of the vehicle?
- Own vehicle
- Borrowed (go to question H.3)
- Rented (go to question H.2)
- Owe (go to question H.3)
- Busines (go to question H.3)

(ii) How often do you clean your vehicle?
- After each use
- _____ per day/week/month (please circle appropriate unit)
- Never (go to question H.2)

(iii) What products are used for cleaning the vehicle?
- No products are used
- Water
- Disinfectant (Karbol, Lysol, Creolin)
- Soap (Detergent)
- Other (please specify)

H.2 Do you use okam (rice paddy banks) on the surface of your vehicle when transporting pigs?
- Yes
- No (go to question H.3)

(i) If YES, how do you dispose of this when you are finished transporting?
- Bury
- Burn
- Re-use
- Throw away
- Other (please specify)

H.3 How are the pigs restrained during transport?
- Not restrained
- Tied up
- In bag
- In case
- Other (please specify)

Those who did NOT answer "IN CASE" go to Part I: Hog Cholera

H.4 How often are the cage/s cleaned?
- After each use
- _____ per day/week/month
- Never (go to Part I: Hog Cholera)

H.5 What products are used for cleaning the cage/s?
- No products are used
- Water
- Disinfectant (Karbol, Lysol, Creolin)
- Soap (Detergent)
- Other (please specify)

Part I: Hog Cholera

I.1 Do you know what Hog Cholera is?
- Yes
- Not sure (Go to Part I: Slaughtering of pigs)
- No (Go to Part I: Slaughtering of pigs)

I.2 Do you know any clinical signs of Hog Cholera?
- Yes
- No (Go to question I.3)

(i) If YES, please specify below (Please circle only what the respondent states, multiple answers are possible)
- Anorexia very skinny
- Unsteady on feet
- Fever
- Purple discoloration on ears, tail, inner thighs
- Diarrhoea
- Other (please specify)

I.3 Please rate how dangerous you believe Hog Cholera is to your pigs using the numbers 1 to 5, with 1 being not dangerous and 5 being very dangerous. (Circle appropriate response)

1 2 3 4 5

I.4 To your knowledge, have you ever sold a pig at the market that showed clinical signs of Hog Cholera?
- Yes
- No (Go to question I.5)

(i) How long ago did this occur?
- _____ days/weeks/months/years (please circle appropriate unit)

(ii) What breed of pig was sick?
- Local
- Crossbreed
Part 2: Slaughtering of Pigs

Q.1 Do you also slaughter pigs?

☐ Yes  ☐ No (go to question J.3)

(i) Please specify, are the pigs you slaughter your own or owned by someone else?

☐ Own pigs  ☐ Pigs owned by someone else

Q.2 Is an inspection performed on the pig prior to slaughter to detect any cases of disease?

☐ Yes  ☐ No (go to question J.3)  ☐ Other (go to part (ii) below)

(ii) If YES, who performs this examination?

☐ You yourself  ☐ Government staff  ☐ Other (please specify)

(iii) If NO, why is no examination performed?

Q.3 Where do you slaughter the pigs?

☐ Home  ☐ Market  ☐ Abattoir
Appendix 3: Weaner prices at market obtained from pig sellers across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009 (Currency: Indonesian Rupiah).

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age group</td>
<td>Age group</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>Seller No.</td>
<td>Weaner Local No.</td>
<td>Local Price Cross No.</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>West Timor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camplong</td>
<td>4</td>
<td>600,000 ± 182,574</td>
</tr>
<tr>
<td></td>
<td></td>
<td>400,000-800,000</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>1</td>
<td>250,000 ± 0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Halulik</td>
<td>3</td>
<td>400,000 ± 259,808</td>
</tr>
<tr>
<td></td>
<td></td>
<td>250,000-700,000</td>
</tr>
<tr>
<td>Overall</td>
<td>8</td>
<td>481,250 ± 228,250</td>
</tr>
<tr>
<td>Flores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbay</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Detusoko</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Mataloko</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Sumba</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melolo</td>
<td>7</td>
<td>714,286 ± 121,499</td>
</tr>
<tr>
<td></td>
<td></td>
<td>500,000-</td>
</tr>
</tbody>
</table>

386
<table>
<thead>
<tr>
<th></th>
<th>$800,000$</th>
<th>$800,000$</th>
<th>$900,000$</th>
<th>$400,000$</th>
<th>$800,000$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Wetabula</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>400,000-800,000</td>
<td>566,667 ± 208,167</td>
<td>600,000 ± 282,843</td>
<td>500,000 ± 0</td>
<td>612,500 ± 217,466</td>
<td>550,000 ± 217,945</td>
</tr>
<tr>
<td>500,000-800,000</td>
<td>408,000-800,000</td>
<td>400,000-800,000</td>
<td>-</td>
<td>400,000-800,000</td>
<td>400,000-800,000</td>
</tr>
<tr>
<td><strong>Waikabubak</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>500,000-1,000,000</td>
<td>775,000 ± 206,155</td>
<td>766,667 ± 257,661</td>
<td>800,000 ± 0</td>
<td>625,000 ± 284,103</td>
<td>490,000 ± 96,177</td>
</tr>
<tr>
<td>1,000,000-2,000,000</td>
<td>500,000-1,000,000</td>
<td>500,000-1,000,000</td>
<td>-</td>
<td>350,000-1,250,000</td>
<td>350,000-600,000</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>14</td>
<td>14</td>
<td>2</td>
<td>16</td>
<td>18</td>
</tr>
<tr>
<td>700,000-1,700,000</td>
<td>708,353 ± 172,986</td>
<td>650,000 ± 212,132</td>
<td>607,895 ± 247,354</td>
<td>508,833 ± 190,494</td>
<td>788,571 ± 251,425</td>
</tr>
</tbody>
</table>
**Appendix 4:** Grower prices at market obtained from pig sellers across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009 (Currency: Indonesian Rupiah).

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age group</td>
<td>Age group</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>West Timor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camplong</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>4</td>
<td>393,750 ± 116,145</td>
</tr>
<tr>
<td></td>
<td>250,000-500,000</td>
<td>-</td>
</tr>
<tr>
<td>Halulik</td>
<td>2</td>
<td>475,000 ± 35,355</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>350,000-1,500,000</td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>6</td>
<td>420,833 ± 100,519</td>
</tr>
<tr>
<td>Flores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbay</td>
<td>7</td>
<td>842,857 ± 297,809</td>
</tr>
<tr>
<td></td>
<td>450,000-1,250,000</td>
<td>-</td>
</tr>
<tr>
<td>Detusoko</td>
<td>8</td>
<td>1,425,000 ± 898,496</td>
</tr>
<tr>
<td></td>
<td>450,000-6,000,000</td>
<td>450,000-6,000,000</td>
</tr>
<tr>
<td>Mataloko</td>
<td>6</td>
<td>1,613,333 ± 1,613,333</td>
</tr>
<tr>
<td></td>
<td>1,104,204</td>
<td>1,104,204</td>
</tr>
<tr>
<td>-------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>550,000-3,500,000</td>
<td>550,000-3,500,000</td>
<td>1,280,000-2,350,000</td>
</tr>
</tbody>
</table>

