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Abbreviations

95%CI	95% Confidence Interval
ACIAR	Australian Centre for International Agricultural Research
ADB	Asian Development Bank
ADG	average daily gain
AP	apparent prevalence
ASF	African swine fever
AU$	Australian Dollar
BK	Bokeo
BPP	Business Partnership Platform
CBA	Cost-Benefit Analysis
CPS	Champasak
CSF	classical swine fever
CSIRO - AAHL	Commonwealth Scientific and Industrial Research Organisation Australian Animal Health Laboratory
DAFO	District Agriculture and Forestry Office
DFAT	Department of Foreign Affairs and Trade
DIVA	differentiate infected from vaccinated animals
DLF	Department of Livestock and Fisheries
ELISA	enzyme-linked immunosorbent assay
FAO	Food and Agricultural Organization of the United Nations
FGD	focus group discussion
FISQ	financial impact statement questionnaire
FMD	foot and mouth disease
FMDv	foot and mouth disease virus
GLM	generalised linear model
GLMM	generalised linear mixed model
GoL	Government of Laos
HPAI	highly pathogenic avian influenza
HS	haemorrhagic septicaemia
ICC	Intraclass correlation
ID	identification
KAP	knowledge, attitudes and practices
KM	Khoummoune
LNT	Luang Namtha
LPB	Luang Prabang

MORU	Mahidol Oxford Research Unit
MVPHMgt	Master of Veterinary Public Health Management
NAFRI	National Agriculture and Forestry Institute
NSP	Non-Structural Proteins
NUOL	National University of Laos
OIE	World Organisation for Animal Health
OR	Odds ratio
PRRS	porcine reproductive and respiratory syndrome
RDA	Rural Development Agency
s.d	standard deviation
S.E	Standard Error
SEACFMD	South-East Asia and China Foot and Mouth Disease Campaign
SP	Structural Proteins
spp	species
STANDZ	Stop Transboundary Animal Disease and Zoonoses initiative
SVK	Savannakhet
SVKU	Savannakhet University
TAD	Transboundary animal diseases
TP	true prevalence
USYD	University of Sydney
VVW	village veterinary worker
XK	Xieng Khoung
XYL	Xayabouli

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Attendees of the End of Project Review in Luang Prabang March 2019 (Photo: Nichola Calvani)

2. Executive summary

Lao PDR (Laos) remains one of the poorest countries in the world, with high rates of rural poverty and constant threats of food insecurity. While the country has experienced economic growth in the last decade, widespread undernutrition and food insecurity remain. Since the early 2000's red meat consumption has been increasing in the Greater Mekong Subregion and Laos is strategically located to participate in this trade. However, with increased livestock movements and the location of Laos on the major livestock trade routes, creates increased risks for transboundary animal disease outbreaks, particularly if biosecurity measures are inadequate. This project aimed to identify the most cost-efficient and effective disease mitigation strategy (vaccination only, biosecurity only or biosecurity with vaccination) that can be implemented at the village-level; evaluate the current disease reporting and response systems; develop versatile training materials that target a wide audience; build capacity in animal health at local universities; and contribute to regional foot-and-mouth disease (FMD) control initiatives.

Whilst it was determined that a vaccination only strategy had the net benefit of AU$ 15,098.80, this was highly sensitive to price fluctuations of vaccine-associated costs. The biosecurity with vaccination strategy was found to be less sensitive to fluctuations, with a similar net benefit of AU$ 15,087.38. These strategies, including biosecurity only, were also assessed for effectiveness through a serological longitudinal survey which monitored non-structural protein FMD virus antibody prevalence in large ruminants. The Australian government funded Stop Transboundary Animal Diseases and Zoonoses (STANDZ) initiative involved strategic vaccination of large ruminants in identified FMD 'hotspots' in northern Laos during 2012–16. This campaign was highly successful during this period with no official FMD outbreak reports from 2013–17. However, since late 2017 the number of FMD outbreaks occurring has been increasing and the longitudinal study found an increase in seroprevalence as the project progressed, with animals from the biosecurity and biosecurity with vaccination villages having a higher seroprevalence (32.5%) compared to vaccination only villages (18.6%). There was evidence of transmission during the project, with 29.5% of animals between 12 months and 3 years of age being seropositive. These findings highlight the importance of effective and sustainable biosecurity measures in disease control programs.

The disease outbreak report response system was evaluated through surveys and focus group discussions and found to have limitations relating to record keeping, traceability and transparency. It was reported that participants in the disease reporting chain use their discretion when deciding when to report an outbreak 'upwards'. While this practice may be prudent to ensure allocation of limited national veterinary resources, it has significant impacts on monitoring for and estimating the incidence and burden of FMD and other important livestock diseases in the country, impacting on future control strategies and external donor funding priorities.

Farmer knowledge, attitudes and practices for animal health and biosecurity, nutrition and reproduction were quantitatively assessed at the beginning (2015) and midpoint (2018) of the project and followed by focus group discussions at the end of the project (2019). There were marginal increases in biosecurity (61% in 2015 to 64.5% in 2018), and reproduction (59% in 2015 to 61% in 2018) knowledge. However, nutrition scores declined between 2015 and 2018 (65% to 59%). The focus group discussions and associated field observations found that while some farmers were able to realise the benefits of vaccination and biosecurity on animal health, others felt helpless in preventing disease and therefore were not motivated to invest in disease mitigation. These findings also highlighted the importance of regular, structured and on-going education extension activities in animal health to ensure knowledge transfer of disease management is comprehensive and sustainable.

In 2015, an outbreak of a novel FMDv strain (O/ME-SA/Ind2001d) occurred in Laos, highlighting the constant high risk of transboundary disease incursion into Laos from the increased trade in livestock and their products. A risk factor analysis identified that a key risk in this outbreak was the use of communal grazing lands prior to the outbreak and that movement controls were protective. This study further highlights the need for targeted education programs and government regulated biosecurity measures applied to all livestock movements.

Small ruminants, particularly goats, are increasing in popularity in Laos in recent years, with the national herd estimated to be just under 600,000 in 2017. While many of these animals are native breeds owned by smallholders in free ranging systems there has been an increase in imported Boer cross animals raised in commercial and semi-commercial systems. As increasing intensification also increases the risk of animal diseases, a seroprevalence study of FMD virus, *Coxiella burnetii* and *Brucella* species in goats, was investigated, as was a case study of Orf disease that was initially misdiagnosed as FMD. Further, a case study of endoparasitism comparing commercial and smallholder goat herds was also instigated following major losses in the commercial enterprise. These investigations provided a valuable insight into the risks, diagnosis and management of different diseases in an environment where disease recognition knowledge is limited.

The findings from this project reinforce the urgent need for ongoing training and support in livestock health and biosecurity to build animal health management capacity in Laos, particularly at the smallholder level. While the serological studies provide evidence for the need for government action on imposing and enforcing stricter biosecurity strategies and implementing quarantine compliance for the transport of animals into and throughout the country, promulgation of widespread and ongoing vaccination against diseases of importance, particularly FMD and Haemorrhagic Septicaemia, plus more effective disease reporting and response procedures, are required to minimise the severe impacts on livestock health and food security currently occurring in Laos.

Farmers in Xieng Khoung preparing their cattle for vaccination using a traditional bleeding pole for restraint (Photo: Nichola Calvani)

3. Background

Lao PDR (Laos) remains one of the poorest countries in the world with a high rate of rural poverty and food insecurity (WFP, 2019). The rural areas of the country are inhabited by more than two-thirds of the 6.5 million people currently in Laos (WFP, 2019). Despite economic growth and poverty reduction since the early 2000s (FAO and MAF, 2013), food insecurity and malnutrition are still some of the biggest threats to public health (FAO, 2020). The chronic malnutrition rate for children under 5 years of age is 35.6% and the country ranks 139/189 on the human development index (WFP, 2019).

While the agricultural sector employs nearly 80% of the population in Laos (FAO, 2020), it remains underdeveloped, with the majority of farmers practicing subsistence-based farming, often relying on rice production for household food security and livestock as cash stores, with wild-caught foods often supplementing household nutrition (FAO, 2020; FAO and MAF, 2013). Livestock farming contributes significantly to the household and national economies with livestock numbers, with the exception of buffalo, increasing steadily at 3-5% per annum (FAO and MAF, 2013). However, low agricultural productivity is a key constraint to improved household food security (FAO, 2020).

Red meat consumption in the region has gradually increased since 2000, with consumption in Vietnam and China peaking at 10.13 kg and 3.63 kg per capita in 2014, respectively (OECD, 2018). Laos is ideally situated geographically to participate in these growing markets. However, numerous transboundary animal diseases (TAD) such as foot and mouth disease (FMD) are endemic in the region and in Laos, resulting in negative impacts on production and smallholder livelihoods. Although in island nations in South-East Asia (Indonesia, The Philippines), FMD control and eradication has been achieved, this was achieved by combining vaccination strategies with quarantine and improved animal movement controls, enhanced disease surveillance for more effective disease reporting, and public awareness programs promoting biosecurity (Windsor, 2011; Blacksell et al., 2019). However, in mainland South-East Asia and particularly Laos, FMD control is extremely challenging. Due to its location, porous land borders, the high proportion of informal trade, poor understanding and implementation of biosecurity and under-developed livestock services system, there are many challenges for implementing effective disease control in Laos.

To address the shortage of adequately trained veterinary and para-veterinary personnel in Laos, the first cohort of Bachelor of Veterinary Science students graduated from The National University of Laos (NUOL) in 2013. This training program was then converted to a Doctor of Veterinary Medicine (DVM) degree, graduating the first cohort in 2020. However, there are concerns regarding the graduate level competencies of these students and their ability to operate effectively in the historically under-resourced national veterinary services sector (Bastiaensen et al., 2011). Further, agricultural extension services are also under-resourced and many programs are reliant on donor aid to continue providing appropriate farmer education and capacity building (FAO and MAF, 2013). There is a particular need to improve the capacity of extension workers, farmers and para-veterinary personnel in village to national level biosecurity practices, plus the technical capacity of individuals involved in providing advice for livestock nutrition, parasite control and reproduction management.

The AH-2012-067 project aligns with goals outlined in the Agricultural Master Plan (AMP) developed by the Government of Laos (GoL) (MAF, 2010). This includes: Goal 1: The improvement of livelihoods (through agriculture and livestock activities) with food security as its first priority; and Goal 2: Increased and modernised production of agricultural commodities will lead to 'pro-poor and green value chains', targeting domestic, regional and global markets, based on organisations of smallholder farmers partnering investments with the private sector (MAF, 2010). Interventions introduced in project AH-2012-067 project were designed to utilise a multi-stakeholder, village-wide, multidisciplinary engagement approach, aimed at improving livestock production and husbandry practices and introducing the sustainability of biosecurity procedures that contribute to the goals of the AMP.

For large ruminants, a strategic mass vaccination program in northern Laos was used to control FMD, funded by the Australian government through the Stop Transboundary Animal Disease and Zoonoses (STANDZ) initiative, administered by the OIE within the South-East Asia and China FMD (SEACFMD) campaign. Although this initiative was highly successful at suppressing outbreaks in the north of Laos, outbreaks were still occurring in the south of the country with continuation of the threat of re-incursion in the north. An absence of FMD in proposed AH-2012-067 sites provided the opportunity to focus on improving risk management and potentially improving the report-response surveillance systems. Hence, the project design included the implementation of vaccination only, biosecurity only and biosecurity with vaccination village-level disease mitigation strategies. This design enabled comparative evaluation of the most cost-effective method of preventing disease occurrence and transmission by each strategy in the current context of northern rural Laos.

Further, as goat farming has increased in popularity in Laos, it was considered important to evaluate their potential role in disease risk mitigation. Small ruminants are widely promoted as an entry point into livestock-raising due to the reduced capital investment required and popularity of their meat in Muslim markets, although many programs have been instigated without adequate comprehension of the disease risk to these initiatives. There is minimal information on the potential role of goats in FMD virus transmission, plus limited data on other production limiting caprine diseases in Laos, particularly when production is intensified. Pigs and poultry are also crucial livestock species for many smallholder families due to their relative ease of management, especially for female farmers. They are important providers of regular household income, with egg production contributing significantly to household nutrition as a primary source of animal-derived protein. The village-level livestock productivity approach employed in this project provided an opportunity to investigate animal health and production issues facing all of these species.

An important aspect of this project was to continue the contributions from active 'coal-face' research in Laos on FMD, with regular contributions from our participants to the regional SEACFMD campaign, informing the development of more effective control strategies. The project design was built on recent work conducted successfully in Laos with ACIAR-support, addressing the following research questions:

- How can village biosecurity incorporating all village livestock be strengthened to improve smallholder livelihoods?
- How can animal disease reporting and response systems be improved to achieve accurate prevalence and incidence data that can be utilised to strengthen FMD control programs?
- What are the most appropriate tools and processes to engage the Lao rural community in the uptake of livestock health and production interventions?

A farmer and her grandson in Xieng Khoung during the foot-and-mouth disease financial impact statement questionnaire survey (Photo: Nichola Calvani)

4. Objectives

The overall aim of this project was to develop and deliver livestock health, biosecurity and productivity interventions at the village-level, to improve smallholder livelihoods, improve disease risk management and increase public awareness of biosecurity with the view of establishing FMD-free zones.

Objective 1: Develop a model 'whole of village biosecurity program 'for pigs, poultry, goats, cattle and buffalo.

Activities:

- Conduct an inception workshop with key stakeholders to confirm project aims and background understanding, select potential project sites and participants, plus identify project training requirements.
- Conduct an audit of potential projects sites then select 9 villages in 3 provinces using selection criteria established in Activity 1.2.
- Identify and select a minimum of 30 farmers per village to participate in the project.
- Develop and deliver in one of each of the three villages in each province a program of:
    - V – FMD vaccination interventions only
    - B – Biosecurity and production program (including interventions in nutrition, health, reproduction, marketing and biosecurity) to engage farmers and promote uptake
    - BV – Implement both V and B together.
- Conduct an FMD virus (FMDv) serological longitudinal study across all project sites to determine intervention (V, B, BV) effectiveness in preventing virus transmission.
- Conduct a cost benefit analysis (CBA) of intervention options for the 'whole of village biosecurity program'.
- Conduct baseline and midpoint farmer, village veterinary worker (VVW), and extension staff knowledge, attitudes and practices (KAP) and socioeconomic surveys to assess intervention impacts among the three groups (V, B, BV). Conduct farmer focus group discussions (FGD) to obtain more detailed qualitative data regarding attitudes and practices among the three intervention groups (V, B, BV).

Objective 2: Improve current disease event reporting and emergency response systems, primarily focused on potential FMD-free zoning in northern Laos.

Activities:

- Identify and assess current disease event reporting systems for cattle and buffalo, pigs and poultry, to identify critical constraints and improvement opportunities.
- Evaluate the FMD outbreak reporting and response network at the village and district level using qualitative research rapid assessment with the Rural Development Agency (RDA)

Objective 3: Develop a communication strategy for a widespread public awareness biosecurity campaign, potentially applicable to the Greater Mekong Subregion.

- Develop pilot extension and training materials on FMD, biosecurity and disease prevention and control with the aim of being suitable to distribute nationally. Program to include digital stories, awareness signage, foot-baths, cartoons, posters, radio spots and cross-visits.
- Assess the use of training programs and materials provided to farmers and district/provincial staff through RDA rapid assessment interviews.
- Use project data to assist regional decision making on the allocation of resources for future FMD control strategies in Laos and the Greater Mekong Subregion, including building capacity within project staff, National University of Laos (NUOL) and Savannakhet University (SVKU) staff and students.

Ms Phaivanh collecting data from farmers in Xieng Khoung for the cost-benefit analysis of the village intervention methods (Photo: Nichola Calvani)

5. Methodology

An inception workshop was held in February 2015, involving key project stakeholders from the provinces (Luang Prabang, Xayabouli and Xieng Khoung), and partner institutions (Department of Livestock and Fisheries (DLF), NUOL and National Agriculture and Forestry Institute (NAFRI). The project objectives and activities were thoroughly discussed to ensure there was clear understanding that although this project and project AH-2012-068 project were to run concurrently and be implemented by similar teams, they had entirely different research objectives and activities. Planning strategies were discussed to ensure the data collected was of value to the project team and end-users (farmers and extension workers). Ownership over the project research activities and interventions by the Lao team was deemed important for long term sustainability, especially post-project. Project workshops were conducted annually to provide stakeholders and partners with progressive updates and opportunities for reflection and discussion of future activities. Mid-term and final project reviews were conducted with Australian Centre for International Agricultural Research (ACIAR) staff and appointed delegates, providing strategic and constructive feedback to ensure target objectives were achieved.

Provincial project locations were selected in close consultation with the DLF and consideration of successes and challenges from the previous ACIAR project (AH-2006-159). Village and farmer selection criteria were determined at the project inception meeting. These included:

Village criteria

- Village leaders and farmers willing to cooperate and improve livestock health and production, trial new technologies such as fattening stalls and forage growing
- At least 200 large ruminants
- A minimum of 10km between project villages
- Year-round access

Farmer criteria

- Willing to cooperate with the project and adopt new technologies, provide access to animals
- Currently own large ruminants (+/- poultry, goats and pigs)
- Own at least 2 sows (5 farmers per village)

Each village required a minimum of 20 farmers to participate in project activities to ensure there was a sufficient and representative sample available for data collection activities. A randomisation approach was not utilised for farmer selection as this enabled any interested farmer the opportunity to participate or withdraw at their own volition, as per Human Ethics guidelines and approval processes.

The project implemented a participatory epidemiological approach to ensure improved disease understanding and options for control (Catley et al., 2012). Communities were engaged in defining and prioritising veterinary related problems and solutions (Catley et al., 2012). This participatory approach provides flexibility in attempts to improve understanding of animal diseases, particularly in marginalised and resource-poor areas, plus ensures localised and appropriate disease control options are implemented (Thrusfield, 2018). Qualitative and quantitative data collection activities were conducted alongside the participatory epidemiological activities, ensuring critical assessments of interventions and positive project progress. Research activities were developed by the collaborations of the central Lao and Australian team members, with an individual from each team being responsible for the design, implementation, analysis and reporting of activities. All team members were involved with the review of research plans through all stages.

The following provides an outline of the methodology used for each of the objectives.