**Overall**

| 21 | 1,282,762 ± 1,304,426 |
| 45 | 1,324,000 ± 2,032,877 |
| 10 | 2,532,500 ± 324,722 |
| 13 | 860,000 ± 324,722 |

<table>
<thead>
<tr>
<th>Sumba</th>
</tr>
</thead>
</table>

| 10 | 995,000 ± 362,438 |
| 8  | 841,667 ± 201,039 |
| 8  | 855,556 ± 251,799 |
| 9  | 1,250,000 |
| 13 | 868,750 ± 265,838 |
| 2  | 750,000 ± 0 |

| 500,000-1,700,000 |
| 500,000-1,000,000 |
| 700,000-1,700,000 |
| 450,000-1,250,000 |
| 450,000-1,250,000 |
| 750,000-1,250,000 |

| 8 | 1,375,000 ± 353,553 |
| 21 | 1,400,000 ± 418,330 |
| 5  | 1,333,333 ± 288,675 |
| 8  | 2,425,000 ± 1,630,074 |
| 20 | 3,525,000 ± 1,676,057 |
| 13 | 1,325,000 ± 405,175 |

| 1,000,000-2,000,000 |
| 1,000,000-1,500,000 |
| 800,000-5,800,000 |
| 800,000-5,800,000 |
| 1,750,000 |

| 800,000-2,500,000 |
| 800,000-1,500,000 |
| 750,000-1,250,000 |
| 750,000-1,250,000 |
| 2,000,000 |

<table>
<thead>
<tr>
<th>Waikabubak</th>
</tr>
</thead>
</table>

| 12 | 1,416,667 ± 563,807 |
| 13 | 1,222,222 ± 281,859 |
| 5  | 2,000,000 ± 866,025 |
| 6  | 1,225,000 ± 517,446 |
| 3  | 800,000 ± 28,868 |
| 3  | 1,666,667 ± 288,675 |

| 800,000-2,500,000 |
| 800,000-1,500,000 |
| 1,000,000-2,500,000 |
| 750,000-1,250,000 |
| 800,000-1,500,000 |

<table>
<thead>
<tr>
<th>Overall</th>
</tr>
</thead>
</table>

| 30 | 1,265,000 ± 479,071 |
| 42 | 1,132,500 ± 360,363 |
| 18 | 1,490,000 ± 617,252 |
| 23 | 1,497,826 |
| 36 | 1,560,000 ± 1,463,875 |
| 18 | 1,381,250 ± 433,373 |
### Appendix 5: Fattener prices at market obtained from pig sellers across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009 (Currency: Indonesian Rupiah).

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>West Timor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Camplong</td>
<td>5</td>
<td>2,600,000 ± 2,234,897</td>
</tr>
<tr>
<td></td>
<td>900,000-9,000,000</td>
<td>900,000-9,000,000</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>3</td>
<td>1,600,000 ± 1,053,565</td>
</tr>
<tr>
<td></td>
<td>600,000-2,700,000</td>
<td>600,000-1,500,000</td>
</tr>
<tr>
<td>Halulik</td>
<td>2</td>
<td>1,075,000 ± 459,619</td>
</tr>
<tr>
<td></td>
<td>750,000-1,400,000</td>
<td>750,000-1,400,000</td>
</tr>
<tr>
<td>Overall</td>
<td>10</td>
<td>2,040,000 ± 1,151,927</td>
</tr>
<tr>
<td>Flores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbay</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Detusoko</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Mataloko</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>0</td>
<td>-</td>
</tr>
<tr>
<td>Sumba</td>
<td>10</td>
<td>1,650,000 ± 1,250,000</td>
</tr>
<tr>
<td></td>
<td>636,895</td>
<td>331,662</td>
</tr>
<tr>
<td>----------------</td>
<td>---------</td>
<td>---------</td>
</tr>
<tr>
<td>800,000-2,500,000</td>
<td>800,000-1,500,000</td>
<td>1,000,000±2,500,000</td>
</tr>
<tr>
<td>Wetaula</td>
<td>14</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>2,857,143±1,063,893</td>
<td>3,000,000±901,388</td>
</tr>
<tr>
<td></td>
<td>1,500,000-4,000,000</td>
<td>2,000,000-4,500,000</td>
</tr>
<tr>
<td>Waikabubak</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td></td>
<td>2,444,444±768,295</td>
<td>2,500,000±1,060,660</td>
</tr>
<tr>
<td></td>
<td>1,500,000-4,000,000</td>
<td>1,500,000-4,000,000</td>
</tr>
<tr>
<td>Overall</td>
<td>33</td>
<td>40</td>
</tr>
<tr>
<td></td>
<td>2,378,788±993,654</td>
<td>2,472,222±1,079,654</td>
</tr>
</tbody>
</table>
**Appendix 6:** Sow prices at market obtained from pig sellers across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009 (Currency: Indonesian Rupiah).

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age group</td>
<td>Age group</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>Camplong</td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Timor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niki Niki</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halulik</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbay</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detusoko</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mataloko</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age group</td>
<td>Age group</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>Camplong</td>
<td>9</td>
<td>1,594,444 ± 1,105,227</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Niki Niki</td>
<td>7</td>
<td>900,000 ± 403,113</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Halulik</td>
<td>5</td>
<td>1,060,000 ± 155,724</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
<td>21</td>
<td>1,235,714 ± 804,541</td>
</tr>
<tr>
<td>Flores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbay</td>
<td>3</td>
<td>1,466,667 ± 57,735</td>
</tr>
<tr>
<td>Detusoko</td>
<td>1</td>
<td>1,500,000 ± 0</td>
</tr>
<tr>
<td>Mataloko</td>
<td>6</td>
<td>1,625,000 ± 0</td>
</tr>
</tbody>
</table>

392
<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>525,119</td>
<td>495,480</td>
<td></td>
<td>419,183</td>
<td>419,183</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1,000,000-2,300,000</td>
<td>1,000,000-2,300,000</td>
<td>-</td>
<td>1,000,000-2,000,000</td>
<td>1,000,000-2,000,000</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>10</td>
<td>1,565,000 ± 400,035</td>
<td>13</td>
<td>1,494,444 ± 352,176</td>
<td>2,200,000 ± 0</td>
<td>12</td>
</tr>
<tr>
<td>Sumba</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Melolo</td>
<td>4</td>
<td>2,425,000 ± 942,956</td>
<td>3</td>
<td>2,500,000 ± 0</td>
<td>2</td>
<td>2,350,000 ± 1,626,346</td>
</tr>
<tr>
<td></td>
<td>1,200,000-3,500,000</td>
<td>-</td>
<td>1,200,000-3,500,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wetabula</td>
<td>9</td>
<td>3,388,889 ± 600,925</td>
<td>10</td>
<td>2,875,000 ± 250,000</td>
<td>5</td>
<td>3,800,000 ± 447,214</td>
</tr>
<tr>
<td></td>
<td>2,500,000-4,500,000</td>
<td>2,500,000-3,000,000</td>
<td>3,500,000-4,500,000</td>
<td>3,000,000-6,750,000</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Waikabubak</td>
<td>4</td>
<td>3,000,000 ± 408,248</td>
<td>2</td>
<td>2,750,000 ± 353,553</td>
<td>2</td>
<td>3,250,000 ± 353,553</td>
</tr>
<tr>
<td></td>
<td>2,500,000-3,500,000</td>
<td>2,500,000-300,000</td>
<td>3,000,000-3,500,000</td>
<td>1,500,000-3,500,000</td>
<td>2,500,000-3,500,000</td>
<td>-</td>
</tr>
<tr>
<td>Overall</td>
<td>17</td>
<td>3,070,588 ± 735,497</td>
<td>15</td>
<td>2,750,000 ± 267,261</td>
<td>9</td>
<td>3,555,5556 ± 908,448</td>
</tr>
</tbody>
</table>
Appendix 7: Boar prices at market obtained from pig sellers across West Timor, Flores and Sumba, Nusa Tenggara Timur, eastern Indonesia, 2009 (Currency: Indonesian Rupiah).

<table>
<thead>
<tr>
<th>Island / Market</th>
<th>Round 1</th>
<th>Round 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Age group</td>
<td>Age group</td>
</tr>
<tr>
<td></td>
<td>Mean (± SD) and Range</td>
<td>Mean (± SD) and Range</td>
</tr>
<tr>
<td>Camplong</td>
<td>5</td>
<td>1,410,000 ± 361,248</td>
</tr>
<tr>
<td>Niki Niki</td>
<td>6</td>
<td>1,250,000 ± 346,410</td>
</tr>
<tr>
<td>Halulik</td>
<td>5</td>
<td>1,205,000 ± 223,184</td>
</tr>
<tr>
<td>Overall</td>
<td>16</td>
<td>1,229,688 ± 338,036</td>
</tr>
<tr>
<td>Flores</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mbay</td>
<td>3</td>
<td>2,000,000 ± 500,000</td>
</tr>
<tr>
<td>Detusoko</td>
<td>3</td>
<td>1,708,333 ± 364,292</td>
</tr>
<tr>
<td>Mataloko</td>
<td>7</td>
<td>2,566,667 ± 1,808,498</td>
</tr>
</tbody>
</table>

394
<table>
<thead>
<tr>
<th></th>
<th>5,800,000</th>
<th>5,800,000</th>
<th>3,400,000</th>
<th>1,500,000</th>
<th>1,500,000</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall</strong></td>
<td>13</td>
<td>16</td>
<td>8</td>
<td>18</td>
<td>41</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>2,210,417 ± 1,306,255</td>
<td>2,203,125 ± 1,477,476</td>
<td>2,250,000 ± 1,078,193</td>
<td>1,313,529 ± 489,171</td>
<td>1,282,000 ± 502,141</td>
<td>1,550,000 ± 353,553</td>
</tr>
<tr>
<td><strong>Sumba</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Melolo</strong></td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3,666,667 ± 577,350</td>
<td>3,000,000 ± 0</td>
<td>3,666,667 ± 577,350</td>
<td>2,500,000 ± 0</td>
<td>-</td>
<td>2,500,000 ± 0</td>
</tr>
<tr>
<td></td>
<td>3,000,000-4,000,000</td>
<td>-</td>
<td>3,000,000-4,000,000</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Wetabula</strong></td>
<td>6</td>
<td>1</td>
<td>5</td>
<td>6</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>4,000,000 ± 1,095,445</td>
<td>6,000,000 ± 0</td>
<td>4,000,000 ± 1,095,445</td>
<td>5,166,667 ± 683,130</td>
<td>5,500,000 ± 707,107</td>
<td>5,000,000 ± 707,107</td>
</tr>
<tr>
<td></td>
<td>3,000,000-6,000,000</td>
<td>-</td>
<td>3,000,000-4,000,000</td>
<td>4,500,000-6,000,000</td>
<td>5,000,000-6,000,000</td>
<td>4,500,000-6,000,000</td>
</tr>
<tr>
<td><strong>Waikabubak</strong></td>
<td>8</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>4,500,000 ± 755,929</td>
<td>4,000,000 ± 816,497</td>
<td>4,428,571 ± 786,796</td>
<td>4,333,333 ± 1,154,701</td>
<td>-</td>
<td>4,333,333 ± 1,154,701</td>
</tr>
<tr>
<td></td>
<td>3,000,000-5,000,000</td>
<td>3,000,000-5,000,000</td>
<td>3,000,000-5,000,000</td>
<td>3,000,000-5,000,000</td>
<td>-</td>
<td>3,000,000-5,000,000</td>
</tr>
<tr>
<td><strong>Overall</strong></td>
<td>17</td>
<td>6</td>
<td>13</td>
<td>10</td>
<td>2</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>4,176,471 ± 882,843</td>
<td>4,166,667 ± 1,169,045</td>
<td>4,125,000 ± 885,061</td>
<td>4,650,000 ± 1,131,616</td>
<td>5,500,000 ± 707,107</td>
<td>4,437,500 ± 1,147,591</td>
</tr>
</tbody>
</table>
Appendix 8: Buyer Questionnaire used in Market Survey across Nusa Tenggara Timur province, eastern Indonesia, 2009.

Livestock Movement and Managing Disease in Eastern Indonesia and Eastern Australia

Pig movements in Nusa Tenggara Timor

Pig Buyer Questionnaire

Introduction to project: This questionnaire is aiming to improve our understanding of pig trade movements throughout NTT. The research is being conducted by the Australian Centre for International Agricultural Research. You were selected as a respondent due to your involvement with pigs within NTT. All information provided will remain confidential and used for project purposes only. The questionnaire should take approximately 1 hour and you are free to pass on any question if you do not want to answer it or stop the interview at any time.

Participating is voluntary. However, your report is needed to make movement estimates as accurate as possible.

Code Identification No:

Please include:
* 01-06 for island = 01 for Timor, 02 for Flores and 03 for Sumba,
* 04-06 for Market No = 01 for Market 1, 02 for Market 2 and 03 for Market 3
* Respondent No. (3 digits)
* S (Seller), B (Buyer) or F (Farmer) at the end of each Code Identification No.

Example Code Identification No: 0301001B (Timor, Market 1, Respondent no. 1, Buyer)

Name of Interviewer:

Date of interview: / / (dd/mm/yyyy)

Round of interview: I OR II

Instruction for interviewing:
1) Please read out the ‘Introduction to project’ at the commencement of each interview.
2) The questionnaire should be read to the respondent word for word to ensure consistency. The validity of the survey will depend on the truthfulness of responses so persuasion should not be used to gain the most desirable answers.
3) Interview questions should be stated clearly to each respondent with answer options repeated to assist respondents in their answer choice.
4) To answer each question, please tick all relevant boxes for each question, multiple answers are possible. In the case of a question not being answered, please circle the box with ‘99’ on the right side of the page. If the respondent answers ‘I do not know’, please tick the ‘Other’ answer box and write ‘Not sure’ in the ‘please specify’ section.
5) This questionnaire is a total of 12 pages. Please check before starting the interview that all pages are present.
6) All hard copies of the questionnaire need to be retained following the interview.