Objective 1

Three provinces were selected for research locations including Xieng Khoung, Xayabouli and Luang Prabang. Each were selected based on known livestock numbers, importance of livestock to smallholder family income and their proximity and importance to domestic and export trade markets and the associated animal movement routes. The provinces all had adequate infrastructure, ensuring project activities and associated travel would occur safely. Within each province, three villages meeting the above criteria were selected (Figure 1; Table 1). Villages were designated as Vaccination only (V), Biosecurity only (B) and Biosecurity with Vaccination (BV) (Table 2). This reflected potential disease mitigation strategies aimed at achieving enhanced biosecurity and a potential zone for freedom from FMD. Assessment of the interventions introduced at each village was obtained through longitudinal serology and KAP surveys. These aimed to identify interventions that were most successful at reducing risks of animal exposure to and development of transboundary disease, plus improved farmer uptake and implementation. A CBA was conducted to provide an economic comparison of the village-level interventions.

Table 1. Project locations in Luang Prabang, Xayabouli and Xieng Khoung provinces

Province	District	Village	Classification	Large Ruminant owning households
Luang Prabang	Pakou	Hardkor	Vaccination	53
Luang Prabang	Pakou	Phonhom	Biosecurity	48
Luang Prabang	Pakou	Hardkham	Biosecurity with Vaccination	32
Xayabouli	Phieng	Phonsavang	Vaccination	93
Xayabouli	Phieng	Naboum	Biosecurity	352
Xayabouli	Phieng	Nanonghoung	Biosecurity with Vaccination	139
Xieng Khoung	Phoukhoud	Naxaythong	Vaccination	141
Xieng Khoung	Phoukhoud	Laethong	Biosecurity	75
Xieng Khoung	Phoukhoud	Bong	Biosecurity with Vaccination	97

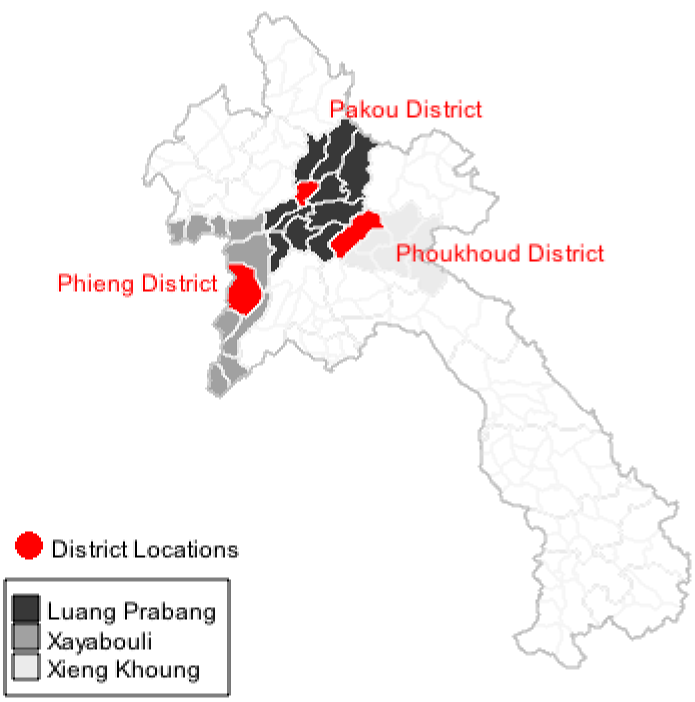

Figure 1. Map of project locations

Table 2. Interventions implemented in project villages for each disease mitigation strategy

Disease mitigation strategy	Interventions implemented
Vaccination only	• Biannual vaccinations for Haemorrhagic Septicaemia and Foot and Mouth Disease • On-the-job and formal training on livestock nutrition (forage growing and feeding) • Advice was given on biosecurity if requested by farmers
Biosecurity only	• Biannual vaccination for Haemorrhagic Septicaemia • On-the-job and formal training on biosecurity protocols to reduce disease incidence • On-the-job and formal training on livestock nutrition (forage growing and feeding)
Biosecurity with Vaccination	• Biannual vaccinations for Haemorrhagic Septicaemia and Foot and Mouth Disease • On-the-job and formal training on biosecurity protocols to reduce disease incidence • On-the-job and formal training on livestock nutrition (forage growing and feeding)

Structured data collection activities

KAP surveys

This survey documented the biosecurity and disease status, prevention and treatment practices of smallholder farmers in the nine project villages. Simple random sampling was used to select 15-20 farmers per village to participate in the surveys with a total of 177 surveyed in 2015, and 133 in 2018. Farmers were selected from the same farmer sampling frame compiled at the commencement of the project. Original project activities planned to conduct the surveys at baseline, midpoint and end of project, with the midpoint survey capturing a smaller sample. However, due to time restrictions after the midpoint survey, it was deemed more beneficial to conduct a qualitative focus group discussion data collection activity as this ensured a more thorough investigation of farmer attitudes and their actual and potential resistance to interventions. Surveys were conducted one-on-one, face-to-face with Lao team members and farmers. The survey was separated into four parts: (1) participant demographics and household information; (2) farmer knowledge, separated into animal health and biosecurity (/10), nutrition (/5) and reproduction (/5); (3) farmer attitudes, separated into animal health and biosecurity (/9), nutrition and reproduction (/5) and marketing (/3); and (4) farmer practices, separated into general large ruminant use (/5), biosecurity and animal health (/15), nutrition and reproduction (/7). Results were used to direct extension activities and monitor the effectiveness of the interventions implemented in the communities.

Longitudinal livestock survey

This survey collected individual livestock information (body weight, estimated value, body condition score, coat condition and serum for FMD serostatus) over the course of the project. Collections were scheduled to occur in each village every four months and monitor approximately 20 animals per village. Ear-tags with unique identifying numbers were used to identify individual animals. DIVA[1] testing utilising Non-Structural Protein (NSP) and serotype-specific Structural Protein (SP) antibody enzyme-linked immunosorbent assays (ELISA), were used to monitor the seroconversion of animals. This contributed to measuring the success of interventions preventing FMDv circulation within the large ruminant population.

Cost-benefit analysis

A CBA was used to determine which of the three interventions implemented was the most cost-effective disease mitigation strategy. Data was collected primarily through a financial impact statement questionnaire (FISQ) conducted in July 2018 (n = 90) in Xieng Khoung and Luang Prabang and in May 2019 (n = 56) in Luang Prabang. Additional data was obtained through the literature and the FGD to ensure an accurate representation of farming systems in each intervention group. Data from the farmer trading surveys conducted in the AH-2012-068 project was also utilised to build the baseline case. Economic modelling involved the development of a baseline case for a cost-benefit analysis, with

[1] *The ability to* D*ifferentiate* I*nfected from* V*accinated* A*nimals*

mitigative success conducted to examine the 'true cost 'of FMD in these villages. Sensitivity analysis was applied to account for economic fluctuations impacting income and expenditure.

Objective 2

Activities within this objective were designed to assess and evaluate the current disease event report-response systems present in northern Laos. The serology from the longitudinal study (activity 1.5) and serology and questionnaire data from a cross-sectional FMD serosurvey in northern Laos were utilised to assess the current FMD reporting systems. In addition, negative disease reporting was introduced, involving district and provincial staff contacting the project team in Luang Prabang to notify of the absence or presence of disease. The report-response system was further investigated through FGDs, with case study surveys conducted to further explore some of the FGD findings.

Farmer training activities covered a range of topics. Information on nutrition and parasite control was provided to farmers in all project villages, whereas those located in the Biosecurity only and Biosecurity with Vaccination villages were provided with formal biosecurity training. The training provided information and hands-on skills on a range of tasks, including the checking of expiry dates on vaccine bottles, the administration of vaccinations, and strategies including hygiene that improves biosecurity to prevent further spread of disease if an outbreak occurs. The introduced biosecurity practices also included quarantining new and sick animals, using separate feed and water equipment for sick animals, and tending to these last, practising appropriate hygiene such as handwashing, plus the washing of footwear after visiting properties or dealing with animals.

The role of small ruminants in FMDv transmission and circulation in South-East Asia has not been previously investigated. A collaboration developed in consultation with colleagues from the Commonwealth Scientific and Industrial Research Organisation Australian Animal Health Laboratory (CSIRO-AAHL) resulted in the opportunity between September 2017 and March 2018, to conduct a cross-sectional FMD serosurvey in the Lao goat population. Serum samples were collected from northern, central and southern provinces and examined for the presence of SP and NSP antibodies. In February 2019 a two-stage cross-sectional large ruminant serosurvey was conducted in the northern provinces, with 1.6 million FMD vaccinations administered to cattle and buffalo, as part of the Australian government funded STANDZ[2] vaccination program, conducted between 2012 and 2016. The STANDZ program proved very successful in suppressing FMD outbreaks in the northern provinces. However, following cessation of the program in 2016, FMD slowly re-emerged, with an increasing number of reported outbreaks, most likely due to both the decreased number of naturally immune and vaccinated animals. This survey included a questionnaire focusing on farmer perception of outbreaks and their reporting actions when they suspected an outbreak. This information was cross-checked with available disease reporting information for those time periods.

An opportunistic investigation of a porcine reproductive and respiratory syndrome (PRRS) outbreak, reported in Bokeo province in August – September 2016, was conducted. PRRS virus was introduced into Laos in 2010 (Ni et al., 2012) and has had a devastating impact on the pig population. Serum samples were collected for antibody ELISA testing and a risk-factor survey was conducted. The risk factor survey obtained information on husbandry and reproductive management practices, reasons for keeping pigs, other livestock or animals present, and trading behaviours.

A collaboration with the Mahidol Oxford Tropical Research Unit (MORU) was instigated that led to an investigation into zoonotic diseases commonly found in goats, including *Brucellosis* species and *Coxiella burnetii* (causative agent of Q fever). The survey was conducted in five provinces (Vientiane capital, Xayabouli, Xieng Khoung, Savannakhet and Attapeu) between October 2016 and May 2017. Serum samples (n = 1,458) were collected from goats from smallholder, semi-commercial and commercial farms in these locations. The serum was tested for pathogen specific antibodies in the ELISA testing and the Rose Bengal assays. Animal (age, breed and sex), farm-level (farm size, location and production system) and risk factor data were collected for analysis with serological results.

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[2] The Stop Transboundary Animal Disease and Zoonoses (STANDZ) initiative was funded by the Australian Government to encompass the South-East Asia and China FMD (SEACFMD) campaign, the Strengthening Veterinary Services Initiative (STRIVES) and One Health Component with a focus on rabies reporting. A major component of the initiative in northern Laos focused on FMD control through mass vaccination.

Objective 3

Public awareness, understanding and mitigation of the risks associated with FMD and certain livestock management practices, such as communal grazing and the trading of sick or unvaccinated animals, are widely recognised as being crucial to sustainable control and eradication of FMD. A range of communication strategies were investigated and developed, including digital training programs utilising verbal and written information and village information sessions conducted in tandem with other intervention activities. Annual general meetings were held, providing an opportunity for project stakeholders to attend and provide feedback and strategic input into activities and planning for the following year. Project data and findings were utilised in regular SEACFMD meetings to provide a situation update for northern Laos.

Pathology training activities were conducted with the NUOL, Nabong, adapting and utilising training materials developed for Australian field veterinarians. These training activities involved formal lectures and hands-on necropsy activities. University staff were involved in disease case studies that were progressed to scientific publications. A series of scientific writing workshops were conducted in the final stages of the project aimed at improving the research and communication capacity of staff and students at NUOL and SVKU. These workshops culminated in a student conference, providing final year students with the opportunity to present their research and practice the skills developed through the capacity building activities.

FGDs were conducted at the end of the project in all villages to obtain farmer feedback on perceptions and impacts of the project, providing useful information for future ACIAR projects. The RDA, a local Lao non-government organisation, conducted the data collection, working closely with the local district project teams. Extensive planning was involved in the preparation of this activity, ensuring that questionnaires promoted open conversations and that there was adequate inclusion of female farmers and members of ethnic minorities. Group discussions were conducted in male only, female only and combined gender groups, followed by semi-structured individual interviews. Children also participated in a supervised children's discussion session to determine the impact of the project on their daily activities. Data were collected on paper and using KoBo[3], a mobile acquired data platform which also facilitated recordings.

The team from the Rural Development Agency and Francesca Earp conducting farm observations as part of the Focus Group Discussions in Savannakhet (Photo: Viengmany)

[3] https://www.kobotoolbox.org/

6. Achievements against activities and outputs/milestones

Objective 1: To develop a model 'whole of village biosecurity program' for pigs, poultry, goats, cattle and buffalo.

no.	activity	outputs/ milestones	completion date	comments
1.1	Conduct an inception workshop with key stakeholders to confirm project aims and background understanding, select potential project sites and participants, plus identify project training requirements.	Identify potential project villages (PC), including survey training and data management for project, provincial and district staff (A)	21 February 2015	Site selection deemed appropriate by all relevant stakeholders based on the proximity to domestic and export trade and associated animal movement routes.
	The inception workshop was held on 21 February 2015, in Vientiane and brought together key project stakeholders from the DLF and NAFRI as well as provincial leaders from three provinces including Xieng Khoung, Luang Prabang and Xayabouli to outline the project objectives and planned activities. At this meeting, the criterion was agreed upon for location (province, district, and village) and farmer selection as well as the training required by provincial staff to conduct project activities.			
1.2	Conduct an audit of potential projects sites then select 9 villages in 3 provinces using selection criteria established in Activity 1.1.	Completed field visits and field reports for recommending village inclusion (PC,A)	October 2015	Project sites were confirmed after a series of field visits to each province and extensive stakeholder consultation
	An audit of potential project sites was conducted to select 9 villages, 3 per province (1 x vaccination (V); 1 x biosecurity (B); 1 x biosecurity with vaccination (BV) (Table 1, Figure 1). *Provincial project team members were confirmed in June 2015, with a two-day project team meeting held in Luang Prabang in July 2015 to provide training to staff so that they were cable of effectively conducting research activities. Project villages were confirmed by October 2015 with a preliminary survey being conducted within each village to determine the total number of households, households with livestock, household financial status and households with females where the females are the head.*			
1.3	Identify and select a minimum of 30 farmers per village to participate in the project.	Smallholder participant database with effective double identification (name and ID number of people and livestock)	September 2015	Selected project farmers provide the sampling frame for the planned surveys.
	From the audit data collected in Activity 1.2, 30 households per project location were randomly invited to participate in the project and receive all associated interventions, other households were able to participate in activities as the project progressed. To facilitate timely KAP surveying, a sub-sample of 15-20 farmers from each village were randomly selected. Note: farmer selection did not exclude other farmers within each village from observing and adopting interventions such as forage growing/feeding and FMD vaccinations. All project sites experienced a high level of farmer participation and retention. However, in accordance with the University of Sydney Human Ethics Committee regulations, farmers could cease participation with the project at their own discretion with no negative repercussions.			
1.4	Develop and deliver in one of each of the three villages in each province a program of: 1) V – FMD vaccination interventions only, 2) B – Biosecurity and production program (including interventions in nutrition, health, reproduction, marketing and biosecurity) to engage farmers and promote uptake, 3) BV – Implement both V and B together.	A detailed description of interventions and implementation instructions (A, PC)	July 2019	Sourcing forage seeds within Laos proved problematic due to shortages. Hence, seed was sourced from Thailand resulting in preferred species not always being available. Reproductive and biosecurity interventions were met with some resistance due to limited land availability.

	The FGD involved an audit of the interventions implemented within the project sites to determine farmer perceptions and provide feedback for future projects. FMD and haemorrhagic septicaemia (HS) vaccinations were administered throughout the project lifespan, with no official outbreaks reported in any of the project sites. Data collection activities indicated that quarantine practices were implemented. However, the full understanding and appropriate implementation of the practices did not occur. The reasons were explored further in the FGD.			
1.5	Conduct an FMD virus serological longitudinal study across all project sites to determine intervention (V, B, BV) effectiveness in preventing virus transmission.	Comparison of serology across project lifetime to indicate intervention impact (PC, A)	January 2019	Serological samples were collected for approximately 20 large ruminants in the 9 project villages.
	Longitudinal data for large ruminants (approximately 20 per village), including serum, body weights, estimated value, body condition score and coat condition were collected at four-monthly intervals. Serum samples we tested in 2018 and 2019 for NSP and SP FMDv antibodies in order to identify exposure to circulating FMDv. Serum results and production parameters were then used to determine which intervention group was most successful at minimising exposure and improving production. Other opportunistic and collaborative disease investigation activities, including zoonoses, parasites and FMD in goats and PRRS in pigs were conducted throughout the project.			
1.6	Conduct a cost benefit analysis (CBA) of intervention options for the 'whole of village biosecurity program'.	Recommended least-cost 'whole of village biosecurity program'	December 2018 June 2019	The CBA has indicated that biosecurity with vaccination, if implemented correctly, is the recommended disease mitigation strategy despite initial setup costs.
	Data was collected throughout the project through a range of different activities to ensure the most accurate information was obtained. Descriptive analysis indicated that all three intervention strategies were successful at mitigating disease if applied correctly. Further, a sensitivity analysis was applied to the economic models to determine the strategy affected the least by cost fluctuations; this demonstrated that vaccination activities were highly sensitive to fluctuations. Therefore, biosecurity with vaccination was determined to be the most cost-effective strategy.			
1.7	Conduct baseline and midpoint farmer, village veterinary worker (VVW), and extension staff knowledge, attitudes and practices (KAP) and socioeconomic surveys to assess intervention impacts among the three groups (V, B, BV). Conduct farmer Focus Group Discussions (FGD) to obtain more detailed qualitative data regarding attitudes and practices among the three intervention groups (V, B, BV).	A detailed assessment of current KAP of farmer groups, VVWs, district and provincial staff (PC, A)	November 2015 May 2018	Improvements occurred in animal health and biosecurity and reproduction knowledge scores. Overall (animal health and biosecurity, nutrition and reproduction) attitudes improved. Uptake of reproduction practises was still very low.
	KAP surveys were conducted in 2015 (baseline) and 2018 (midpoint). Initial plans included a final project KAP survey to be conducted in May 2019. However, based on analysis of the previous two surveys and feedback from the end of project review it was determined that a qualitative research activity in the form of Focus Group Discussions, facilitated by RDA Laos would be more beneficial and assist with validating quantitative research findings.			