Please report any errors in data entry here:

Part A: Respondent demographics

A.1 Name (not compulsory):

A.2 Year of birth: OR Not sure

A.3 Gender: Male Female

A.4 Address: District Subdistrict Village

A.5 Education - Please circle the highest year of school completed:

- School not attended or primary not completed
- Primary school
- Secondary School
- High School
- Undergraduate University degree
- Postgraduate University degree

A.6 Religion: Christian Catholic Islam Other (please specify)

A.7 Primary Occupation: Secondary Occupation

Part B: Respondent Background

B.1 Are you a pig buyer at this market? Yes No (go to TERMINATE QUESTIONNAIRE)

B.2 What other animal and animal products do you buy at the market?

- Live poultry
- Live cattle
- Cattle meat
- Poultry meat
- Other (please specify)
- Live goats

Part C: Purchasing live pigs

C.1 How many pigs are you purchasing today?

<table>
<thead>
<tr>
<th>Pig Age Group</th>
<th>Pig Breed</th>
<th>Number of pigs purchased</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piglet</td>
<td>Local</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Crossbred</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Duroc</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Other (specify)</td>
<td>4</td>
</tr>
<tr>
<td>Weaner</td>
<td>Local</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Crossbred</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Duroc</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Other (specify)</td>
<td>4</td>
</tr>
<tr>
<td>Grower</td>
<td>Local</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Crossbred</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Duroc</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Other (specify)</td>
<td>4</td>
</tr>
<tr>
<td>Fattener</td>
<td>Local</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Crossbred</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Duroc</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Other (specify)</td>
<td>4</td>
</tr>
</tbody>
</table>
C.2 What months do you purchase the highest number of pigs? (Circle all relevant months or tick below)

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Or

☐ Not sure (go to question C.4)

6. Please explain why you think these months have higher demand for pigs:

C.3 During high demand periods, how many pigs do you purchase per week?

☐ per week

☐ Not sure

C.4 What months do you purchase the lowest number of pigs? (Circle all relevant months or tick below)

<table>
<thead>
<tr>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>May</th>
<th>June</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Or

☐ Not sure (go to question C.6)

6. Please explain why you think these months have lower demand for pigs:

C.5 During low demand periods, how many pigs do you purchase per week?

☐ per week

☐ Not sure

C.6 What are the pigs purchased at this market used for?

☐ Home consumption

☐ Keep at home on property/farm

☐ Sell the pig

☐ Purchased to fill a customer order/s

☐ Religious festival

☐ Traditional festival

☐ Other (please specify) _

C.7 Why do you choose this market to purchase pigs?

☐ Close to your residence

☐ It has the type of pigs you want to purchase

☐ The market is open on days that suit you

☐ Other (please specify)

C.8 Do you purchase live pigs from another market place?

☐ Yes

☐ No (go to question C.9)

6. If yes, please specify the location of the market you predominantly use other than this market:

District: _

Subdistrict: _

Village: _

Market Name: _

C.9 What is the most common source used to purchase live pigs?

☐ Market

☐ Pig farmer (purchase pigs directly from farm)

☐ From another pig seller

☐ Other (please specify)

C.10 Please rank the following factors from 1-4 in order of importance when purchasing a live pig, with 1 being not important and 4 being very important

- Price

- Pig health

- Age/Size

- Breed

C.11 When purchasing live pigs, what time do you go to the market? (Please tick the most appropriate time period and fill in the time at the market example 7:10:30am)

☐ Morning

☐ Lunch

☐ Afternoon

☐ Night

☐ All day

☐ All night

C.12 Do you do anything to ensure the pigs you purchase are free from disease?

☐ Yes

☐ No (go to Part D: Purchase of pig meat products)
Part D: Purchase of pig meat products

D.1 How much pig meat are you buying today?  

<table>
<thead>
<tr>
<th>Meat Product Type</th>
<th>What Products ((\square = \text{Yes}, \times = \text{No}))</th>
<th>How many kg</th>
<th>Price per kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>I am not buying any meat products.</td>
<td>Go to question D.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fresh pork</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smoked pork</td>
<td>Rs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dried pork</td>
<td>Rs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local sausage Budik Tabuk</td>
<td>Rs</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other (please specify)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

D.2 What months do you purchase the highest amount of pig meat? (Circle all relevant months or tick below)

Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

OR \(\square\) Not sure

D.3 Please explain WHY you think these months have the highest demand for pig meat products:

D.4 During these high demand months, how much meat do you purchase per week?

kg per week \(\square\) Not sure

D.5 What is the most common source used to purchase pig meat and other pig meat products?

\(\square\) Market  
\(\square\) Pig farmer (purchase pigs directly from farms)  
\(\square\) Abattoir  
\(\square\) Other (please specify)

D.6 Does purchase location of live pigs or pig meat change depending on whether it is a low or high demand period?

\(\square\) Yes  
\(\square\) No (go to question D.7)

D.7 If YES, please specify WHY you use alternative locations:

D.7 Which product is more suitable for specific occasions?

<table>
<thead>
<tr>
<th>Live pig</th>
<th>Pig meat</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Birthday celebrations</td>
<td></td>
</tr>
<tr>
<td>2. Religious celebrations</td>
<td></td>
</tr>
<tr>
<td>3. Weddings</td>
<td></td>
</tr>
<tr>
<td>4. Traditional celebrations</td>
<td></td>
</tr>
<tr>
<td>5. Funerals</td>
<td></td>
</tr>
</tbody>
</table>

D.8 When purchasing pig meat products, what time do you go to the market? (Please tick the most appropriate time period and fill in the time at the market example 7-10:30am)

Morning  
Lunch  
Afternoon  
Night  
All day  
All night

D.9 Are you concerned if the meat you purchase is free from disease?

\(\square\) Yes (go to section (i) below)  
\(\square\) Not sure (go to Part E: Pig Health)  
\(\square\) No (go to section (ii) below)

D.10 If YES, please specify why you are concerned?

D.11 If NO, please specify why you are not concerned?
Part E: Pig Health

E.1 Are there any symptoms you are aware of that indicate that a pig is sick?  
☐ Yes ☐ No (go to Part F: Transportation and destination of pigs)
☐ If YES, please specify from the options below (Please tick only what the respondent states, multiple answers are possible)
☐ Coughing ☐ Vomit ☐ Minimal response to touch
☐ Loss of appetite ☐ Fever ☐ Drooping ears
☐ Depression ☐ Diarrhoeas ☐ Red eyes
☐ Other (please specify)  

E.2 If you believe a pig is sick, will you still purchase it?  
☐ Yes ☐ No (go to Part F: Transportation and destination of pigs)  
☐ If YES, please explain why you would purchase a pig you believe it is sick?  