PC = partner country, A = Australia

Objective 2: To improve current disease event reporting and emergency response systems, primarily focused on potential FMD-free zoning in northern Laos

no.	activity	outputs/ milestones	completion date	comments
2.1	Identify and assess current disease event reporting systems for cattle and buffalo, pigs, goats and poultry, to identify critical constraints and improvement opportunities.	Evaluation of the current reporting system considered along with serological results in Activity 1.5 to develop recommendations for improvements (PC, A)	July 2019	Most official reports are still being submitted on paper via fax or postage with lack of record keeping of initial verbal reports. The reporting chain involves multiple steps and stakeholders, including private para-veterinarians (village veterinary workers) and government-employed animal health authorities.
	'Negative disease reporting' was implemented in project sites. Provincial staff members contacted the Luang Prabang based central project team to provide monthly reports. The number of diseases reported monthly was decreased from the initial 11 diseases of economic and zoonotic importance to four diseases of current concern based on local prevalence data. Focus group discussions found that it was not uncommon for district-level animal health authorities to decide not to report a disease event/outbreak to their provincial-level counterparts if there were less than three adult animal fatalities, suggesting a key blockage in the reporting process may be at the district level. The reporting process is still yet to be fully computerised, increasing the risk of losing historical data, such as Blackleg or Anthrax outbreaks which can impact future animal health programs.			
2.2	Evaluate FMD disease reporting and response network at the village and district level using qualitative research rapid assessment with RDA	Understanding of reporting and response systems at the village and district level (PC, A)	February 2018	Reporting actions at the village and district level were explored at the village and district level in the FGD.
	Key issues detected in the reporting process were associated with the discretion allowed at the district level for reporting disease events to the next level. VVW and district officials are hesitant to report a disease event if they are able to contain an outbreak to their jurisdiction. District officials advised that more than three adult animals are required to die for an FMD outbreak to be officially reported to the provincial level			

PC = partner country, A = Australia

The project team with provincial and district team members in Luang Prabang practicing blood sample collection for serological studies (Phot: Brooke Gallagher)

Objective 3: To develop a communication strategy for a widespread public awareness biosecurity campaign, potentially applicable to the Greater Mekong Subregion.

no.	activity	outputs/ milestones	completion date	comments
3.1	Develop pilot extension and training materials on FMD, biosecurity and disease prevention and control with the aim of being suitable to distribute nationally. Program to include digital stories, awareness signage, foot-baths, cartoons, posters, radio spots and cross-visits.	A dual language website, digital stories, signage, foot-baths at key sites, cartoons, radio spots and cross-visits developed	ongoing	Billboards and posters in project villages plus e-platforms are used to promote biosecurity messages. FGDs facilitated by RDA were used to evaluate the intervention uptake and general success of communication methods
	Billboards and posters promoting biosecurity messages have been displayed in all project villages. Team members also use social media (https://www.facebook.com/MekongLivestockResearch/?ref=bookmarks) and a website (https://mekonglivestock.wordpress.com/) to promote project activities using blogs and posts. *Farmer training and biosecurity handbooks were developed and provided to farmers and extension workers. However, more consideration of community literacy and dialect is recommended for future projects to ensure training materials are accessible to all project participants and minority groups are not excluded due to communication barriers. Dr Jim Young has developed an e-platform (https://www.closethegate.net/collections) that is designed for use in low resource and low literacy environments and will incorporate spoken (and written) messages in the local language.*			
3.2	Assess use of training programs and materials provided to farmers and district/provincial staff through RDA rapid assessment interviews	Training and public material meets the needs of wide ranging groups	August 2019	Audit of training activities conducted in the FGDs found low levels of participation by females and farmers of ethnic minority groups
	There was low training attendance by female farmers in all project sites. This was possibly due to an unintentional exclusion of female farmers due to socio-cultural factors. The disparity in attendances can have negative impacts on biosecurity adoption and uptake if there is not a good understanding of the importance of both males and females in the household. Training activities have been open to all project participants. However, based on attendance data, future activities should consider female-only training session, potentially facilitated by female extension staff.			
3.3	Use project data to assist regional decision making on allocation of resources for future FMD control strategies in Laos and the Greater Mekong Subregion. Build capacity within project staff, NUOL and SVKU staff and students	Contribute to regional understanding of FMD control through direct communication with the OIE Bangkok office and associated regional meetings. Capacity building through write-shops and research activities	July 2019	There has been the continual collaboration with project team members and the OIE SEACFMD. 'Write-shops' and a University conference were conducted in 2019 for NUOL and SVKU staff and student.
	The project team has very close links with the World Organisation for Animal Health (OIE) and the SEACFMD program and are routinely invited to regional meetings/activities to present research findings on FMD from project activities, plus address OIE meetings of member countries on biosecurity initiates and FMD control. The team has published several research activities investigating the biological and financial impacts of FMD, along with an FMD outbreak risk factor survey. Ms Corissa Miller (MVPHMgt student) and DLF staff investigated the household-level risk factors for FMD in Naxaythong District following an outbreak of a novel FMDv (O/ME-SA/Ind2001d) in 2015. A case-control questionnaire and serological study identified the risk factors associated with this emerging virus and the endemic circulating viruses in the outbreak area. Households sharing communal grazing land with neighbouring villages were found to have 5.5 times the odds of owning one or more animals with a laboratory-confirmed positive titre. Hence, implementing basic biosecurity and improved husbandry measures to minimise FMDv circulation at the household level is important, and reinforce the need to enhance the education of smallholder farmers in infectious disease control. As this study is one of the first FMD risk factors in Laos, it is likely to have an impact in directing biosecurity extension activities and transboundary animal disease control policy in the Mekong sub-region. *A series of three 'write-shops' were conducted for both NUOL and SVKU staff and students covering the scientific writing process from literature searches through to scientific presentations. These workshops culminated in a University Conference held in Vientiane in January 2020, which provided students and staff the opportunity to present their research to their peers.*			

PC = partner country, A = Australia

7. Key results and discussion

7.1.Knowledge, attitudes and practices

KAP surveys were conducted in 2015 (baseline) and 2018 (mid-point). A summary of the participants is provided in Table 3. In addition, the 2018 survey collected data from the seven VVWs participating in the project.

Table 3. Total number of questionnaires per province, ethnic group and village classification conducted in 2015 and 2018.

Province	Classifier	2015	2018	N
Luang Prabang	Biosecurity	20	13	33
	Biosecurity with Vaccination	20	15	35
	Vaccination	20	18	38
	Lao ethnicity	40	28	68
	Lue ethnicity	20	18	38
	Mixed ethnicity	0	0	0
Xayabouli	Biosecurity	20	13	33
	Biosecurity with Vaccination	20	13	33
	Vaccination	17	15	32
	Lao ethnicity	57	41	98
	Lue ethnicity	0	0	0
	Mixed ethnicity	0	0	0
Xieng Khoung	Biosecurity	20	15	35
	Biosecurity with Vaccination	20	16	36
	Vaccination	20	15	35
	Lao ethnicity	20	15	35
	Lue ethnicity	0	0	0
	Mixed ethnicity	40	31	71
Total		177	133	

7.1.1.Farmer knowledge

Biosecurity

Overall, the biosecurity knowledge scores (/10) increased from 6.07 (±2.24) in 2015 to 6.45 (±2.62) in 2018. There was no significant difference for each province between the two surveys (Table 4). In 2015 and 2018 there were significant differences between the provinces ($P < 0.0001 – 0.0001$ and $P < 0.0001 – 0.5067$, respectively) (Figure 2). Provincial differences may be a result of differences in the training capacity of provincial and district staff or project access and time spent in each of the provinces. Between the two collections, the overall scores for the ethnic groups did not differ significantly. However, in 2015 there was a significant difference between the Lao and Mixed (Lao and Hmong) groups (5.56 ±2.45 vs 7.50 ±0.87; $P = 0.0002$). In 2018 there was a significant difference between the Lue and Mixed groups (4.78 ±1.63 vs 7.68 ±1.98; $P = 0.0004$) and a difference nearing significance between the Lao and Mixed groups (6.36 ±1.62 vs 7.68 ±1.98; $P = 0.073$). Although difficult to determine without further investigations, it is likely that the language and cultural differences between the project staff and the farmers may impact their learning capacity and knowledge uptake. The only significant difference seen between the village classifications was in the 2018 survey between the BV and V groups (5.47 ±2.48 vs 7.17 ±2.66; $P = 0.01$). The V villages scored the highest in both surveys (6.22 ±1.85 in 2015 and 7.17 ±2.66 in 2018).

Table 4. Overall biosecurity knowledge scores (mean ±s.d.) and associated *P*-values for provinces between the two surveys

Province	2015	2018	*P*-value
Luang Prabang	4.3 (±2.1)	5.13 (±2.29)	0.307
Xieng Khoung	7.83 (±0.99)	7.52 (±1.94)	0.974
Xayabouli	6.1 (±1.82)	6.75 (±3.0)	0.631

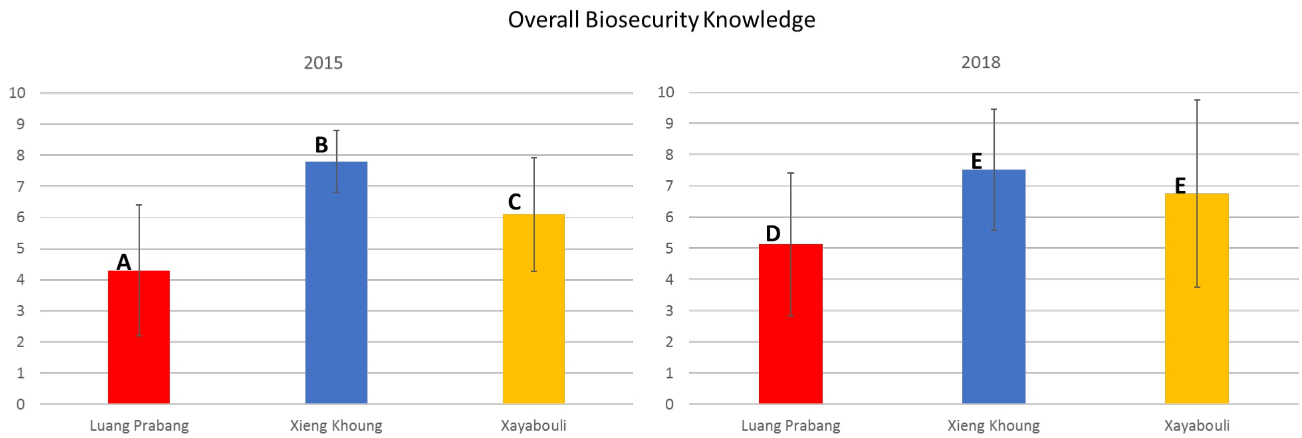

Figure 2. Overall biosecurity knowledge scores. The letters denote significant differences between provinces within each survey (2015: LPB vs XK < 0.0001, LPB vs XYL < 0.0001, XK vs XYL 0.0001; 2018: LPB vs XK < 0.0001, LPB vs XYL 0.0035, XK vs XYL 0.507).

When examining individual questions in the biosecurity section, several questions had overall lower scores in 2018 compared to 2015. These included questions regarding the definition of biosecurity, the role of regular vaccination, FMD transmission, antibiotic use for HS, appropriate quarantine practices for sick animals and highly pathogenic avian influenza (HPAI), zoonoses risks. This may be reflective of training methods; with 'on-the-job' training rather than structured 'formal' training sessions were the main methods implemented in 2016–18. The FGDs also indicated that extension workers were not confident in their own knowledge and understanding of biosecurity and this likely contributed to the lack of formal training sessions. Interestingly, there was a higher average correct score regarding antibiotic use for FMD, but not for HS. This indicates that there remains confusion regarding what situations antibiotics are deemed appropriate. The data indicates that formal training sessions are more appropriate for sustainable knowledge transfer and delivery of biosecurity and antimicrobial use education. Further, these training activities are very challenging, but highly warranted if progress with important issues including transboundary disease and antimicrobial residue and resistance risks are to be ameliorated.

Nutrition

Overall nutrition scores (/5) decreased between 2015 (3.24 ±1.67) and 2018 (2.96 ±1.58). At the provincial level, only scores from Xayabouli farmers differed significantly between the 2015 and 2018 (3.73 ±0.8 vs 2.56 ±1.28 respectively; $P = 0.0003$). There were significant differences between the provinces and ethnic groups (Figure 3). As with the biosecurity questions, the farmers scored lower in the 2018 survey. The most poorly answered questions were related to the need for freshwater (correctly answered by 50%), and the use of body condition score to assess the nutritional status (correctly answered by 28%). This suggests ongoing formal nutritional education and training is required for farmers to retain key information.

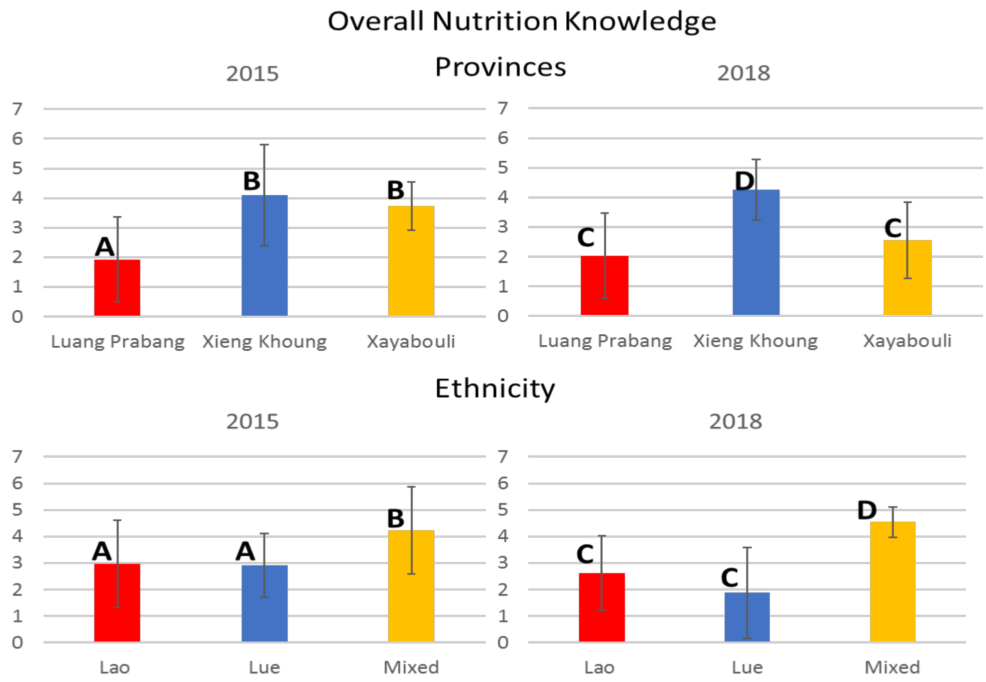

Figure 3. Overall nutrition knowledge scores. Mixed denotes villages with Lao and Hmong ethnicities. The letters denote significant differences between the groups within each survey (2015: LPB vs XK < 0.0001, LPB vs XYL < 0.0001, XK vs XYL 0.681, Lao vs Lue 0.999, Lao vs Mixed 0.0001, Lue vs Mixed 0.015; 2018: LPB vs XK < 0.0001, LPB vs XYL 0.461, XK vs XYL < 0.0001, Lao vs Lue 0.403, Lao vs Mixed < 0.0001, Lue vs Mixed < 0.0001).

Reproduction

Overall reproduction knowledge scores (/5) improved from 2.95 ±0.17 in 2015 to 3.06 ±1.47 in 2018. There were significant differences between the provinces and ethnic groups within both collection periods (Figure 4). The poorest answered questions were those relating to cow and bull selection for breeding (52% of farmers answered correctly) and the effect of feed during pregnancy on the health of calves (39% of farmers answered this correctly). As castration and planned joining are not routinely practiced by smallholder farmers throughout Laos, it is not surprising that questions relating to cow and bull selection for breeding were not well answered. As with the nutrition questions, these results suggest the need for prolonged farmer training in all areas to ensure ongoing knowledge transfer and retention. Discussions with project staff at the end of project meeting indicated that improving reproductive management has been a consistently difficult and challenging task, with socio-cultural factors identified in the FGDs and a general lack of farming resources impacting farmer adoption of reproduction activities. Specifically, their perception of farm productivity and their limited access to infrastructure to allow for effective separation of male and female animals are two constrictive factors commonly cited. While no ethnic group scored significantly better in the 2018 survey, the villages with a predominantly mixed ethnic group (Lao and Hmong) scored higher each year. As Hmong have traditionally owned large ruminant livestock as a primary income it is not unexpected that they have scored higher in the nutrition and reproduction sections. In addition, anecdotal evidence from the 2018 FISQ survey found that farmers often considered Hmong communities as the champion farmers in their village due to their superior farm maintenance, and animal husbandry knowledge and management skills.

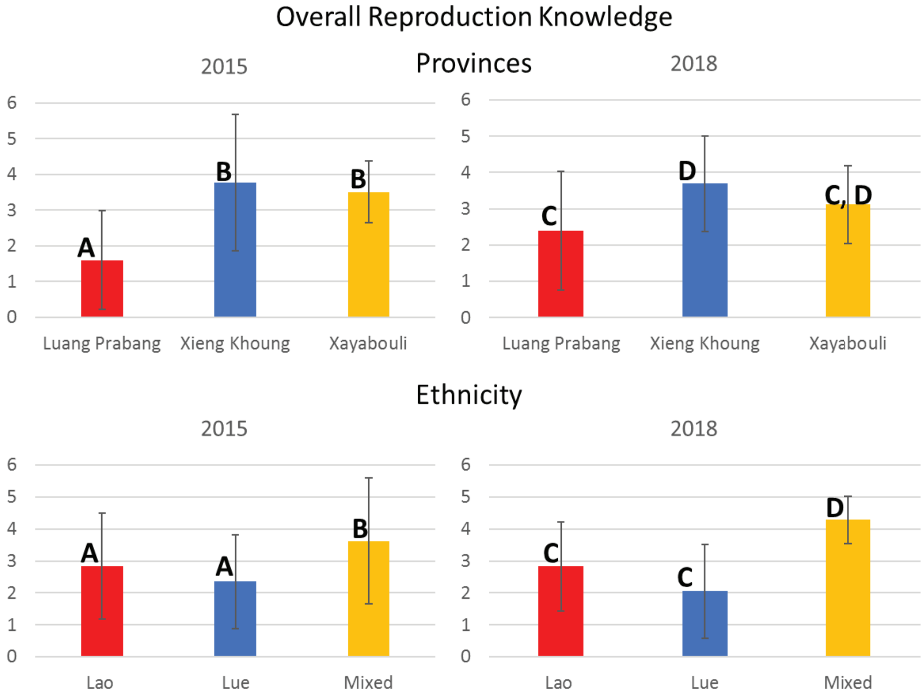

Figure 4. Overall reproduction knowledge scores. Mixed denotes villages with Lao and Hmong ethnicities. The letters denote significant differences between the groups within each survey (2015: LPB vs XK < 0.0001, LPB vs XYL < 0.0001, XK vs XYL 0.903, Lao vs Lue 0.796, Lao vs Mixed 0.059, Lue vs Mixed 0.034; 2018: LPB vs XK 0.0002, LPB vs XYL 0.163, XK vs XYL 0.419, Lao vs Lue 0.382, Lao vs Mixed 0.0002, Lue vs Mixed < 0.0001).