Part F: Transportation and destination of pigs

F.1 Following purchase of live pigs at this market, where do you transport them to?
☐ Your home ☐ Abattoir (please specify location below)
☐ District ☐ Subdistrict
☐ Village
☐ Another market (please specify location below)
☐ District ☐ Subdistrict
☐ Village
☐ Market Name
☐ Other (please specify) (please specify location below)
☐ District ☐ Subdistrict
☐ Village

F.2 How do you transport live pigs?
☐ Car ☐ Truck ☐ Motorbike
☐ Animal (please circle) Horse/ Buffalo/ Other (go to question F.4)
☐ Boat ☐ Bus

☐ By foot (go to question F.4)
☐ Other (please specify)  

(1) Please specify the owner of the vehicle?
☐ Own vehicle
☐ Borrowed (go to question F.3)
☐ Rented (go to question F.3)
☐ Ojek (go to question F.4)
☐ Biskayn (go to question F.4)

(2) How often do you clean your vehicle?  
☐ After each use
☐ _______ per day/week/month (please circle appropriate unit)
☐ Never (go to question F.3)  

(3) What product/s are used for cleaning the vehicle?  
☐ No products are used
☐ Water
☐ Disinfectant (Karbol/Lysol/Creolin)
☐ Soap (Detergent)
☐ Other (please specify)  

F.3 Do you use paddy husks (sekam) on the surface of your vehicle when transporting pigs?  
☐ Yes ☐ No (go to question F.4)

(1) If YES, how do you dispose of this when you are finished transporting?  
☐ Bury ☐ Burn ☐ Re-use ☐ Throw away
☐ Other (please specify)

F.4 How are the pigs restrained during transport?
☐ Not restrained ☐ Tied up ☐ Other (please specify)  
☐ In cage ☐ In bag  
Those who did NOT answer ‘IN CAGE’ go to question F.6

F.5 How often are the cages/cars cleaned?  
☐ After each use
☐ _______ per day/week/month (please circle appropriate unit)
☐ Never (go to question F.6)
Part G: Hog Cholera

G.1 Do you know what Hog Cholera is?  
- Yes  
- No (Go to Part H: Slaughtering of pigs)  
- No (Go to Part I: Slaughtering of pigs)

G.2 Do you know any clinical signs of Hog Cholera?  
- Yes  
- No (Go to question G.3)

G.4 To your knowledge, have you ever purchased a pig at the market that showed clinical signs of Hog Cholera?  
- Yes  
- No (Go to question G.5)

G.5 To what extent are you likely to report any suspect Hog Cholera cases?  
- Very Unlikely  
- Unlikely  
- Unsure  
- Likely  
- Very Likely

G.6 Please rate how important you believe biosecurity is for control of Hog Cholera using the numbers 1 to 5, with 1 being not important and 5 being very important. (Circle appropriate response)  
- 1  
- 2  
- 3  
- 4  
- 5  
- Not sure

G.7 Where did you get your knowledge about Hog Cholera?  
- Television  
- Friends  
- Newspaper/book/magazine  
- Field Extension Agent  
- Radio  
- Colleagues at the market place
Part II: Slaughtering of pigs

H.1 Do you also slaughter pigs?
☐ Yes ☐ No (go to question H.9)

(9) Please specify, are the pigs you slaughter your own or owned by someone else?
☐ Own pigs OR ☐ Pigs owned by someone else

H.2 Is an inspection performed on the pig prior to slaughter to detect any cases of disease?
☐ Yes ☐ Not sure (go to part (ii) below) ☐ No (go to part (ii) below)

(ii) If YES, who performs this examination?
☐ Yourself
☐ Government staff
☐ Other (please specify)

(iii) If NO, why is no examination performed?

H.3 Where do you slaughter the pigs?
☐ Home
☐ Market
☐ Abattoir
☐ Other (please specify)

H.4 What do you do with the pig meat once the animal has been slaughtered?
☐ Consumed by family
☐ Sold at market
☐ Sold to family/friends in your village
☐ Other (please specify)

H.5 What months are the highest numbers of pigs slaughtered? (Circle all relevant months or tick below)

Jan Feb March April Mei Juni Juli Aug Sept Okt Nov Des
☐ Not sure

H.6 During months of increased slaughter, how many are slaughtered per week?
☐ pigs per week OR ☐ Not sure

H.7 Following slaughter of pigs, which of these waste disposal methods do you use for carcass waste?
☐ Burying
☐ Burning
☐ Feed to pigs
☐ Throw away
☐ Other (please specify)

H.8 How often is slaughtering equipment cleaned?
☐ Cleaned following every pig slaughter
☐ After each use
☐ per day/week/month (please circle appropriate unit)
☐ Never

H.9 Do you have pigs slaughtered by someone else?
☐ Yes ☐ No (go to Completion of questionnaire)

(9) If YES please specify:
☐ Abattoir
☐ A farmer in your village
☐ By another pig seller
☐ Other (please specify)

Completion of questionnaire: Thank you very much for your participation in this questionnaire!

Would you be willing to provide additional information if we need to contact you for future inquiries?
☐ Yes ☐ No
Appendix 9: Farmer Questionnaire used during Smallholder Farmer Survey across Nusa Tenggara Timur province, eastern Indonesia, 2009.

**Livestock Movement and Managing Disease inEastern Indonesia and Eastern Australia**

**Pig movements in Nusa Tenggara Timur**

**Pig Farmer Questionnaire**

**Introduction to project**: This questionnaire is aiming to improve our understanding of pig trade movements throughout NTT. The research is being conducted by the Australian Centre for International Agricultural Research. You were selected as a respondent due to your involvement with pigs within NTT. All information provided will remain confidential and used for project purposes only. The questionnaire should take approximately 1 hour and you are free to pass on any question if you do not want to answer it or stop the interview at any time.

Participating is voluntary. However, your report is needed to make movement estimates as accurate as possible.

**Code Identification No:**

Please include:
- T. F or S for island = T for Timor, F for Flores and S for Sumbu
- 01-09 for Subdistrict No. = 01 for Subdistrict 1, 02 for Subdistrict 2 and up to Subdistrict 9
- Enter Subdistrict name:
- 01-18 for Village No. = 01 for Village 1, 02 for Village 2 and up to Village 18.

Enter Village name:
- *Respondent No. (Right)
- F (Farmer) at the end of each Code Identification No.

Example Code Identification No: **T0101001F** (Timor, Subdistrict 1, Village 1, Respondent no. 1, Farmer)

**Name of Interviewer:**

**Date of interview:**

(dd/mm/yyyy)

**Instruction for interviewing:**

1) Please read out the Introduction to project at the commencement of each interview.
2) Questions should be read to the respondent word for word to ensure consistency. The validity of the survey will depend on the truthfulness of responses so persuasion should not be used to gain the most desirable answers.
3) Interview questions should be stated clearly to each respondent with answer options repeated to assist respondents in their answer choices.
4) To answer each question, please tick all relevant boxes for each question, multiple answers are possible. In the case of a question not being answered, please circle the box with “99” on the right side of the page. If the respondent answers “I do not know”, please tick the “Other” option box and write “Not sure” in the “Please specify” textbox.
5) This questionnaire is a total of 18 pages. Please check before starting the interview that all pages are present.
6) All hard copies of the questionnaire need to be retained following the interview.