7.1.2.Farmer attitudes

Animal health and biosecurity

Most farmers in 2015 and 2018 did not believe vaccination was harmful (87.5% and 75.2%, respectively) and there was an improvement in the number of farmers not believing that vaccinations cause abortions (67.2% and 78.9%, respectively). There was an improvement between 2015 and 2018 for the number of farmers recognising that vaccination is a way to increase the value of livestock (75.1% and 81.9%, respectively). When asked what would make farmers more inclined to use their village veterinary worker (VVW), in both surveys over 95% wanted their VVWs to have better training, better equipment and more products. In both surveys, over 96% said they would be willing to pay their VVW for vaccinations. However, the cost they were prepared to pay for an FMD vaccination per animal decreased from 8,959.06 (±15,696.51) Kip (AU$ 1.47 ±2.57[4]) to 6,815.78 (±4,341.25) Kip (AU$ 1.13 ±0.72[5]). The FGD explored this further and found that 37% of farmers from V and BV villages were paying for vaccines and the associated labour or petrol costs. The value that farmers were paying for the actual vaccines were reportedly 5,000 kip (AU$ 0.85[6]) per animal which may explain the decrease in amount they were prepared to pay.

When asked if farmers thought unvaccinated livestock may become infected with FMD in the next 12 months, 55.4% believed they would in 2015 whereas 34.5% were unsure; and in 2018, 42.8% believed they would and 46.6% were unsure. In 2018, 32% of farmers from the B and BV villages and 65.2% of farmer from the V villages thought their unvaccinated livestock will become infected with FMD in the next 12 months. This indicates that farmers are still very concerned about the risk of FMD. Further, it suggests that while those in the villages with biosecurity training have improved confidence in biosecurity practices there is still room for improvement. In 2015, 16.9% of farmers felt that after recovering from FMD, livestock only returned to 20% of their previous value. In 2018, this had increased to 36.8% of farmers reporting

[4] *Conversion rate from 31 December 2015, https://www1.oanda.com/currency/converter/*

[5] *Conversion rate from 31 December 2018, https://www1.oanda.com/currency/converter/*

[6] *Conversion rate from 1 March 2020, https://www1.oanda.com/currency/converter/*

that their animals reached up to 40% of their previous value. Caution is required when interpreting these specific results, as there have been no official reports of outbreaks in project villages.

Nutrition and reproduction

In both surveys, there was high interest (80.2% in 2015 and 84.9% in 2018) in growing forages. The risks of feeding uncooked swill to pigs were better realised in 2015 with 53.6% believing there were risks associated with this practice, whereas in 2018 only 32.3% believed there were risks and 60.1% were unsure. While this survey was conducted prior to the African Swine Fever (ASF) outbreak in China, it is concerning that the dangers of swill feeding were not being regularly promoted to smallholder farmers. There was also a reduction in the number of farmers that were interested in early weaning of calves. In 2015, 56.5% indicated that they were interested and 23.2% were unsure, whereas in 2018, only 42.1% were interested and 35.3% were unsure. This trend may be due to improved nutrition of cows resulting in improved lactation and calf growth, obviating the need for early weaning, especially as this requires more labour and infrastructure. An alternative reason may also be that as extension staff identified reproduction management as a challenge, there may have been reduced focus throughout the project. Fewer farmers were showing interest in castration with 41.2% indicating they were interested in 2015 and 30.8% indicated interest in 2018. There was an increase in the number of farmers believing they know when their cattle and buffalo are pregnant (7.8% in 2015 to 19.5% in 2018). However, nearly 40% still did not know how to tell if their animals are pregnant. These results reflect the challenge of delivering even basic knowledge of livestock husbandry in rural communities in Laos and need for ongoing training to ensure farmers have the correct knowledge to influence attitudes and practices.

Marketing

No change was seen in the number of farmers knowing the market price before they sell animals, with only 56% of farmers in each survey responding that they knew the market price. There was a slight increase (12% to 16%) for farmers knowing where their livestock went after the sale. In 2018, most cattle appeared to be sold to other farmers in the village, whereas in 2015 they were being sold to a village in another commune. In 2018, most buffalo appeared to be sold to other villages in the district, whereas in 2015, most buffalo were being sold to villages in other communes. In 2018, goats appeared to be sold to other villages in the district, with pigs to other communes and provinces or for export, and most poultry stayed within the village.

7.1.3.Farmer practices

General large ruminant use

A slight change was seen in where farmers obtain their advice. In 2015, 59.3% of farmers were obtaining information from their VVWs and 37.3% from their district animal health authorities. In 2018, this changed to 45.1% obtaining advice from the VVWs and 42.1% approaching the district animal health authorities. This could possibly indicate that through project activities farmers have had the opportunity to develop relationships with their district animal health officials, presumably improving their communication and accessibility for farmers.

There was an increase in the number of farmers owning hand tractors, with 68% in 2015, increasing to 73% in 2018. This has corresponded with a decrease in the number of farmers keeping large ruminants for draught power, with 10% in 2015 decreasing to 4% in 2018. In addition, there was also a decrease in the number of farmers utilising livestock manure as fertiliser, with 77% in 2015 decreasing to 53% in 2018. There was also a decrease in the number of farmers using a biodigester, with 6% in 2015 down to 1% in 2018. However, this may reflect increased access to electricity, with 90.5% of the rural population having access to electricity in 2017 (World Bank, 2019).

Animal health and biosecurity

In 2015 and 2018, farmers were asked about their treatments for large ruminants that had been affected with FMD. In 2015, 44.1% used antisepsis, 57.6% used lime juice, and 20.3% used topical antibiotics on lesions, with 46.3% using injectable parenteral antibiotics. There were interesting changes in the response in the 3 years between surveys. In 2018, 24.1% used antisepsis, 66.2% used lime juice, and 9.8% used topical antibiotics on lesions, with 36.8% using injectable parenteral antibiotics. While this indicates some improvement on the inappropriate use of antibiotics, as there have been no official reports of FMD in the project villages during the project lifespan, caution is required when interpreting these findings.

There was a reduction in the amount of money farmers were willing to pay for a course of antibiotic treatment for an FMD affected animal. In 2015, farmers were willing to pay 57,394.96 (±57,034.22) kip (AU$ 9.44 ±9.38[7]), whereas in 2018, this reduced to 24,689.47 (±28,350.22) kip (AU$ 4.10 ±4.70[8]). This may reflect a shift in the perception of the need for antibiotics for FMD. Interestingly, fewer farmers appeared to have been told to withhold from selling their livestock for a period after the use of antibiotics, with 42.4% in 2015 being told and only 36.1% being told in 2018.

There was an increase in the number of cattle being vaccinated for FMD (44% in 2015 increased to 48% in 2018) but a decrease in the number of buffalo vaccinated (45% in 2015 decreased to 38% in 2018). A similar trend was seen with HS vaccinations for cattle and buffalo (63% to 76% and 52% to 47%, respectively). Field observations noted that the lack of animal identification and reduced preference for handling buffalo may have limited the number of buffalo presented for vaccination. Goats and pigs were not reported to be vaccinated against FMD; this is unsurprising as these species are not routinely included in FMD vaccination programs in Laos.

Despite no official FMD reports, in 2018, 6.7% of farmers believed their large ruminants or pigs had been affected by FMD and 20% believed their large ruminants had been affected by HS. While the FMD number is low, and there is some speculation as to whether these may be 'misdiagnoses' by the farmers, there should be accompanying official reports to support these farmer observations. However, these reports are not available at the central level. Review of the 'negative disease reports' did not provide detailed information on potential village level reports and subsequent investigations (Section 7.2.1). Based on information obtained in the FGD, reports of suspected FMD are unlikely to be officially recorded if there are less than three adult animal mortalities or if the outbreak is well contained. Longitudinal serology (Section 7.2.2) does provide evidence of FMDv transmission within the project sites. However, as many of these animals were vaccinated, the presence of clinical disease is expected to be very mild and outbreaks may have been missed, not reported, or contained within the village or herd, depending on management practices.

There was an improvement in the number of farmers reporting that they 'always' separate newly purchased stock, with 9% reporting in 2015 and 28.5% reporting in 2018. However, in 2018, 36.1% reported that they never do this. For management of sick animals, 38.9% in 2015 and 38.3% in 2018 reported they 'always' separate sick animals from healthy animals. Unfortunately, the number who reportedly never did this increased from 29.9% in 2015 to 42.8% in 2018. In 2018, farmers were asked about specific quarantine practices they undertook when separating sick or new incoming livestock; these results are in Table 5. The FGD and associated field observations further investigated quarantine strategies. Group discussions found that most participants did not quarantine new or sick animals. Reasons given were that it was too laborious, there was limited land available and it may interfere with livestock interactions and herd hierarchy. There was also a sense of helplessness with some farmers stating that they did not think they could stop the spread of diseases so there was no point trying.

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[7] *Conversion rate from 31 December 2015, https://www1.oanda.com/currency/converter/*

[8] *Conversion rate from 31 December 2018, https://www1.oanda.com/currency/converter/*

Table 5. The proportion of farmers reporting quarantine practices for newly acquired and sick livestock

Quarantine practice	For newly acquired livestock	For sick animals requiring treatment
Tether the animal separately in the field	12.0%	39.8%
Keep in pens completely separated from other animals*	16.5%	30.1%
Use separate buckets for feeding	13.5%	17.3%
Attend to these animals last	12.0%	12.0%
Wash my hands before tending to these animals	11.3%	10.5%
Wash my hands after tending to these animals	11.3%	9.8%

*field observations showed non-quarantined animals coming in to contact with quarantined animals

In the last 5–10 years there has been a consistent increase in red meat consumption in South-East Asia (OECD, 2018). This increase in regional consumption may be the reason why the number of farmers reporting that traders visiting their farms, more than doubled from 4% in 2015 to 9% in 2018. There was also an increase in the number of livestock-owning individuals visiting farmers (55% and 2.89 visits per week, increasing to 91% and 5.7 visits per week) and non-livestock owning individual visiting farmers (7% and 1.8 visits per week to 26% and 2.5 visits per week). Discussions with project staff indicated that many district officials like to promote the use of farmer networks to disseminate information within villages, rather than implementing a top-down approach. These changes in household visitors may be reflective of this and an increase in knowledge sharing within communities.

During the dry and wet seasons, most farmers did not come into contact with livestock they did not own (67% in 2015 for both seasons and 51.1% in 2018 for both seasons). The number of farmers containing cattle with fencing has increased from 48% in 2015 to 95% in 2018. The time spent per day fenced in the dry season increased from 42.3% in 2015 to 53.5% in 2018 and during the wet season, decreased from 96.8% in 2015 to 75% in 2018. All farmers surveyed utilised fencing for their buffalo, with buffalo fenced for 54% of the day in 2015 during the dry season, increasing to 57.2% in 2018. During the wet season, buffalo were fenced for 64.6% of the day in 2015, decreasing to 54.3% in 2018. In 2018, when farmers were asked if other animals could come into contact with their livestock whilst fenced, 50.4% were unsure, 36.1% said yes, other animals could come into contact with them, and only 13.5% did not think that their animals could make contact with others while fenced. While it is promising to see that more farmers are utilising fencing, field observations during the FGD found that many animals were able to have contact with other animals through the fencing, demonstrating that the risk of direct disease transmission remains.

During disease outbreaks, VVWs are the primary individual receiving farmer reports (74% in 2015 and 59.4% in 2018). However, the number of farmers advising they will report disease decreased from 94% in 2015 to 85% in 2018. Most farmers will report on the same day that they detect an issue (92% in 2015 and 69% in 2018). However, the number of farmers saying that they never report increased from 1% in 2015 to 21.8% in 2018. These changes may well be due to a recent decrease in disease events so farmers may feel that they never have to report the disease. Further, comments made during the serosurvey and the FGD indicated that farmers did not trust the reporting system and this influenced their likelihood to report.

Nutrition and reproduction

Cattle being fed fresh grass and allowed to field graze increased from 2015 to 2018 (50% to 54% and 67% to 72%, respectively). However, there is still a high proportion of farmers feeding rice straw to their cattle (58% in 2015 and 64% in 2018). The number of farmers feeding fresh grass to buffalo increased from 30% in 2015 to 41% in 2018. In 2018, goats were being fed a range of feeds, including rice bran (56%), vegetables (36%), cereals (24%) and household scraps (48%).

Dry season communal grazing decreased from 88% to 76% over the study period and wet season communal grazing decreased from 75% to 50%. There was no change seen in the number of farmers selecting bulls for breeding, with less than 17% practicing this. Other breeding management activities were poorly practiced, including the separation of unwanted males (10% down to 6%) and castrating unwanted males (1% increased to 2%).

There has been an increase in the number of farms using a feeding plan, increasing from 13.5% in 2015 to 26.3% in 2018. However, weaning is still poorly practised with only 4.5% of farmers practicing this in 2018 (decreased from 11.8%). These findings support the claims made by project staff that reproductive management has been a very challenging topic to improve with smallholder farmers.

7.2. Negative disease reporting, large ruminant longitudinal and cross-sectional FMD serological studies

7.2.1. Negative disease reporting

Negative disease reporting (the reporting of specific absence of diseases) was introduced to all project sites at the inception of the project in 2015. The monthly reports were initially planned to collect information on 11 diseases of economic or zoonotic importance: FMD, haemorrhagic septicaemia (HS), blackleg, anthrax, classical swine fever (CSF), PRRS, highly pathogenic avian influenza (HPAI), fowl cholera, Newcastle disease, duck plague, and rabies. However, as the project progressed a decision was made to limit this list to FMD, HS, CSF and fowl cholera as these presented as the main diseases of concern.

The reporting process was similar to the regular process for an outbreak or disease event. The VVW would report to their district animal health authority, who would then report to their provincial animal health authority, who would then be responsible for contacting the central project staff at the Luang Prabang project office. There were no measures in place to confirm that the reports were originating from staff or VVW who visited these project sites in the preceding month. Information gathered in the FGD and final workshop suggests that individuals at each point in the reporting process are expected to use their discretion whether to report to the next level. In particular, in situations where there are less than three adult livestock fatalities, or if the outbreak is able to be contained to the village or district, the district animal health authorities may not deem it necessary to report this event to the provincial animal health authorities. This finding is concerning and warrants further investigation, particularly as there are diseases, including FMD, that rarely result in high mortality rates but significantly impact livestock production. In addition, the flexible nature of such reporting can result in negative impacts on the ongoing control of FMD, contributing to a lack of reliable prevalence and incidence data. This affects the knowledge and perceptions by government, and international animal health agencies, plus the ability of donors to prioritise and designate appropriate funding for controlling disease. This lack of accurate epidemiological data also hinders the progression of the country in the progressive control pathway for FMD (PCP-FMD[9]).

7.2.2. Longitudinal FMD serological study

Over the course of the project, 640 serum samples and weights from approximately 184 large ruminants were collected in all nine project village sites. The serum samples were tested for the presence of NSP FMD antibodies. Factors associated with FMD seropositivity were also investigated using univariable generalised linear models (GLM) at the large ruminant level (using sample serostatus) and at the farmer level (using proportion FMD positive per farmer per collection); these data are presented in Table 6. There were no significant differences between the categories and subcategories for age, species, sex, origin, use, weight, estimated value or vaccination in the preceding 6 months at the large ruminant level. At the farmer level, there were no significant differences found for farmer age or the subcategories of species farmed.

NSP positive samples were tested for serotype-specific SP antibodies; these are presented in Table 7. Serological evidence indicates that animals in the B villages also received FMD vaccinations, with this observation also supported by the findings of the FGDs. As a result, for statistical modelling, B and BV

[9] *The global OIE-FAO progressive control pathway for foot and mouth disease control (PCP-FMD)*

villages were both coded as BV. There were four samples that were NSP positive yet negative for both O and A serotype-specific SP antibodies. This is highly suggestive of neutral FMDv infection which may have resulted in unrecognised clinical disease, as occurs with clinical suppression in vaccinates. Of the samples that were NSP positive, 17 were serotype O SP positive (Table 7). This could be due to the serotype A SP antibodies from bivalent vaccinations falling below the detectable level, or alternatively, this may be the result of a natural serotype O infection. There is evidence of animals in the project locations being exposed to naturally circulating FMDv as 27% of samples from animals 3 years or under were NSP positive.

Table 6. Summary of non-structural protein (NSP) seropositive large ruminants and farmers with seropositive animals from samples collected in northern Laos between October 2016 – February 2019 (n = 640). *P*-values presented are for variables in each of the two models (large ruminant-level and farmer-level) in the univariable generalised linear models.

	Large Ruminant Level		
Variable	**NSP Positive (%)**	**Total samples**	***P*-Value**
Collection Period			7.74E-09
Early Dry Season (2016)	21 (11.4)	184	
Late Dry Season (2017)	45 (29.2)	154	
Wet Season (2017)	24 (31.6)	76	
Dry Season (2018)	45 (37.5)	120	
Dry Season (2019)	43 (40.9)	105	
Village Classification			0.0001
Vaccination	40 (18.6)	215	
Biosecurity with Vaccination[a]	138 (32.5)	425	
Use			0.182
Draught	0 (0)	0	
Fattening	0 (0)	1	
Breeding	151 (26.7)	566	
Other	18 (38.3)	47	
Vaccination in the preceding 6 months			0.361
Yes	88 (26.3)	335	
No	90 (29.5)	305	
Origin			0.476
Born in the Village	162 (27.3)	594	
Introduced to the Village	6 (35.3)	17	
Age category			0.5028
≤12 months	28 (23.5)	119	

>12 months ≤3 years	49 (29.5)	166	
>3 years	98 (28.2)	348	
Species			0.593
Cattle	143 (28.8)	497	
Buffalo	31 (24.4)	127	
Unconfirmed	4 (25)	16	
Sex			0.802
Male	37 (26.2)	141	
Female	132 (28.0)	471	
Unconfirmed	9 (32.1)	28	
Weight	174 (28.0)	621	0.862
Estimated Value	171 (27.7)	616	0.627
Total	178 (27.8)	640	
	Farmer level		
Variable	**Farmers with Positive large ruminants (%)**	**Total number of farmers**	***P*-Value**
Collection Period			0.001
Early Dry Season (2016)	20 (21.7)	92	
Late Dry Season (2017)	35 (43.2)	81	
Wet Season (2017)	19 (47.5)	40	
Dry Season (2018)	37 (61.7)	60	
Dry Season (2019)	36 (62.1)	58	
Village Classification			0.024
Vaccination	35 (29.9)	117	
Biosecurity with Vaccination[a]	112 (52.3)	214	
Species presented at that collection			0.760
Cattle	107 (47.5)	225	
Buffalo	21 (34.4)	61	
Mixed	18 (41.8)	43	
Farmer age	137 (44.2)	310	0.985
Total	147 (44.4)	331	

[a] Due to the serological evidence and field reports of large ruminants in the 'Biosecurity Only' villages receiving FMD vaccinations these villages were included in the 'Biosecurity with Vaccination' villages

Table 7. Summary of non-structural protein (NSP) and serotype-specific structural protein seropositive results from large ruminant samples collected in northern Laos between October 2016 – February 2019 (n = 640)

	Vaccination	Biosecurity Only	Biosecurity with Vaccination	Total
Total samples	215	201	224	640
NSP positive	40	60	78	178
NSP + and Serotype specific structural antibodies				
Type A	36	48	62	146
Type O	38	55	69	162
Type A and O	35	48	62	145

A cow being restrained with a traditional bleeding pole for blood collection for the foot-and-mouth disease serological studies (Photo: Isabel MacPhillamy)

Production data

Despite being inconclusive, reports of the average weights and daily gains for large ruminants across the study period were included in this report to demonstrate the variation between seasons. Village classification had a strong effect on the weights of the sampled large ruminants at the univariable level with large ruminants from the BV villages being 12.3 kg (95%CI -25.83, 1.35) lighter than large ruminants from the V villages with an average weight of 210.13 kg (95%CI 199.03, 221.23) (P = 0.078). Figure 5 shows the average weights of large ruminants for each village class over the five collection periods. Figure 6 shows the trends in average daily gains (ADGs) for large ruminants in each village class. Collection period and village classification were not found to have a significant effect on large ruminant weights (P >0.05).