**Please report any errors in data entry here:**

<table>
<thead>
<tr>
<th>Part A: Respondent Demographics</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.1 Name (not compulsory):</td>
</tr>
<tr>
<td>A.2 Year of birth:</td>
</tr>
<tr>
<td>OR Unknown</td>
</tr>
<tr>
<td>A.3 Gender: Male Female</td>
</tr>
<tr>
<td>A.4 Education - Please tick the highest year of school completed:</td>
</tr>
<tr>
<td>School not attended or primary not completed High School</td>
</tr>
<tr>
<td>Primary school Undergraduate University degree</td>
</tr>
<tr>
<td>Secondary School Postgraduate University degree</td>
</tr>
<tr>
<td>A.5 Religion: Christian Catholic Islam Hindu Other (please specify)</td>
</tr>
<tr>
<td>A.6 Primary Occupation: Secondary Occupation</td>
</tr>
</tbody>
</table>

**Part B: Respondent Background**

**B.1 What animals do you keep on your property?**

- Pigs
- Poultry
- Goats
- Cattle
- Buffalo
- Dogs
- Other (please specify)

IF A FARMER DOES NOT MEET INCLUSION CRITERIA – IF no pigs present on farm on day of interview, sample another farmer

**B.2 How long have you been a pig farmer? (Please enter number in the box below and circle the appropriate time unit)**

| days/weeks/months/years |

**B.3 Why do you keep pigs?**

- Primary income
- Extra income
- Cultural traditions
- Food consumption
- Other (please specify)
**Part C: On-Farm Pig Management**

C.1 How many pigs do you have in your herd? (Fill in all appropriate boxes with the number of pigs in each age group according to breed type ON DAY OF VISIT)

<table>
<thead>
<tr>
<th>Pig Age Group</th>
<th>Local</th>
<th>Crossbred</th>
<th>Other (specify below)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piglets</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaners</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Growers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fattener</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sows</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boars</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C.2 How do you house your pigs?
- [ ] A pen adjacent to your house
- [ ] Tethered next to your house
- [ ] Free range – pigs are free to roam
- [ ] Adult pig in pen and piglets free to roam
- [ ] Other (please specify)

C.3 What are your pigs fed?
- [ ] Commercially prepared feed
- [ ] Table scraps from home
- [ ] Rice hulls mixed with water
- [ ] Waste food from external sources (such as restaurants, markets)
- [ ] Local agriculture product (please specify) (such as sweet potato, cassava, coconut, taro)
- [ ] Other (please specify)

C.4 Are your pigs provided water?
- [ ] Yes
- [ ] No (go to question C.5)

(a) Where is this water from?
- [ ] Well on your property
- [ ] River
- [ ] Communal well in your village
- [ ] Other (please specify)

C.5 Are housing/pig pen areas ever cleaned?
- [ ] Yes
- [ ] Sometimes
- [ ] No (go to question C.8)

C.6 How do you clean the housing/pig pen areas?

C.7 Are any products used for cleaning the housing/pig pen areas?
- [ ] No
- [ ] Water
- [ ] Disinfectant (Karbol, Lysol, Credina)
- [ ] Soap (Detergen)
- [ ] Other (please specify)

C.8 Which of these waste disposal methods do you use for removal of animal waste and faeces?
- [ ] I do not do anything
- [ ] Burn
- [ ] Compost
- [ ] Clean by hand
- [ ] Other (please specify)

C.9 Do you use an identification method with any of your pigs?
- [ ] Yes
- [ ] No

(a) If YES, please specify method used:
- [ ] Ear notch
- [ ] Ear tag
- [ ] Paint on skin
- [ ] Tattoo
- [ ] Other (please specify)

**Part D: Pig Health**

D.1 Are there any symptoms you are aware of that indicate that a pig is sick?
- [ ] Yes
- [ ] No (go to question D.6)

(a) If YES, please specify from the options below (Please tick only what the respondent states, multiple answers are possible)
- [ ] Coughing
- [ ] Vomit
- [ ] Red eyes
- [ ] Loss of appetite
- [ ] Fever
- [ ] Drooping ears
- [ ] Depression
- [ ] Diarrhoea
- [ ] Hair standing
- [ ] Other (please specify)

D.2 Do you usually separate sick pigs from other animals in your herd?
- [ ] Yes
- [ ] Sometimes
- [ ] Not sure
- [ ] No

D.3 In the past 12 months have any of your pigs died suddenly without any signs of illness?
- [ ] Yes
- [ ] Not sure (go to question D.4)
- [ ] No (go to question D.4)
**D.5 If a pig is sick, what is usually done?**

- Nothing
- Call a veterinarian
- Slaughtered and meat consumed by family
- Sold live for slaughter/consumption
- Loses
- Other (please specify)

**D.6 During the last 12 months, have you heard of anyone having sick or dead pigs?**

- Yes
- Not Sure (go to question D.7)
- No (go to question D.7)

**D.7 Does a veterinarian, veterinary assistant or field extension agent ever come to your farm?**

- Yes
- No (go to question G.8)

**(i) Please specify the type of individual**

- Veterinarian
- Veterinary assistant
- Field Extension Agent

**(ii) Do you contact the individual in question?**

- Yes
- No

**(iii) Under what circumstances do they come to your property?**

- When a pig is sick
- Vaccination (please specify vaccination type)
- Provide animal health information
- Other (please specify)
### D.8 How do you dispose of dead pigs?

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>What is done with pig body? (Circle correct response)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspected Disease</td>
<td>Burn</td>
</tr>
<tr>
<td>Sudden death</td>
<td>Burn</td>
</tr>
<tr>
<td>Considered not to be sick</td>
<td>Burn</td>
</tr>
</tbody>
</table>

### D.9 Are dead or sick pigs on your farm reported to anyone?

<table>
<thead>
<tr>
<th>Pig status</th>
<th>Reported (Yes, Sometimes, Not sure OR No)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sick pig</td>
<td></td>
</tr>
<tr>
<td>Dead pig</td>
<td></td>
</tr>
</tbody>
</table>

If YES or SOMETIMES, go to section (i) below
If NOT SURE, go to question D.10
If NO, go to section (ii) below

Please specify who you report a sick or dead pig to:
- [ ] Veterinarian
- [ ] Village head
- [ ] Field Extension Agent
- [ ] Other (please specify):  

Please go to Question D.10

### D.10 How do you think you can protect your pigs from disease?

#### Part E: Buying Practices and Farm Biosecurity

**E.1 How many pigs did you purchase over the last 12 months? (DO NOT include pigs received as gifts)**

**FOR EACH PURCHASE** – How many pigs did you buy? What month was the purchase? Why did you purchase these pigs? Where did you buy them from? Where did they come from? If you DO NOT purchase any pigs or DO NOT REMEMBER, please tick the box at the bottom of the table.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>How many?</th>
<th>Month</th>
<th>WHY?</th>
<th>WHO*</th>
<th>Where From?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piglet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaner</td>
<td></td>
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</tr>
<tr>
<td>Grower</td>
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<td></td>
</tr>
<tr>
<td>Fattener</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Sow Boar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Piglet     |           |       |      |      |             |
| Weaner     |           |       |      |      |             |
|Grower     |           |       |      |      |             |
| Fattener   |           |       |      |      |             |
|Sow Boar   |           |       |      |      |             |

**E.2 In the past 12 months, what celebrations and/or other events have resulted in pigs being given to you as a gift? FOR EACH GIFT** – What was the celebration? eg wedding or funeral. What month was the celebration? How many pigs were given? Was the pig(s) slaughtered on day of you received it? Did the pigs have contact with pigs already on your property? Where did the pigs come from?