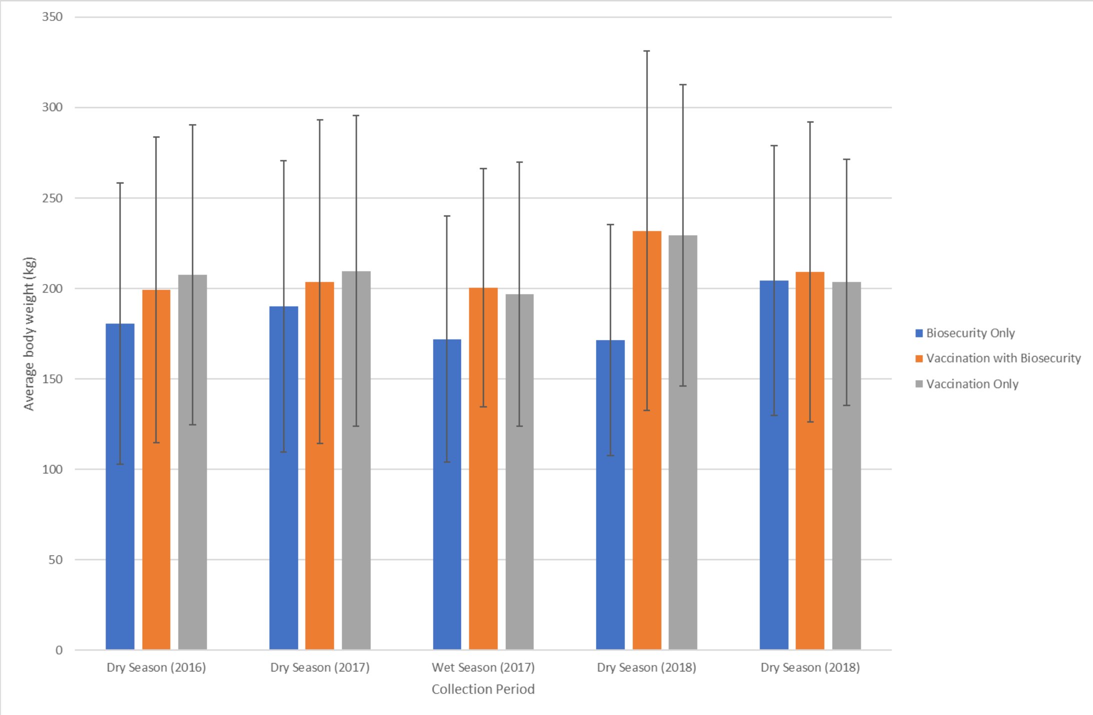

Figure 5. Average weights of large ruminants in each village class, from samples collected in northern Laos between October 2016 – February 2019 (n = 640)

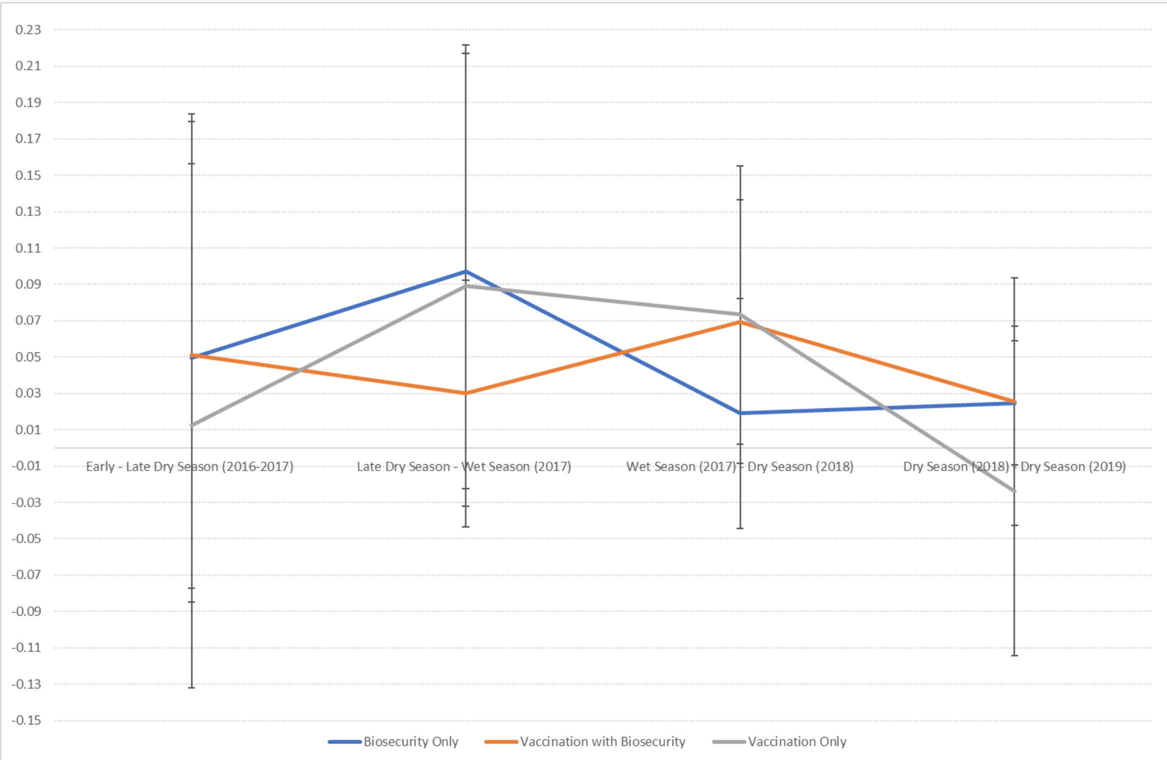

Figure 6. Average daily gain trends from large ruminant samples collected in northern Laos between October 2016 – February 2019 (n = 640)

Serological multivariable generalised linear mixed model (GLMM)

A multivariable analysis was conducted to determine the relationship between the significant univariable variables on FMD seropositivity. Both the large ruminant-level and farmer-level multivariable GLMMs investigated the interaction between collection period and village classification, that was found not significant ($P > 0.05$). The odds of a sample being NSP positive significantly increased as the study period progressed ($P < 0.0001$ at the large ruminant level and $P = 0.001$ at the farmer level) with samples from large ruminants in villages receiving biosecurity interventions also found to have a higher odds of being seropositive ($P = 0.041$) (Tables 8 and 9). The variances and intraclass correlations (ICCs) for the random term (village) for each model are shown in Table 10. There was low clustering detected at this level for both the large ruminant- and farmer-level serological models. This suggests there is more variation present between variables investigated in the villages at the large ruminant- and farmer-level analysis. The data was highly clustered at the village level for the multivariable model investigating weights. As the weight data is longitudinal, this indicates there is less variation in animal weights within the villages, compared to the variation between villages.

Table 8. Multivariable generalised linear mixed model investigating the factors associated with the non-structural protein serostatus of animals in the longitudinal survey conducted in northern Laos between October 2016 and February 2019 (n = 640)

Variable	Estimate	S.E	OR	95%CI	*P*-Value
Fixed effects					
Intercept	-1.89	0.29			5.74e-11
Collection Period					3.129e-09
Early Dry Season (2016)					
Late Dry Season (2017)	1.21	0.30	3.36	1.90-6.02	
Wet Season (2017)	1.49	0.35	4.45	2.22-8.91	
Dry Season (2018)	1.63	0.31	5.10	2.79-9.31	
Dry Season (2019)	1.70	0.31	5.50	2.98-10.14	
Village Classification					0.04185
Vaccination					
Biosecurity with Vaccination	0.79	0.35	2.21	1.11-4.398	

$R^2_{GLMM(c)} = 0.13$ $R^2_{GLMM(m)} = 0.10$

Farmers in Luang Prabang participating in data collection for the serological studies (Photo: Isabel MacPhillamy)

Table 9. Multivariable generalised linear mixed model investigating the factors associated with the proportion of non-structural protein positive animals per farmer in the longitudinal survey conducted in northern Laos between October 2016 and February 2019 (n = 331)

Variable		Estimate	S.E	OR	95%CI	*P*-Value
Fixed effects						
Intercept		-0.99	0.14			1.82e-11
Collection Period						0.001
	Early Dry Season (2016)	-				
	Late Dry Season (2017)	0.40	0.16	1.50	1.09-2.05	
	Wet Season (2017)	0.48	0.20	1.62	1.09-2.41	
	Dry Season (2018)	0.57	0.17	1.77	1.26-2.49	
	Dry Season (2019)	0.62	0.18	1.86	1.32-2.64	
Village Classification						0.079
	Vaccination	-				
	Biosecurity with Vaccination	0.26	0.13	1.30	1.00-1.69	

$R^2_{GLMM(c)}$ = 0.02 $R^2_{GLMM(m)}$ = 0.02

Table 10. Variance and intraclass correlation (ICC) coefficient for 'Village' as random effect term in each of the final multivariable mixed-effects logistic regression model for large ruminant- and farmer-level and weight for the samples collected in the longitudinal study conducted in northern Laos in October 2016 – February 2019

Random effect term	Number in level	Variance	ICC
Large ruminant level – Village	9	0.1541	0.044
Farmer level – Village	9	0.006	0.002
Weights - Village	9	1329	0.99

In the large ruminant-level model, the fixed effects are accounting for 10% of the variance in the data and the entire model is accounting for 13% of the variance, with the random effect of 'village 'only accounting for 4%. This suggests that there is variation in the large ruminant-level data not accounted for in the variables assessed. In the farmer-level model, the fixed effects and whole model both account for 2% variance, respectively, with the random term of 'village 'only accounting for 0.2%. This provides strong evidence that further research at the farmer level is warranted to investigate what factors are associated with owning a higher proportion of NSP seropositive large ruminants. Information was not collected on whether goats were owned and housed with these large ruminants. An investigation into seroprevalence of goats and large ruminants would be beneficial to provide more information on the possible role mixed species play in FMDv circulation within northern Laos.

A key limitation in this study was that unique identifiers were not being used for farmers and animals, resulting in an inability to determine whether individual large ruminants were sampled repeatedly and reliably. 'Farmer ID 'and 'Animal ID 'were included in the models as random effects but as the was no change seen with or without, it was decided to exclude them from the models. This resulted in an inability to accurately track seroconversion rates in individual large ruminants.

7.2.3. Cross-sectional large ruminant FMD serological study

The 9 northern provinces involved in the STANDZ vaccination program between 2012 and 2016 were selected to assess the current NSP FMD seroprevalence levels, using serum samples collected from large ruminants and goats in February 2019. Table 11 shows the apparent and true prevalence of the samples and locations (Appendix 1, Table 24 provides prevalence data for all sampled locations). The seroprevalences (True Prevalence; TP) ranged from 13.0% (95%CI 4.8-23.7) in Bokeo province to 73.3% (95%CI 65.1-80.9) in Huaphan province and an overall TP of 42.9% (95%CI 38.9-46.8). The average village-level apparent prevalence (AP) was 42.1%, with 32% (10/31) of villages having an AP > 50%. Table 12 provides prevalence summaries for other variables collected; the *P*-value provided is from univariable analysis. When examining the variables associated with an NSP positive result, the two variables remaining in the multivariable GLMM were age category and whether that animal had ever shown signs of FMD (Table 13). The prevalence results provide strong evidence of ongoing FMDv circulation, with animals 4 years old and under, having a TP of 39.8% (95%CI 34.7-44.9).

Of the sampled provinces, Vientiane, Huaphan, Xayabouli and Luang Prabang have all officially reported outbreaks since 2017 (Table 14). A review of the WAHIS interface managed by the OIE indicates that there were reported outbreaks in 2015 (Vientiane Capital, Attapeu, Champasak and Savannakhet), 2017 (Champasak, Savannakhet, Huaphan and Xayabouli), 2018 (Attapeu, Champasak, Huaphan and Xayabouli) and in the first 6 months of 2019 (Luang Prabang) (OIE, 2012). When combined with the findings in section 7.2.2, the conclusion is that support for ongoing vaccination campaigns in conjunction with biosecurity programs that are tailored to individual communities, is required. Farmers reported 21.2% (132/623) of large ruminants showing signs of FMD, with 15.5% (97/623) of these NSP positive. While NSP antibodies from natural infection can persist for many years, it is interesting to note the age of NSP positive large ruminants and goats; age categories and the number of NSP positive samples with reported signs of FMD are shown in Table 15. The final multivariable GLMM is shown in Table 13. The sampled livestock greater than 2 years and less than 8 years of age had a higher odds than those under 2 years of being NSP seropositive. This indicates that for the last 8 years there has been continual circulation of FMDv within the population. Large ruminants and goats that showed signs of FMD also had a higher odds of being NSP seropositive.

The FGDs indicated that with ongoing training and support, farmers will be able to improve their understanding of disease management and control. Specifically, farmers commented that they are able to identify and treat FMD in their livestock and that they want to learn more about its mitigation. The fixed effects in the model account for 3% of the variance in the data and the entire model is accounting for 55% of the variance. The ICC values are provided in Table 16 and indicate that there is significant clustering at the village level, indicating a high similarity in results from animals of the same village and more variability between the villages. The low ICC at the province and farmer levels, suggests increased variability within each farmer or province cluster, rather than between these clusters. Further investigation into management practices at the farmer level and animal movement and trade at the provincial level, is considered warranted.

Mr Chanthong and Francesca collecting blood samples in Bokeo Province (Photo: Mr Sompeth)

Table 11. Prevalence data of the large ruminant and goat serum samples collected in February 2019 from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012 – 2016 (n = 633)

Province	Samples tested	Number positive	Apparent Prevalence (95%CI)	True Prevalence (95%CI)
Bokeo	49	6	12.2 (3.1-21.4)	13.0 (4.8-23.7)
Houphan	123	90	73.2 (65.3-81.0)	73.3 (65.1-80.9)
Luang Namtha	38	5	13.2 (2.4-23.9)	14.3 (5.0-27.0)
Luang Prabang	113	37	32.7 (24.1-41.4)	32.6 (24.2-41.6)
Oudamxay	59	24	40.7 (28.1-53.2)	40.8 (28.8-53.6)
Phongsaly	77	45	58.4 (47.4-69.4)	58.5 (47.4-69.4)
Vientiane Province	61	27	44.3 (31.8-56.7)	44.3 (32.2-56.5)
Xayabouli	52	12	23.1 (11.6-34.5)	23.6 (13.0-36.0)
Xieng Khoung	61	26	42.6 (30.2-55.0)	42.7 (30.6-55.1)
Total	**633**	**272**	**43.0 (39.1-46.8)**	**42.9 (38.9-46.8)**

Buffalo contained in a bamboo pen prior to blood sample collection and vaccination for the serological studies (Photo: Isabel MacPhillamy)

Table 12. Prevalence summaries for large ruminants and goats sampled in February 2019 from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012 – 2016 (n = 633)

Variable	Samples tested	Number positive	Apparent Prevalence (95%CI)	True Prevalence (95%CI)	*P*-value
Species					0.17
Buffalo	104	45	43.3 (33.7-52.8)	43.2 (33.6-52.9)	
Cattle	510	223	43.7 (39.4-48.0)	43.6 (39.3-48.0)	
Goats	19	4	21.0 (2.7-39.3)	23.3 (7.7-43.7)	
Age Category					0.007
≤2 yrs old	143	44	30.7 (23.2-38.3)	30.7 (23.3-38.6)	
>2 yrs old - ≤4 yrs old	223	102	45.7 (39.2-52.3)	45.7 (39.1-52.2)	
>4 yrs old - ≤8 yrs old	236	114	48.3 (41.9-54.7)	48.3 (41.9-54.8)	
>8 yrs old	28	12	42.8 (24.5-61.2)	43.3 (26.3-61.0)	
Have you owned this animal since birth?					0.17
No	107	39	36.4 (27.3-45.5)	36.4 (27.3-45.9)	
Yes	517	225	43.5 (39.2-47.8)	43.4 (39.1-47.8)	
Has this animal ever received an FMD vaccination					0.67
No	313	130	41.5 (36.1-47.0)	41.4 (36.0-47.1)	
Yes	310	134	43.2 (37.7-48.7)	43.1 (37.7-48.8)	
Has this animal ever had signs of FMD?					0
No	491	167	34.0 (29.8-38.2)	33.8 (29.6-38.1)	
Yes	132	97	73.5 (65.9-81.0)	73.7 (65.7-80.9)	

A buffalo restrained with the bleeding pole for blood collection and vaccinations (Photo: Isabel MacPhillamy)

Table 13. Multivariable generalised liner mixed model investigating factors that were associated with animal level NSP seropositivity from the large ruminants and goats sampled in February 2019 from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012 – 2016 (n = 623).

Variable	Estimate	S.E	OR	95% CI	*P*-value
Fixed effects					0.005
Intercept	-1.44	0.52			
Has this animal ever had signs of FMD?					0.05
No	-				
Yes	0.71	0.36	2.03	1.01-4.11	
Age Category					0.001
≤2 yrs old	-				
>2 yrs old ≤4 yrs old	1.02	0.32	2.77	1.48-5.16	
>4 yrs old ≤8 yrs old	1.01	0.31	2.74	1.48-5.08	
>8 yrs old	-0.23	0.58	0.79	0.25-2.47	

$R^2_{GLMM(c)}$ = 0.55 $R^2_{GLMM(m)}$ = 0.03

Cattle contained prior to blood sample collection and vaccinations for the serological studies (Photo: Isabel MacPhillamy)

Table 14. Farmer reports of suspected FMD cases collected during the large ruminant serosurvey conducted in 9 northern provinces in February 2019.

Province	Date reported	Number of farmers reporting suspected cases
Bokeo	-	-
Huaphan	2017	11
	March 2017	1
	April 2017	8
	July 2017	5
Luang Namtha	-	-
Luang Prabang	-	-
Oudamxay	-	-
Phongsaly	2017	6
	April 2017	5
Vientian Province	-	-
Xayabouli	November 2017	12
Xieng Khoung	January 2016	1
	February 2016	1
	May 2016	4
	June 2016	2
	February 2017	5

Table 15. Summary of NSP positive samples and number of animals with reported signs of FMD from the large ruminant and goat samples collected from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012 – 2016 (n = 623)

Age Category	Number of positive samples with reports of FMD signs (%)	Number of reports of FMD signs	Number of positive samples with reports of FMD signs and reports made (%)	Number of samples with reported signs and reports made
≤2 yrs old	16 (11.4)	140	15 (62.5)	23
>2 yrs old -≤4 yrs old	39 (17.6)	222	31 (81.6)	38
>4 yrs old -≤8 yrs old	37 (16.1)	230	30 (75.0)	40
>8 yrs old	5 (16.1)	31	3 (30.0)	10

Table 16. Variance and intraclass correlation (ICC) coefficient for each random effect term the final multivariable mixed-effects logistic regression model for animal level NSP seropositivity from the large ruminants and goats sampled in February 2019 from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012 – 2016 (n = 623).

Random term effect	Number in level	Variance	ICC
Farmer	198	0.54	0.14
Village	31	3.87	0.54
Province	9	0.46	0.12

These seroprevalence findings are similar to those recently found in southern Laos, where there has not been a history of ongoing vaccination campaigns and where, at the individual animal level, the seroprevalence was found to be 46% (McFadden et al., 2017). The STANDZ vaccination program appears to have been very successful at suppressing clinical disease in animals in the north of Laos. However, it is evident that the virus, as expected, was still circulating and since the cessation of the program in 2016, there has been an increase in both identified outbreaks and evidence of FMDv circulation, with seroprevalence levels reaching that of areas without a history of vaccination (OIE, 2012). These findings exemplify the challenges to vaccination only campaigns and supports the argument for prolonged vaccination to be conducted in conjunction with targeted biosecurity. However, results from the longitudinal study suggest that further work is needed to successfully identify biosecurity interventions that will have high and sustainable uptake by smallholder farmers in Laos.

Serotype specific structural protein antibody results

The presence of serotype specific SP antibodies in NSP positive samples was investigated to provide information on serotypes circulating or previously vaccinated against. Serotype specific SP antibody testing was conducted on the 272 samples that were NSP positive, with 49.3% of these animals having a history of receiving FMD vaccinations. As serotype specific SP antibodies can be due to natural infection or vaccination, it can be difficult to determine the source without antibody titre testing and accurate vaccination records. Animals having had only one vaccination are unlikely to retain protective SP antibodies and at least three doses of vaccine are generally required for the maintenance of protective SP antibodies when vaccinated every 6 months (Knight-Jones et al., 2015). In comparison, SP antibodies from a natural infection can be present for many years (Doel, 2005).

Table 17 summarises the SP and related vaccination data for the NSP positive samples. The history of vaccination can complicate the interpretation of SP results. However, vaccine-induced SP antibodies are expected to be seen only in the animals receiving a vaccination in the preceding 6 months. The average age range of large ruminants with serotype O and/or serotype A positive samples was between 3.5±1.6 and 5.4±2.5 (range 1-18). When examining the serotype-specific SP data in relation to animals showing clinical signs of FMD, it was found that between 17.8 and 35.6% of serotype O and/or serotype A positive animals were reported to have clinical signs. This evidence of serotypes O and A circulating support the OIE data available on WAHIS and suggests the strong possibility of reported FMD outbreaks not reaching the higher administrative levels.

Table 17. Summary of serotype specific structural protein (SP) antibody and related vaccination data for non-structural protein (NSP) positive samples from large ruminants sampled in in February 2019 from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012 – 2016 (n = 623).

Summary	n
Total NSP positive samples	272
Samples from vaccinated animals (NSP Positive and Negative)	310
NSP positive	134
Large ruminants vaccinated 6 months prior to sampling	42
NSP positive samples from large ruminants only vaccinated once	86
Samples tested for SP antibodies	
SP negative (NSP positive)	23
Serotype O Only	104
Serotype A Only	1
Serotype O and Serotype A	144

7.3.Goat investigations

In the last decade, there has been a substantial increase in the national goat herd in Laos with the national herd estimated to be 588,000 head in 2017 (MPI, 2018; Windsor et al., 2017). Goats are generally managed in a traditional smallholder system, housed close to the village and grazed in communal areas during the day. Goats require less input than large ruminants and are often managed by female farmers and children, providing a potential pathway to exit poverty (Windsor et al., 2018). With efforts to increase the commercialisation and production of goat meat comes an increased risk of animal health and biosecurity issues. While goats are gaining popularity amongst smallholders in South-East Asia, they are still neglected for inclusion in FMD vaccination and control campaigns. Hence the decision to include activities on goats to expand the limited regional and local research on this species.

7.3.1.Cross-sectional FMD serological study

A cross-sectional serosurvey was conducted to investigate the role of goats in the epidemiology of FMD in Laos. NSP and SP FMDv antibody ELISA tests were conducted to determine exposure to circulating FMDv and the possibility of previous vaccination. This study was conducted between September 2017 and March 2018, in 26 villages from 6 districts in 5 provinces from the north (Bokeo, Luang Namtha, Luang Prabang and Xayabouli), central (Xieng Khoung, Khoummoune and Savannakhet) and southern regions (Champasak). Significant differences were seen between the provinces ($P < 0.0001$) with high NSP and serotype O seroprevalences detected in Bokeo (42.1%), Xayabouli (8%) and Khammoune (20%), indicating the likelihood of recent FMDv transmission and the possibility of FMD outbreaks (Table 18). Risk factor analysis found only goat-level factors such as age ($P = 0.001$), sex ($P = 0.021$) and weight ($P = 0.095$) to be associated with serostatus (Table 19). Older animals and females had higher odds of being seropositive, maybe reflecting that female goats are generally retained for longer for breeding, increasing their chances of exposure to circulating FMDv. This trend has been seen in other FMD serosurveys (Mesfine et al., 2019). Goat weight was suggestive of a strong association with FMDv, though this is also likely linked to age and sex. Unfortunately, information was not collected on the presence of pigs in the villages, with the presence of large ruminants found not to be a significant risk factor. It would be prudent to collect information on the presence of pigs in future studies to provide more information on the possible transmission behaviours in mixed-species smallholder villages.

Table 18. Proportion of sera from goats seropositive for both FMDv non-structural proteins and structural proteins (serotype-specific antibodies) collected in different provinces, districts and villages in northern and southern Laos between September 2017 and March 2018

	BK	LNT	LBP	XK	XYL	KM	SVK	CPS
Total samples (n)	76	75	76	76	75	80	60	75
Only NSP antibodies	1.3	1.3	0	1.3	2.7	2.5	3.3	1.3
NSP and SP antibodies (%)	48.7	0	0	0	9.3	25	5	0
NSP & Serotype O only	42.1	0	0	0	8	20	3.3	0
NSP & Serotype A only	0	0	0	0	0	0	0	0
NSP & Serotype Asia1 only	0	0	0	0	0	0	0	0
NSP, Serotypes O & A	6.6	0	0	0	1.3	5.0	1.7	0
NSP, Serotypes O & Asia1	0	0	0	0	0	0	0	0
NSP, Serotypes A & Asia1	0	0	0	0	0	0	0	0
NSP, Serotypes O, A & Asia1	0	0	0	0	0	0	0	0

Bokeo – BK, Luang Namtha – LNT, Luang Prabang – LBP, Xieng Khoung – XK, Xayabouli – XYL, Khoummoune – KM, Savannakhet – SVK and Champasak – CPS

Table 19. Final multivariable mixed-effects logistic regression model for FMDv serological status amongst 591 goats from 134 farmers surveyed in northern and southern Laos between September 2017 and March 2018

Variables	Estimate	SE	OR	95% CI	*P*-value
Fixed effects					
Intercept	-6.05	1.27			<0.0001
Age					0.001
≤12 month	-	-	1		
13-24 months	1.88	0.66	6.58	1.8-23.8	
>24 months	2.28	0.71	9.75	2.4-39.5	
Sex					0.021
Female	-	-	1		
Male	-1.25	0.56	0.29	0.09-0.86	
Weight					0.095
≤15kg	-	-	1		
16-30	0.96	0.67	2.62	0.70-9.80	
>30	-0.82	1.41	0.44	0.03-7.02	

Log-likelihood: -140.0; $R^2_{GLMM(c)}$ = 0.548

The overall apparent seroprevalence of NSP positive animals in this study was 13%, with an estimated true prevalence of 12.4% (95%CI 9.8-15.3). The average age of goats involved in this survey was 19±12 months of age. This, combined with the prevalence data, suggests that FMDv may be circulating unreported or sub-clinically in the goat population or that previously infected goats have been imported. An absence of serotype-specific AP antibody detected for serotype Asia1 supports current theories that this serotype is no longer in circulation in Laos (Blacksell et al., 2019). These findings strongly indicate it is necessary to include goats in serosurveillance programs for FMD and ongoing vaccination campaigns in Los and presumably throughout South-East Asia.

7.3.2. Cross-sectional serosurveillance of caprine zoonotic diseases in Laos

A collaborative activity with MORU in 2017 (Burns et al., 2018; publication listed in Section 10.2) investigated the seroprevalence of two bacteria of zoonotic importance, *Coxiella burnetii*, the causative agent for Q fever, and *Brucella* species, the causative agent of Brucellosis. A total of 1,458 serum samples were collected from goats from five provinces (Vientiane Capital, Xayabouli, Xieng Khoung, Savannakhet and Attapeu). Overall seropositivity of *C. burnetii* was 4.1% (95%CI 3.0-5.0) and *Brucella* spp was 1.4% (95%CI 0.8-2.2). In the multivariable analysis of risk factors associated with Q fever serostatus, the odds of goats having Q fever antibodies was highest in Vientiane Capital (OR 5.4, 95%CI 1.0-29.35, P = 0.05), Boer mixed breed (OR 6.9, 95%CI 1.74-127.27, P = 0.006) and ≥3 years old (OR 4.06, 95%CI 1.3-12.5. P = 0.014). The analysis of *Brucella* spp risk factors identified Vientiane Capital (4.0%, 95%CI 2.4-6.2) and Attapeu (1.6%, 95%CI 0.3-4.4) as the only provinces with seropositivity. Boer and Boer cross breeds had a seropositivity of 5.6% (95%CI 3.3-8.5) while native breeds were seronegative. Further, 5.6% (95%CI 3.4-8.6) of commercial farms and 5.3% (95%CI 3.2-8.1) of farms with >40 goats were found to be seropositive, with no *Brucella* spp antibodies detected in goats from smallholder farms or those with ≤40 animals. The increased risk of seropositivity in animals located in Vientiane Capital was suggested to be due to the international trade routes in the area and location of emerging commercial goat enterprises using imported animals (Burns et al., 2018). Whether animals were exposed prior to entering Laos, or the process of production intensification has increased risk of infection, there is evidence of an increased public health risk to goat farmers and consumers in Vientiane Capital. Further investigation in the origin of infection and risk factors associated with Boer goats is warranted due to their high seropositivity. Reasons may be due to these breeds being more intensively raised and possible an increased risk of vertical transmission from animals originally imported. This study did not investigate the incidence of infection, presence of shedding animals or the current risk of transmission of each pathogen. This information is recommended to provide public health recommendations and determine the human health risks and economic losses caused by Q fever and Brucellosis (Burns et al., 2018).

7.3.3. Orf infection case study report

In 2016, an increased number of suspected FMD outbreaks in goat herds warranted investigation in 4 rural villages in Xanthay district, Vientiane Province (Windsor et al., 2017; publication listed in Section 10.2). This involved the clinical and pathological examination of infected animals and interviews with smallholder farmers (n = 33). Serum (n = 32) and oral and facial lesion tissue (n = 8) were collected for diagnostic study. Results indicated that all animals were negative for FMD antibodies with histopathology confirming the lesions were caused by the Orf virus. Of the interviewed farmers, 75% reported that some of their goats showed clinical signs suggestive of Orf infection. However, no farmer could reliably recall the initial onset of lesions. The survey indicated that these farmers experienced an annual loss of 2 (±3) goats per year, attributed to Orf, dog bites, strangulation, blackleg, pneumonia, and abdominal disorders. Knowledge of Orf and the ability to recognise clinical signs from an image differed between the affected and unaffected farmers (44% and 25%, respectively; P = 0.34). Separation of sick animals was more likely to occur in the unaffected group (37% compared to 16% in the affected group, P = 0.2).

Goat in Laos with extensive lesions on the lips typical of Scabby Mouth due to Orf virus infection (Photo: Peter Windsor)

Although the suspected FMD outbreaks were actually Orf outbreaks with no evidence of FMD co-infection, as the population and trade in goats increases in South-East Asia, Orf has the potential to become a significant production limiting disease, a concern for trade, and a zoonosis of concern. For these reasons, consideration of control programs including vaccination is recommended, as is participatory and evidence-based training programs for smallholder goat farmers and extension workers to improve knowledge and practices relating to goat health, biosecurity and husbandry.

7.3.4.Endoparasitism in goats

As intensification of goat production increases, so does the likely risk of endoparasitism. Hence, a cross-sectional survey was conducted to investigate the prevalence of gastrointestinal parasites in the indigenous Kambing-Katjang goats on smallholder farms receiving no anthelmintic treatments (n = 389) to provide comparison with a case study of imported crossbred Boer goats (n = 45) from a commercial farm with high level of anthelmintic use and parasite mortality problems (Windsor et al., 2018; publication listed in Section 10.2).

The study indicated significant associations between the presence of endoparasites and farm type, with goats from the commercial farm having a higher odds of having *Strongyles* spp. (OR 1.3; 95%CI 0.6-2.9, $P < 0.001$) and *Eimeria* spp. (OR 4.8; 95%CI 2.5-9.1, $P = 0.008$) infestations. The study found only a moderate prevalence of gastrointestinal parasites (mean EPG for *Stronglyes* spp. <1,000) in the indigenous breeds under smallholder farming systems. It was suggested that these burdens may increase, as can the impact of *Haemonchus contortus* and the development of anthelmintic resistance, with intensified farming of goats. These findings should be considered if the Lao government chooses to continue to promote intensification and the introduction of Boer crossbred goats.

7.4.Swine investigations

7.4.1.An investigation of PRRS

Highly pathogenic PRRS virus was first detected in an outbreak in Vientiane Capital in 2010 (Ni et al., 2012). Unrestricted animal movements, poor biosecurity and lack of multilateral cooperation between neighbouring countries facilitated the entry and spread of the disease (Nguyen, 2013). The occurrence of PRRS outbreaks have also resulted in a potential One Health issue, as an association between PRRS outbreaks and *Streptococcus suis* infection in humans has been found (Huong et al., 2016). *S. suis* is known to be a primary cause of adult meningitis in Vietnam due to the consumption of raw or undercooked pork, and due to the immunosuppressive effects of PRRS, affected pigs are more likely to harbour this bacteria (Wertheim et al., 2009; Xu et al., 2010).

A suspected outbreak of PRRS occurred in Bokeo province in August to September 2016 which was investigated from 19 to 21 October 2016 in 5 villages. Blood samples (n = 41) were collected, with information on farmer demographics, on-farm pig management, trading practices, pig health, suspected history of PRRS, age, sex breed, weight and body condition score of the sampled pigs. Two of the selected villages had confirmed cases of PRRS during the outbreak, while the 3 other villages had no reported cases and served as control villages. Serology was also collected from December 3 to 5 in 2017, from pigs in Vientiane (n = 51; last recorded outbreak 2013) and Xieng Khoung (n = 56; no previous outbreak recorded).

A total of 28 farmers, including 12 females, were surveyed in this activity; due to the small sample size caution is required when interpreting the validity of the associations. The purpose of keeping pigs and other livestock as well as pig management practices are presented in Table 20. Most pigs were fed a range of local agricultural products including banana, corn, other vegetables and rice bran. Farmers also fed commercially produced pig pellets. Enclosed pigs were observed to still be at risk of contact with other village pigs. However, contact with foreign pigs was not found to be associated with a significantly higher likelihood of animals coming from an outbreak village, compared to animals in control villages (OR = 1.67; 95%CI 0.14-20.4; *P* = 0.68).

Table 20. Livestock ownership and pig management practices of the surveyed farmers from five villages in Bokeo province, Laos during the survey period in October 2016 (n = 28)

Variable	Category	Number of farmers	Percentage (%)
Purpose for keeping pigs	Primary Income	5	82.1
	Extra Income	23	17.9
Animals present on-farm	Pigs	28	100
	Poultry	19	67.9
	Goats	5	17.9
	Cattle	7	25.0
	Buffalo	6	21.4
	Dogs	5	17.9
Housing type	Pen adjacent to house	27	96.4
	Sometimes free-range	2	7.1
	Raised pigs on other farm	1	3.6
Pig feed	Rice bran	22	78.6
	Local agricultural products	20	71.4
	Commercial diet	9	32.1
	Waste from alcohol production	5	17.9
	Table scraps	2	7.1
Pig-to-pig contact	Contact with foreign pigs	4	14.2
	Village pigs (same)	3	10.7
	Village pigs (other village)	1	3.6
	Wild pigs	0	0

The main age group of pigs being purchased were adult/grower pigs with peak purchases found in January and June. Pig sales occurred primarily in June and September. There were no significant differences between the villages for the sale or purchase of pigs.

Breeding management behaviours have the potential to increase the risk of disease introduction. Table 21 outlines the current reproductive characteristics of surveyed farms. The odds of a farmer coming from a suspected PRRS outbreak village did not differ significantly between those that bred pigs on-farms compared to those did not breed on-farm (OR 0.05; 95%CI 0.05-5.04; P = 0.56). Borrowing a boar for mating, a common practice in South-East Asia (Leslie et al., 2015), can present multiple disease entry risks and can result in the transmission of disease via direct contact or via semen. Poor biosecurity and disease transmission risk knowledge further increases the risk of disease introduction, as farmers are unlikely to ascertain the disease status of the boar prior to use.