<table>
<thead>
<tr>
<th>Event / Celebration</th>
<th>Month</th>
<th>Pig No.</th>
<th>Age Group (Circle)</th>
<th>Slaughtering on receiving day</th>
<th>Contact with your pigs at home (Circle)</th>
<th>Where from?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piglet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>District</td>
</tr>
<tr>
<td>Weaner</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Subdistrict</td>
</tr>
<tr>
<td>Grower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Village</td>
</tr>
<tr>
<td>Fattener</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sow Boar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Piglet              |       |         |                    |                               |                                           | District    |
| Weaner              |       |         |                    |                               |                                           | Subdistrict |
| Grower              |       |         |                    |                               |                                           | Village     |
| Fattener            |       |         |                    |                               |                                           |             |
| Sow Boar            |       |         |                    |                               |                                           |             |

| Piglet              |       |         |                    |                               |                                           | District    |
| Weaner              |       |         |                    |                               |                                           | Subdistrict |
| Grower              |       |         |                    |                               |                                           | Village     |
| Fattener            |       |         |                    |                               |                                           |             |
| Sow Boar            |       |         |                    |                               |                                           |             |
E.3 When you purchase new pig(s) and take them home, do you quarantine (keep them separated) from other pigs already on your property for a period of time?

☐ Yes
☐ No
☐ Sometimes
☐ Not sure (go to question E.4)
☐ No (go to question E.4)

If YES or SOMETIMES, please specify how long the pigs are quarantined for:

days/weeks/months OR ☐ Not sure

E.4 Have you heard of the term biosecurity?

☐ Yes
☐ No (go to section (ii) below)

If YES, please specify what you believe biosecurity is:

Go to section (iii) below

If NO, are any management practices put in place to reduce the introduction of disease such as cleaning, vaccination or isolating new animals?

☐ Yes
☐ Not sure (go to question E.5)
☐ No (go to question E.5)

If YES, please specify the measures put in place on your farm:

☐ Separate sick and healthy animals
☐ Clean pig transportation vehicles
☐ Clean equipment in contact with pigs
☐ Footbath at entrance to farm
☐ Vaccination (please specify type)
☐ The use of protective clothing when handling pigs (please circle) Gloves/Masks/Boots/Overalls/Other
☐ Other (please specify)

E.5 To your knowledge, do your pigs at home come in contact with foreign pigs at any time (pigs that are not owned by you)?

☐ Yes
☐ Not sure (go to Part F)
☐ No (go to Part F)

If YES, please tick the types of possible contact with foreign pigs:

☐ Your neighbour’s pigs
☐ Wild pigs
☐ Village pigs (pigs owned by other members of your village)
☐ Other (please specify)

F.2 To what extent are you likely to sell your pig when the following factors occur? (Please circle one response for each factor)

(i) Need for money

- Very Unlikely
- Unlikely
- Not sure
- Likely
- Very Likely

(ii) Pig is sick

- Very Unlikely
- Unlikely
- Not sure
- Likely
- Very Likely

(iii) Pig is getting old

- Very Unlikely
- Unlikely
- Not sure
- Likely
- Very Likely

F.3 What months are you most likely to sell your pigs? (Please circle all appropriate months)

- Jan
- Feb
- March
- April
- May
- June
- July
- Aug
- Sept
- Oct
- Nov
- Dec
F.4 Please explain WHY you are more likely to sell pigs during these months:

F.5 For the months you have not selected in question F.3, WHY are less pigs sold during these months?

F.6 How do you transport live pigs to and from your home?

- Buyers bring their own vehicle and pick up from my house (go to question F.7)
- Truck
- Motorbike
- Bus
- Bemo
- Tractor
- Cart
- By foot (go to question F.7)
- Other (please specify)

(i) Please specify the owner of the vehicle?

- Own vehicle
- Borrowed
- Rented
- Oek (go to question F.7)
- Biskyn

(ii) How often do you clean this vehicle?

- After each use
- When it looks dirty
- Never (go to question F.7)
- Other (please specify)

(iii) What products are used for cleaning the vehicle?

- No products are used
- Water
- Disinfectant (Karbol, Lysol, Creolin)
- Soap (Detergen)
- Other (please specify)

F.7 Are rice paddy humus (sekam) placed on the surface of the vehicle during transportation?

- Yes
- No (go to question F.8)

(i) If YES, how do you dispose of this when you are finished transporting?

- Burn
- Re-use
- Throw away
- Other (please specify)

F.8 How are the pigs restrained during transport?

- Not restrained
- Tied up
- Other (please specify)

- In cage
- In bag

F.9 For the following situations, when does the Kepala Desa need to be informed?

(i) You sell your pig at market

- Yes
- No (Go to question G.6)

(ii) You buy a pig from market and want to bring it home, into your village

- Yes
- No

(iii) You give a pig as a gift to a member of your village

- Yes
- No

(iv) You take your pig as a gift outside this village

- Yes
- No

(v) You receive a pig as a gift

- Yes
- No

Part G: Pig Meat Products and Slaughtering

G.1 Are pigs ever slaughtered on your property?

- Yes
- No (Go to question G.6)

(i) Please specify who slaughters these pigs?

- Yourself
- Another family member
- A farmer in your village
- Other (please specify)

(ii) Please specify, are the pigs slaughtered on your property your own or are they owned by someone else?

- Own pigs OR
- Pigs owned by someone else

G.2 Is an inspection performed on the pig prior to slaughter to detect any cases of disease?

- Yes
- No (go to question G.3)
- Not sure (go to question G.3)

(i) If YES, who performs this examination?

- Yourself
- Veterinary assistant
- Veterinarian
- Other (please specify)
6b) If NO, why is no examination performed?