Table 21. On-farm breeding characteristics of smallholder pig farmers from five villages in Bokeo province, Laos during the survey period of October 2016 (n = 28)

Variable	Category	Number of farmers	Percentage (%)
Breed pigs on farm	Yes	5	17.9
	No	23	82.1
borrow boar for mating	Yes	5	17.9
	No	23	82.1
Source of borrowed boar	Within village	3	60.0
	Outside village	2	40.0
Take sow to other farm	Yes	3	10.7
	No	25	89.3
Sow farm location	Within village	3	75.0
	Outside village	1	25.0

Most farmers (74.1%), were able to identify several clinical signs that indicate illness in pigs. However, all respondents were unsure of disease routes or pathways, and no one reported knowledge of PRRS, FMD, brucellosis or CSF. Only six farmers reported using vaccines as preventative health measures for their pigs, but on-farm antibiotic use was common with 78.6% of farmers using antibiotics as a treatment or prophylactic measure. Despite the relatively recent incursion of high pathogenic PRRS, 92.9% of farmers had never heard the term PRRS before, and no farmers could recognise any of the relevant clinical signs. Vaccination was demonstrated as an effective measure of control, particularly when used in combination with appropriate biosecurity measures (Lager et al., 2014; Zhang et al., 2017). The poor biosecurity knowledge highlights important areas for target interventions, especially considering the recent ASF epidemic occurring in South-East Asia and the human health risks that can be imposed by poor livestock hygiene practices.

An example of the type of local pig kept in a free-ranging system. These pigs are allowed to roam the villages feeding on available food scraps and vegetation (Photo: Isabel MacPhillamy)

7.4.2. Important zoonoses in Laos associated with food-borne parasites of pigs

In Laos, the majority a pig raising occurs in low-input backyard systems. Many of these systems have poor hygiene and biosecurity practices, and pigs are commonly allowed to scavenge around households and within villages and farmland. Infrastructure for livestock slaughtering and meat processing is absent or severely underdeveloped, compromising the hygiene and safety of meat products. The Strategy for Agricultural Development 2011–2020, outlined by the Ministry of Agriculture and Forestry, aims for sustainable development to improve household food and income security. A component of this is to increase meat production by 5% annually.

To identify the important zoonoses in Laos a review document was compiled. This document focused on food-borne parasites in swine and fish. The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization have designated the 'top ten' food-borne parasites of global concern (Table 22) as food safety and parasitic contamination are major public health concerns. Some of these parasites are prevalent in Laos, including *Taenia solium* and *Trichinella spiralis*.

Table 22. Food and Agriculture Organization of the United Nations (FAO) and World Health Organization 'Top Ten' food-borne parasites of global concern (FAO, 2014).

Parasite	Source
Taenia solium (pork tapeworm)	Pork – especially raw or undercooked
Echinococcus granulosus (hydatid worm/dog tapeworm)	Fresh produce contaminated with canine faeces
Echinococcus multilocularis	Fresh produce contaminated by fox, dog or cat faeces
Toxoplasma gondii	Meat from small ruminants, pork, beef and game meat (red meat and organs)
Cryptosporidium spp	Fresh produce, fruit juice, milk
Entamoeba histolytica	Fresh produce
Trichinella spiralis (pork worm)	Pork
Opisthorchiidae (flatworms)	Freshwater fish
Ascaris spp (small intestinal roundworms)	Fresh produce
Trypanosoma cruzi	Fruit juices

Taenia solium can lead to taeniasis (infection with adult stage tapeworm) and/or cysticercosis (larval cysts with body tissues). Whilst taeniasis can be asymptomatic with occasional gastrointestinal signs, cysticercosis can lead to more severe clinical signs depending on the location of the cysts, such as cardiac dysfunction and seizures. Cysticercosis in pigs can impact their growth and reduce their value due to poor carcass quality. Poor processing infrastructure and lack of meat inspection and food safety standards increases the likelihood of contaminated carcasses entering the wet meat market and human food chain (Conlan et al., 2008; Okello et al., 2015). Prevalence data indicates that hotspots of *T. solium* hyper-endemicity exist in Laos and while *T. solium* is known to be common in Laos, other species have not been well-documented (Okello et al., 2015). Considering the consumption of raw meat dishes is common in parts of Laos, further research is required to determine the prevalence of other *Taenia* species.

Trichinellosis in South-East Asia is caused by *Trichinella spiralis* through the consumption of raw or undercooked pork containing the *Trichinella* cysts. The clinical signs associated with trichinellosis can be debilitating and severe and are believed to be correlated with the concentration and frequency of consumption of larvae, and host immune response (Gottstein et al., 2009). Two official outbreaks in Laos have been recorded since 2000, in 2004 and 2005 (Okello et al., 2015). However, due to the poor disease surveillance protocols and limited diagnostic abilities in regional areas the prevalence of human cases may be much higher.

Successful control programs require multiple interventions at the livestock and human health interface to improve household hygiene, disease control in livestock and food safety. Further research to determine the financial impact, disability-adjusted life years and the knowledge, attitudes and practices towards these zoonotic parasites in the different ethnic groups throughout the country is required to develop a coordinated and sustainable one-health approach to the control in the animal source population.

7.5.FMD risk factor investigation

Due to the porous nature of land borders and informal trade of large ruminants, there is a continual threat of the introduction of new or emerging FMDv in South-East Asia, and in 2015 Laos experienced an outbreak of a novel FMDv (O/ME-SA/Ind2001d). Research was undertaken to identify household-level risk factors associated with this outbreak and endemic circulating virus ((Miller et al., 2018; publication listed in Section 10.2). This study found the practice of quarantining new livestock for a minimum of two weeks before introduction to the herd was found to be protective (OR 0.225; 95%CI 0.06-0.88; P = 0.003). Households with cattle showing evidence of prior infection were more likely to have participated in sharing communal grazing land with neighbouring villages (OR 5.5; 95%CI 6.16-49.11; P <0.001). These findings indicate that the implementation of basic on-farm biosecurity and improved husbandry measures to minimise FMDv circulation at the household level are important and reinforce the need to enhance the education of smallholder farmers in infectious disease control (Miller et al., 2018). These findings also apply to the current ASF outbreak in the region.

Mr Bouakeo, Mr Laethong, Isabel and Francesca with farmers in Luang Prabang after collecting data on foot-and-mouth disease outbreaks (Photo: Mr Kong)

7.6.Cost-benefit analysis

Recent research has reported regional losses due to FMD ranging from 16-60% of yearly household incomes (Truong et al., 2018). The cost-benefit of three FMD mitigation strategies (V, B and BV) to improve food security and the agricultural economy via FMD control was determined through developing a model of the 'true' cost of FMD. This model examined the cost variation under the three intervention schemes. Using a financial impact statement questionnaire (FISQ) to assess the costs and benefit of each intervention, farmers were interviewed in July 2018 (n = 90), in Luang Prabang and Xieng Khoung and in May 2019 (n = 56) in Luang Prabang. The 2018 and 2019 survey had eight sections covering farmer demographics, general costs, FMD occurrence, general disease cost, FMD-related specific costs, vaccination costs, biosecurity costs, and the social cost of the disease. The 2018 survey covered general livestock diseases with a focus on FMD, whereas the 2019 surveyed followed an outbreak report and was more specific to the costs associated with that outbreak. The 2018 survey data was used in collaboration with economic data available from the literature, and the 2019 survey data, to build assumptions for the base case (Table 23).

Team members Francesca, Ms Phaivanh and Ms Manichan conducting the financial impacts statement questionnaire for the cost-benefit analysis in Xieng Khoung (Photo: Nichola Calvani)

Table 23. Lao farmer Base case

Type	Running cost/benefit	Input Cost (AU$)	Source
Disease costs	Injectable antibiotics	12.25	2019 FISQ raw data
	Oral antibiotics	14.52	2019 FISQ raw data
	VAHW	10.25	2019 FISQ raw data
	Quarantine of sick animals	9.39	2019 FISQ raw data
	Income losses due to FMD	20% of annual income	(Truong et al., 2018)
	Losses due to abortion	23% abortion rate due to FMD	(Şentürk and Yalçın, 2008)
Livestock husbandry	Feed purchase	854	2018 FISQ raw data
Livestock purchase	Buffalo calf purchase	1,976.03	2019 Farmer trading survey (AH-2012-068); (Keovilay, 2012)
	Cattle calf purchase	1,515.03	2019 Farmer trading survey (AH-2012-068)
	Cattle adult purchase	1,423.26	2019 Farmer trading survey (AH-2012-068)
Vaccination costs	Cost of a single dose of vaccine[a]	5.64	2018 FISQ raw data (Nampanya et al., 2017)
	Cost of vaccination labour[a]	2.56	2019 Focus group discussion
Biosecurity costs	Quarantine[a]	40.18	2019 FISQ raw data
	Footbath[a]	44.60	2018 FISQ raw data
Livestock sales	Buffalo calf	6,896.53	2019 Farmer trading survey (AH-2012-068)
	Buffalo adult	1,952.78	2019 Farmer trading survey (AH-2012-068)
	Cattle calf	11,184.15	2019 Farmer trading survey (AH-2012-068)
	Cattle adult	1,427.38	2019 Farmer trading survey (AH-2012-068)
Vaccination benefit	Reduction in FMD	56.3%	(Waters et al., 2018)
Biosecurity benefit	Reduction in FMD	Reduced by a factor of 5	(Nampanya et al., 2017)

[a]parameters underwent sensitivity testing of +/-50% fluctuations of the baseline cost

The study found that the most cost-effective disease mitigation intervention was vaccination only, with a cost of AU$ 0.12/animal that became protected. However, the model did not account for the cost of vaccine storage, transport and development, which are subject to market changes. The application of sensitivity testing on this model found costs related to vaccines were the most sensitive to market and supply fluctuations.

The CBA for the B villages indicated an increased cost compared to the V villages. However, the model for the B villages had fewer ‘hidden’ costs. The V villages had the greatest net benefit of AU$ 15,098.80, closely followed by the BV villages with a net benefit of AU$ 15,087.38. In comparison the model predicted that farmers not practicing any disease mitigation were likely to experience a loss of AU$ 2,510.09 in the event of an FMD outbreak.

The highly sensitive nature of vaccination costs combined with the added protection of applying biosecurity, makes BV the most effective and cost-efficient form of FMD control in Laos. The challenges associated with sourcing high quality serotype specific vaccines, maintaining cold chain and ensuring access to the vaccines also contribute to the risk of relying solely of vaccination as the primary disease control strategy. By combining biosecurity practices with regular vaccination, disease control actions will be more sustainable and effective at disease control, especially in the event of vaccine failure or poor vaccination rates. However, other findings from this project (Section 7.2.2) indicate that achieving effective biosecurity interventions is challenging and these need to be tailored to individual communities to ensure successful implementation and sustainable uptake.

Mr Bouakeo conducting the financial impact statement questionnaire survey with a farmer in Luang Prabang (Photo: Francesca Earp)

8. Impacts

8.1.Scientific impacts – now and in 5 years

The research activities conducted in this project have led to current impacts that are very likely to progress to greater future impacts, particularly relating to more effective disease monitoring and control strategies that contribute to capacity-building and socioeconomic benefit impacts. The longitudinal and cross-sectional large ruminant FMD serological studies, in conjunction with the KAP and FGD activities, demonstrate the critical challenges of implementing effective biosecurity for the control of FMD. The STANDZ program was highly successful in reducing the apparent incidence of FMD outbreaks in the target areas during 2012-2016. The serological studies confirmed that strategic mass vaccination is effective in FMD suppression, despite continued circulation of FMDv. Following cessation of the vaccination program there was re-emergence of FMD and an increasing number of outbreaks in northern Laos. This situation exemplifies both the importance and precarious nature of donor-funded dependence on vaccination programs in Laos, plus the challenges to current biosecurity intervention delivery, implementation and compliance. As evidenced during the FGDs and the final project meeting, farmers and project staff are anxious that FMD outbreaks have and will continue to occur with increased frequency following cessation of project training and vaccination activities. The increasing prevalence of NSP-positive animals in project sites, in the absence of reported outbreaks, indicates the continual and increasing circulation of FMDv and the suboptimal implementation of biosecurity practises.

The selection of project participants was based on their identification of likely being ‘early adopters’; those willing to adopt new technologies in order to improve their livestock production. However, through the FGD and KAP, it became evident that there are intrinsic and extrinsic challenges related to biosecurity adoption. While knowledge has generally improved, the obstacles to biosecurity implementation include lack of farm-level infrastructure to implement quarantine areas. When village-level options were attempted to be implemented, key barriers were associated with who would be responsible for the maintenance and enforcement of the measures. Farmers currently require incentives and coordinated strategic assistance from the GoL for consistent, effective and sustainable biosecurity measures to be implemented.

Improved disease reporting also requires a more coordinated government strategy. Other externally funded projects (e.g. OIE and Hungarian Government) are trialling the introduction of a computerised reporting system at various administration levels. Although these may prove beneficial, this project demonstrates the importance of having a computerised reporting system available that records data from the VVW level to ensure all potential disease events are recorded. Provision of either financial incentives to report, or legislation that ensures improved compliance with reporting responsibilities are required, as currently, VVWs are private entities and have no legal obligation to report disease.

Importantly, the cross-sectional FMD goat serological study, believed to be one of the first of that size to be conducted in Laos, was an essential investigation into the diagnostic considerations, serosurveillance implications, and the potential role of goats in FMD transmission in South-East Asia. This activity has important policy implications, especially in determining zonal FMD freedom. It also provided evidence for the efficacious use of commercial FMD ELISA kits when utilised with caprine sera. The Orf investigations confirmed the presence of this zoonotic disease in Laos. The study provided diagnostic evidence for local animal health authorities that guides them in distinguishing the disease from FMD, with the case study demonstrating how to conduct differential diagnostic investigations when confronted by clinical presentations resembling Orf and FMD in goats. The other goat studies (endoparasites and zoonoses) also guide the management of these animals and provide baseline data for a rapidly growing economic enterprise in Laos, including the importance of maintaining the population of the native Kambing-Katjang due to their decreased disease incidence, plus the health challenges of intensification and importation of Boer crossbreed goats.

8.2.Capacity impacts – now and in 5 years

Capacity-building activities were integrated throughout the project activities and targeted various stakeholder and participant groups. The project has had a major influence at the regional international level, with OIE regularly promoting the benefits of the FMD research conducted in Laos on policy development, particularly with strategic vaccination and biosecurity strategies, more effective surveillance programs, and the role of goats in developing approaches to evidence-based zonal freedom. At the local level, the discussions with provincial and district level project participants during the final project workshop in January 2020 indicated that many are capable of continuing activities implemented during the project once the project activities cease. Key challenges identified were access and cost of reliable FMD vaccines, preventing co-grazing and improving uptake of other biosecurity measures, water availability during the dry season and changing cultural attitudes toward livestock breeding.

8.2.1.University workshop series

A series of interactive workshops for staff and students were conducted in conjunction with the AH-2012-068 project at NUOL in Nabong and SVKU. This included techniques for developing on-line learning modules, based on case studies documented by the project (Russell Bush and Peter Windsor). Pathology training including necropsy examination for improved diagnostic capacities, was also delivered (Peter Windsor and Sonevilay Nampanya) and arrangements made for the donation of teaching equipment (20 microscopes surplus to needs at USYD) plus donation of numerous texts and other training materials. The inclusion of students and staff in the three-part workshop series on scientific writing and presentation skills (Francesca Earp and John Dillon Fellowship alumni Dr Malavan Chittavong of NUOL) and university staff member Mr Phonetheb Porsavathdy (SVKU). Staff engagement is also ensuring that the project had capacity-building impacts. Along with the skills learned, these workshops were excellent opportunities for staff and students to experience a collaborative learning environment different from the didactic techniques generally implemented in the Lao classroom. Staff engagement at each university allowed these individuals to gain specific experience in project planning and delivery as well as material and activity ownership. By promoting ownership and responsibility, it is hoped that each university can continue to provide these workshops for future students, providing a long-term legacy of student capacity building. The workshops were very successful with an average of 30 staff and students joining each session, including the attendance of project scholarship recipients at both universities.

Francesca Earp conducting a scientific writing workshop session at Savannakhet University (Photo: Mr Phonetheb)

8.2.2.University student conference

On 8 January 2020, the university student conference was held at the Vansana Riverside Hotel, Vientiane. Students and staff attended the event from NUOL (n = 33, including 3 staff and 23 females) and SVKU (n = 43, including 4 staff and 29 females). Students could present research projects with two oral presentations from each university; Paveena Chansy and Chansamone Aitthaphone (NUOL) and Chnpheng Chindavong, Moukdasavan Xaymahathep and Anounee Mahasongkham (SVKU); Somhak Sonlamany and Latsamee Phengsamone (SVKU) also presented a poster. Keynote speakers at the conference included: Matt Champness and Stephen Lang, Australian Volunteers working in

Savannakhet, team member Francesca Earp speaking about the projects gender initiatives on behalf of Ms Chanthalangsy, Dr Vannaphone (NUOL) and Mr Phonetheb (SVKU). In addition to student presentations, a conference magazine was compiled (Appendix 2) which included student, staff and project field reports and scientific papers from university students. All students and staff attending the conference were given the opportunity to submit to the conference magazine with everyone receiving a hard copy of the publication at the event.

Such initiatives are very likely to have long-term capacity building impacts. The university student conference magazine (Appendix 2), included a testimonial from Mr Phonetheb (SVKU): "Through the training, the students and professors who participated in the study gained a greater understanding of scientific research topics such as understanding issues about conducting research, sourcing information from sources such as Google Scholar, finding and understanding a journals impact factor and referencing using EndNote." In addition to this at our final project workshop in January 2020, Dr Vannaphone (NUOL) mentioned that the workshop series and the on-going collaboration between the project, NUOL and the University of Sydney have helped to build the capacity and confidence of students and staff. In addition, he described how the universities close relationship with the project assisted in the development of the veterinary and agricultural science university curricula. These comments reflect the prolonged association of Professors Windsor and Bush with NUOL and their conduct of several curriculum reviews and discipline advisory activities during the current projects, with financial assistance from the Asian Development Bank (ADB).