G.3 For pigs slaughtered on your farm, what do you do with the pig meat?
- Consume at home
- Sell directly from your property to consumers
- Sell pig meat at the market
- Less
- Other (please specify)

G.4 How do you dispose of the carcass waste following slaughter?
- Burn
- Throw away
- Feed to your pigs
- Other (please specify)

G.5 What months are the highest numbers of pigs slaughtered on your property? (Circle all relevant months)

G.7 Where is the most common place for you to buy pig meat?
- I do not buy pig meat
- From the market
- From a meat seller in your village
- From a meat seller from another village
- Less
- Other (please specify)

G.8 What months have the highest demand for pig meat? (Circle all relevant months)

6a) During these months, how many pigs are slaughtered per week?
- Pigs per week
- Not sure

G.9 What months have the lowest demand for pig meat? (Circle all relevant months)

6a) During these months, how many pigs are slaughtered per week?
- Pigs per week
- Not sure

Part II. Pig Breeding

H.1 Have you ever bred pigs on your property?
- Yes
- No (Go to Part 1. Hog cholera)

H.2 What breeding method do you use with your pigs?
- Natural mating (go to question H.3)
- Artificial insemination (go to question H.5 below)
- Both natural mating and artificial insemination (go to question H.3)

H.3 Do you borrow a boar for mating your sows?
- Yes
- No, I already have a boar for mating
- No (Go to question H.4 below)
### Part I: Hog Cholera

#### 1.1 Have you heard of Hog Cholera?
- [ ] Yes
- [ ] No (Go to question 1.7)
- [ ] Not sure (Go to question 1.7)

#### 1.2 Please rate how dangerous you believe Hog Cholera is to your pigs using the numbers 1 to 5, with 1 being not dangerous and 5 being very dangerous. (Circle appropriate response)

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
</table>

#### 1.3 Do you know any clinical signs of Hog Cholera? (Please circle only what the respondent states, multiple answers are possible)
- [ ] No (Go to question 1.7)
- [ ] Anorexia / very skinny
- [ ] Fever
- [ ] Unsteady on feet
- [ ] Diarrhoea
- [ ] Purple discoloration on ear, tail, inner thighs
- [ ] Depression
- [ ] Other (please specify)

#### 1.4 To your knowledge, have you ever had a pig on your farm showing clinical signs of Hog Cholera?
- [ ] Yes
- [ ] No (Go to question 1.5)
- [ ] Not sure (Go to question 1.5)

#### 1.5 For pigs showing clinical, please fill in the following table:

<table>
<thead>
<tr>
<th>Age at start of illness (Circle)</th>
<th>How many sick pigs? (Circle)</th>
<th>Breed (Circle)</th>
<th>What month? (Circle)</th>
<th>Clinical signs</th>
<th>What action was taken?</th>
<th>How many pigs died? (Circle)</th>
<th>Time between clinical signs and death (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piglet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weaver</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grower</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fattener</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sow</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Part II: Hog Cholera - Additional Information

#### 2.1 What months of the year do you mate your pigs?

<table>
<thead>
<tr>
<th>Jun</th>
<th>Feb</th>
<th>March</th>
<th>April</th>
<th>Mei</th>
<th>Juni</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Okt</th>
<th>Nov</th>
<th>Des</th>
</tr>
</thead>
</table>

#### 2.2 Why have these months been selected for mating?
[ ] Not sure (Go to question H.7)

#### 2.3 What do you do with piglets born on your farm?
- [ ] Keep them on your property
- [ ] Sell them within your village
- [ ] Sell directly from your farm (please specify where the piglets are taken if known)
- [ ] Sell them at market (please specify market location)
  | District | Subdistrict |
  | District | Subdistrict |
  | District | Subdistrict |

#### 2.4 If YES, where is this boar’s coming from?
- [ ] Farmer from your village
- [ ] Farmer outside your village
- [ ] Other (please specify)

#### 2.5 Do you take any of your sows to another farm for mating?
- [ ] Yes
- [ ] No (go to question H.5 below)

#### 2.6 If YES, where are you taking this sow’s to?
- [ ] Farmer from your village
- [ ] Farmer outside your village
- [ ] Other (please specify)

#### 2.7 If you artificially inseminate your pigs, who performs this procedure?
- [ ] I do not artificially inseminate my pigs
- [ ] Veterinarian
- [ ] Veterinarian assistant
- [ ] Field Extension Agent
- [ ] Other (please specify)
I.11 How frequently are your pigs vaccinated for Hog Cholera?
- Once only
- Yearly
- Whenever there is a campaign
- Other (please specify)

I.12 Where did you get your knowledge about Hog Cholera?
- Television
- Friends
- Newspaper/book/magazine
- Field Extension Agent
- Radio
- Another farmer
- Vet/Veterinary assistant
- Other (please specify)
- Family

Completion of questionnaire: Thank you very much for your participation in this questionnaire. Would you be willing to provide additional information if we need to contact you for future inquiries?
- Yes
- No

I.10 When was your current herd last vaccinated for Hog Cholera?
- Month
- Year
- Yes OR Not sure
Appendix 10: Seroprevalence results from Australian Centre for International Agricultural Research, Project AH/2006/156, survey conducted in 2010.

<table>
<thead>
<tr>
<th>Site</th>
<th>District</th>
<th>Target number of pigs</th>
<th>Actual number of pigs</th>
<th>PosVacc Removed</th>
<th>FINAL STATUS</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Se = 99%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Sp = 99%</td>
</tr>
<tr>
<td>West Timor</td>
<td>Belu</td>
<td>360</td>
<td>349</td>
<td>2</td>
<td>267</td>
<td>75</td>
</tr>
<tr>
<td></td>
<td>Kota Kupang</td>
<td>360</td>
<td>336</td>
<td>16</td>
<td>294</td>
<td>42</td>
</tr>
<tr>
<td>Flores</td>
<td>Manggarai Barat</td>
<td>360</td>
<td>349</td>
<td>0</td>
<td>311</td>
<td>38</td>
</tr>
<tr>
<td></td>
<td>Sikka</td>
<td>360</td>
<td>356</td>
<td>1</td>
<td>343</td>
<td>13</td>
</tr>
<tr>
<td>Sumba</td>
<td>Sumba Barat Daya</td>
<td>180</td>
<td>127</td>
<td>51</td>
<td>102</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Sumba Timur</td>
<td>180</td>
<td>162</td>
<td>17</td>
<td>119</td>
<td>43</td>
</tr>
<tr>
<td>Lembata</td>
<td>Lembata</td>
<td>360</td>
<td>360</td>
<td>0</td>
<td>360</td>
<td>0</td>
</tr>
</tbody>
</table>

|              |                 |                        |                       |                 | True prevalence | 95%CI       |
|              |                 |                        |                       |                 |               | Rogan-Gladen CL |
|              |                 |                        |                       |                 |               |             |
| West Timor   | Belu            |                         |                        |                 | 0.209         | (0.165 - 0.253) |
|              | Kota Kupang     |                         |                        |                 | 0.117         | (0.081 - 0.153) |
| Flores       | Manggarai Barat |                         |                        |                 | 0.101         | (0.068 - 0.134) |
|              | Sikka           |                         |                        |                 | 0.027         | (0.007 - 0.047) |
| Sumba        | Sumba Barat Daya|                         |                        |                 | 0.191         | (0.12 - 0.261)  |
|              | Sumba Timur     |                         |                        |                 | 0.261         | (0.191 - 0.33)  |
| Lembata      | Lembata         |                         |                        |                 | 0             | (0 - 0.01)    |