8.2.3. Project provincial and district staff training

The FGD with the provincial and district staff and farmers in June 2019 revealed concerns that despite their participation in extensive training, they still felt ill-equipped to train farmers on biosecurity, disease identification and livestock management. This suggests that conducting qualitative investigations with neutral parties at various stages throughout the project is appropriate to ensure stakeholders are receiving the correct training for continued capacity building and knowledge transfer. The farmer-training activities throughout the project consisted of train-the-trainer components. To incorporate findings from the FGD, a final set of training activities were conducted from October to December 2019, in collaboration with staff from the Laos Buffalo Dairy, a local social enterprise with whom the project team has developed a strong relationship. Luang Prabang based central team members, Mr Kong and Mr Bouakeo attended the two-day training program as key team members responsible for facilitating extension activities with their provincial and district counterparts. Staff revised content from the topics: livestock disease identification, control and mitigation, livestock nutrition, livestock breeding and general livestock husbandry. The second day of the training workshop focused on training delivery skills enabling the project staff to practice their oral delivery and teaching skills.

Following this, Mr Kong and Mr Bouakeo, accompanied by USYD team member Francesca Earp, conducted a pilot training session, including a train-the-trainer session with the provincial and district staff before conducting a farmer training session in Luang Prabang province. This training program was conducted in all the project sites in Luang Prabang province (including AH-2012-068 sites). This was a successful technique, enabling project, provincial and district staff to revise their understanding of issues and build confidence in conducting farmer-training sessions, with materials that will help deliver extension activities on cessation of the project. The FGD was gender-inclusive, with emphasis on the need for inclusion of female farmers. As females are known to be the primary financial decision-makers in smallholder farming households, their inclusion in training activities is essential to ensure that they can make fully informed decision regarding household expenditure for animal health and biosecurity.

8.2.4. Farmer capacity building

Farmers openly reflected during the FGD on their experiences and learnings from the project, with both male and female farmers displayed detailed and specific knowledge, such as the importance of checking vaccine expiry dates, forage planting and management, general concepts of improving reproduction and vaccination knowledge and understanding. In helping smallholder farmers develop a better understanding of the scientific concepts behind farm-related issues such as transboundary animal diseases and their control, we are helping them adapt to the challenging issues that often impact livelihoods. Both male and female groups in the FGDs stated the project enabled their learning of livestock diseases, particularly FMD, equipping them with the skills and knowledge to control outbreaks and limit the negative impacts on their income. This commences the change management process required for farmers to move from subsistence to production, with sustainability requiring their motivations to be intrinsic (Young et al., 2015), and training appropriately delivered.

The project provides evidence of farmer motivations in Laos so training and extension can be appropriately tailored. When asked what project activities they enjoyed the most, both male and female groups across all 3 provinces listed the following:

- Livestock vaccination
- Increased knowledge
- Increased income
- Nutrition improvement blocks and forage

Farmers in Luang Prabang at a livestock disease mitigation training session conducted by Mr Lhamphut and Mr Bouakeo (Photo: Francesca Earp)

8.3.Community impacts – now and in 5 years

8.3.1.Economic impacts

The promotion of vaccination and biosecurity mitigation schemes in the various village groups has made important improvements in endemic livestock disease control and farmer understanding of risk management, leading to improved overall incomes. The FISQs conducted in 2018 and 2019 indicate that the presence of an FMD outbreak on a smallholder farm has detrimental socioeconomic implications on smallholder farmer livelihoods. The CBA (Section 7.6) indicated that effective vaccination and/or biosecurity dramatically reduces the costs of an FMD, outbreak even if some of the farmer's livestock do become infected.

The FGD found that farmers were experiencing time-savings of 1.3-1.4 hr/day due to project interventions. Many farmers were utilising this extra time to earn more off-farm income, with extra income potentially re-invested into on-farm biosecurity and disease mitigation. Improved biosecurity and disease control combined with improved livestock nutrition and parasite control is likely to lead to improved reproductive rates, with more better-quality animals available for sale. Although the impacts from improved reproduction can take several calving cycles before the benefits are self-evident, with Laos attempting to increase the number of large ruminants traded with China, these farmers are positioned to benefit from this increased trade. They have developed the knowledge and skills to implement proper biosecurity, and with additional nutritional management training and skills, they can access this market and can progress with successfully quarantined cattle fattening enterprises.

A farmer in Xayabouli selling meat at a local market; this is an important secondary source of income for her family (Photo: Nichola Calvani)

8.3.2.Social impacts

Social enjoyment

Through the various on-farm interventions, the participants in this project gained 1.3-1.4 hr/day time-savings, as was also documented in Cambodia (AH-2011-014). Time-savings can have significant social benefits, enabling farmers more time to spend connecting with their community through religious, cultural and social activities (Ashley et al., 2018). In the FGD, adults and children all acknowledged the time-savings gained through the project activities, using this extra time for education, helping parents (children), and spending time with family and friends (adults and children). Improving social bonds in the village creates stronger communities with potential translation to better cooperation for village level biosecurity interventions, disease reporting, livestock management and marketing power. In addition, improving the female farmer's time spent on social activities is important as she is often the most time-poor member of the community and household. In FGD's, examination of farmer's daily timesheets comparatively identified that as a female farmer spends most of her day working on- and off-farm, often working as the manager for the family's small business, plus responsibility for the household and care of her children, she has less time for social activities. By decreasing her time spent in on-farm activities, female farmers can be more engaged in the community, and thus empowered.

Female farmer engagement

Due to the cultural perception of agriculture in Laos, there is currently a risk of unintentional female disempowerment as female farmers are rarely included in farm management conversations at both a household and village level. To address this, female farmer inclusion was a focus of training and data collection activities. The female-only FGD and inclusive farmer training sessions invited females into a safe space to share values and opinions. The Lao project team members and provincial and district staff observed this and it is expected that female farmers will continue to be included in extension activities and farming dialogue on project completion. Both males and females need inclusion in livestock health and biosecurity discussions and training for effective implementation of livestock activities and financial decision-making on farming investments.

Reduced pressure of livestock disease

The FGD sessions and FISQs indicated that smallholder farmers feel social and emotional pressures when their livestock are sick, with many farmers reporting feelings of shame and embarrassment when their animals have FMD. Although the impact of these pressures is difficult to quantify, it is well known from global animal health emergencies and especially FMD, that the mental toll can be severe. With endemic FMD there are feelings of helplessness inevitability associated with disease outbreaks, plus the financial strain of restoring livestock to the pre-disease condition can be significant (Young et al., 2013). This financial impact can be even more significant if a family is faced with an emergency requiring access to funds. Further, the responsibility the farmer feels to the rest of the village during an outbreak has a negative impact on social standing, with farmers in the project sites recognising the benefits from the reduced FMD risk due to project activities and interventions, including the STANDZ program vaccinations. Project training and interventions focused on disease control empowered the participants, providing a sense of autonomy over disease control and mitigating the social and emotional pressures from FMD and HS disease outbreaks.

A farmer with her livestock in Xieng Khoung (Photo: Nichola Calvani)

8.3.3. Environmental impacts

Analysis of environmental impacts was not an objective of this project, although changes to land use through forage development, reduced free-grazing and better water and animal waste management will result in positive long-term environmental impacts. The utilisation of forages reduces the need for animals to free-graze, reducing pressure on native grasslands and forested areas, reducing soil erosion and minimising resource competition with native animals. Water management and land availability are key challenges facing the Lao agricultural sector, with drought and flooding becoming more common and the impacts of dams still to be fully understood. Further research should be conducted into appropriate methods to capture, store and manage water resources and mitigate flood and drought risk.

8.4.Communication and dissemination activities

8.4.1.Farmer training program and collaboration with the Laos Buffalo Dairy

Throughout the project, multiple farmer training sessions enabled knowledge transfer of project findings to the smallholder farming community. Lessons learned from the FGD sessions detailing how cultural values impact smallholder farmer trading decisions were used to direct the final farmer training sessions, with cultural pressures factored into training to ensure optimal uptake and adoption. The project team developed a productive collaborative relationship with the Lao Buffalo Dairy (LBD), providing considerable animal health management, biosecurity and nutritional advice from inception of the dairy. In 2017, the USYD project team with the Brisbane-based Four Seasons Company were awarded an Australian Department of Foreign Affairs and Trade (DFAT) Business Partnership Platform (BPP) project grant to research and develop high-quality nutrient molasses blocks for Laos. This BPP has been very successful. In 2019, the LBD was also awarded a BPP grant that included training of smallholder farmers in Luang Prabang in the milking of buffalo for provision of milk to improve child and maternal nutrition. The LBD also received an ADB grant to produce farmer-training videos, with a team member (Francesca Earp) assisting in the development of these videos that included training on milking buffalo, livestock husbandry and disease control. The team also collaborated with the LBD to conduct a train-the-trainer session to promote the scale-out and knowledge transfer of this information and build local animal health capacity, plus strengthen in-country relationships different projects.

8.4.2.Project meetings

Annual project meeting – 15 August 2016

- The annual meeting was held in Vientiane, 15 August 2016. The meeting involved District and Provincial Agriculture and Forestry Office (DAFO and PAFO) and DLF representatives from each province as well as central staff and governmental officials.
- The Meeting discussed achievements from the preceding year and outlined the activities for the second year of the project.

Annual Project Meeting – 22 August 2017

- The annual meeting was held in Vientiane, 22 August 2017. The meeting involved DAFO and DLF representatives from each province as well as central government officials (30 males and five females). The meeting discussed achievements from the preceding years and outlined activities for the third year of the project.

Mid-term review – 12–13 February 2018

- The project held a mid-term review workshop and field trip in Luang Prabang 12–13 February. The review was attended by 20 Lao project stakeholders (including four females) representing the DLF, DAFO and PAFO, NUOL and SVKU as well as a delegation from ACIAR including external reviewers. The presentations showcased the activities and achievements of the project to date.

Annual Project Meeting – 21 August 2018

- The annual meeting was held in Vientiane, 21 August 2018. The meeting involved DAFO and DLF representatives from each province as well as central government officials (27 attendees including six females). Based on the feedback received in the mid-term review, the meeting aimed to plan out key activities requiring completion. This provided an opportunity to ensure all project partners were aware of expectations for the remainder of the project.

End of Project Review – 20–22 March 2019

- The project held an End of Project review workshop and field trip in Luang Prabang 20–22 March. The review was attended by 34 Lao project stakeholders (including 8 females) representing the DLF, DAFO and PAFO, NUOL and SVKU as well as a delegation from ACIAR including external reviewers. The presentations showcased the key activities achieved under project objectives and outlined plans for the remainder of the project.

Final Project Meeting – 8 January 2020

- The project conducted a final stakeholder meeting on 8 January 2020. The purpose of this was to highlight key findings that weren't available at the End of Project Review in March 2019. The meeting was also aimed to provide the provincial and district team members with the opportunity to present some of their perceived highlights and lessons learned.

8.4.3.Conference attendance

19th SEACFMD National Coordinators Meeting, 17–19 August 2016, Bangkok:

- Young, J.R., L. Rast, S. Khounsy, S. Suon, S. Nampanya, R.D. Bush and P.A. Windsor *Applied value chain assessment for FMD risk analysis in the Mekong*.

23rd SEACFMD Sub-Commission Meeting, 10–13 March 2017, Siem Reap:

- Windsor, P.A., S. Nixon, R. Duan, I. Game, J.R. Young, S. Nampanya, S. Hamilton, C. Miller, S. Khounsy and R.D. Bush, *Field testing of Australian FMD vaccine injectors in large ruminants in Lao PDR.*

- Abila, R., S. Nampanya, S. Khounsy and P.A Windsor (2017) *Assessment of socioeconomic impact of FMD vaccination programmes in northern and Central provinces Laos*.

One Health Workshop, 21–22 September 2016, Thalad, Vientiane, Lao PDR. FAO and WHO.

- Nampanya, S., S. Khounsy, P. Inthavong, F. Unger, V. Putthana, A. Binot and P.A. Windsor (2017) *Important zoonoses associated with food-borne parasites of pigs in Laos.*

9th International Sheep Veterinary Congress, Harrogate, 22–26 May 2017, Harrogate:

- Windsor, P.A., V. Phutthana, S. Nampanya, K. Keonam, K. Johnson, S. Khounsy and R.D. Bush, *Challenges of distributing goats in smallholder livestock development programs.*

2017 Global Foot-and-Mouth Disease Research Alliance Scientific Meeting, 25–27 October, Incheon, Korea

- Miller, C., Young, J., Nampanya, S., Khounsy, S., Singanallur, N., Vosloo, W., Abila, R., Bush, R. and P. Windsor *Risk factors for endemic and emerging foot-and-mouth disease viruses on smallholder farms in Lao PDR*

- Nampanya, S., Khounsy, S., Abila, R., Bush, R. and P. Windsor *The socioeconomic impact of the foot-and-mouth disease vaccination project implemented in northern and central Lao PDR*

- Windsor, P. and R. Abila, *Was biosecurity awareness more effective than vaccination of pigs for FMD in the Philippines*

20th SEACFMD National Coordinators Meeting, 16–18 August 2017, Pakse, Lao PDR

- Windsor, P., Khounsy, S., Nampanya, S., and R. Abila, *Strategic mass vaccination in northern Laos.*

2018 SEACFMD Epidemiology Network Meeting, 5–6 April 2018, Yogyakarta, Indonesia

- Windsor, P., and I. MacPhillamy, *Research on FMD control and biosecurity in Laos and Cambodia informing SEACFMD*

30th Conference of the OIE Regional Commission for Asia, the Far East and Oceania, 20–24 November 2017, Putrajaya, Malaysia

- Windsor, P., *How to implement farm biosecurity: the role of government and private sector*

30th World Buiatrics Congress, 28 August – 1 September 2018, Sapporo, Japan

- MacPhillamy, I. and P. Windsor, *Improving biosecurity for Foot-and-Mouth Disease (FMD) control in countries from Asia, the Far East and Oceania*
- Windsor, P., Nampanya, S., Young, J., Khounsy, S., Suon, S. and R. Bush, *An evidence-based herd health program for tropical smallholder beef production in Southeast Asia*

21st SEACFMD National Coordinators Meeting, 17–19 July 2018, Penang, Malaysia

- MacPhillamy, I. and P. Windsor, *Enhancing FMD control through promoting farm biosecurity*

24th Meeting of the OIE Sub-Commission for SEACFMD, 27–30 November, Ho Chi Minh City, Vietnam

- Windsor, *Research on improving FMD management through increasing livestock productivity in the Mekong: 1st 10 years*

22nd SEACFMD National Coordinators Meeting, 25–27 June 2019, Ulaanbaatar, Mongolia

- Windsor, P.A., *A new non-antimicrobial therapy for FMD*
- Young, J., *Synchronising FMD control with agricultural priorities – through a change management framework*

The International Society for Economics and Social Sciences of Animal Health – South-East Asia, 17–18 October 2019, Bogor Indonesia

- Earp, F., Paterson, S., MacPhillamy, I., Sanderson, T., Khounsy, S., Windsor, P. and R. Bush, *Put your money where your mouth is: A cost-benefit analysis of three commonly used foot-and-mouth disease mitigation schemes in Lao PDR*

Global Foot-and-Mouth Disease Research Alliance Scientific Meeting, 29–31 October, 2019, Bangkok, Thailand

- MacPhillamy, I., Young, J., Nampanya, S., Toribio, J.A., Khounsy, S., Bush, R. and P. Windsor, *Our challenge is to deliver effective biosecurity in FMD endemic countries in South-East Asia*
- Windsor, P., MacPhillamy, I., Earp, F. and S. Khounsy, *A new topical therapy for FMD to address animal welfare, antimicrobial residues, virus transmission, and potentially improve surveillance*

8.4.4. Newsletters

- Three issues published throughout the projects
    - Available at: https://mekonglivestock.wordpress.com/updates-on-current-research/

8.4.5. Online communication

Online blogs and project updates available from the Mekong Livestock Research website and Facebook page:

https://mekonglivestock.wordpress.com

https://www.facebook.com/MekongLivestockResearch

8.4.6. Student participation

See appendix 3 for a list of student projects conducted during the project

9. Conclusions and recommendations

9.1. Conclusions

This project has been successful at the smallholder farmer level, with improvements recorded in animal health and vaccination rates and farmer capacity, knowledge and attitudes. At the end of the project provincial and district staff felt positive about the ongoing continuation of activities post-project, despite numerous challenges of implementing effective biosecurity and other interventions. However, some of these critical challenges, as identified through the project, reflect the lack of resources, monetary and otherwise, available to the national, provincial and district veterinary and agricultural extension services. For sustainable and long-term improvements to occur the GoL, perhaps through additional donor inputs, needs to improve funding to these sectors, plus developed legislation to ensure compliance with vaccination, quarantine and biosecurity measures in managing emergency disease outbreaks. There is an urgent need to hasten the progress required for continual improvement in TAD and emergency disease management, particularly if Laos is to fully yet safely access the enormous livestock trading opportunities its location within the GMS provides.

9.2. Recommendations

9.2.1. Policy recommendations

Significantly improved knowledge of the challenges of TAD control have been made in this project, particularly of the smallholder level understanding of biosecurity and the implementation of vaccination programs for FMD. This and several other large ruminant animal health projects have provided funding and supply of FMD vaccinations and it is recommended that the GoL focus on ensuring it has consistency of access to high quality FMD vaccines plus funding for delivery in the field. With the GoL agreement on the export of large numbers of cattle into China, there will be increased pressure to improve regional control of FMD. The proposed feedlot areas near the Chinese border will need to implement strict biosecurity and vaccination protocols, with the expertise obtained in this project of direct value to this initiative. Reports from project participants display a desire to continue to protect and improve animal health in Laos. However, due to the low incomes and extensive informal trade of animals, legislature and the power to enforce compliance with the rules of trade requires widespread adoption and change management.

Ongoing agricultural extension work is important to ensure that key messages and skills implemented during the project are able to continue to build capacity for livestock development. Transparency and cohesiveness between extension providers (public, private, non-government organisations and donor bodies) needs to be ensured so that research for development findings can be regularly integrated into programs and policy. This includes a focus on social science and anthropological findings as it is important to understand the social structure and needs of the community that the policy change is being applied to.

9.2.2. Village Classifications

One notable conclusion from the FGD sessions was the fluidity between the various ‘village classifications’. The project planned to have a distinct difference between the three village interventions: V, B and BV. However, the FGD and longitudinal serology uncovered that all three village classification sites were given FMD vaccinations, although this intervention was supposed to be reserved for the V and BV villages. In conversations with provincial, district and project staff, the reasoning for the use of vaccination in all villages was that staff felt uncomfortable giving villages different resources. Although this observation has been made previously and was considered in the planning of this project, the central Lao project team was assured that it was a deliverable as prior to activity implementation, the project leadership imparted the importance of scientific design on the in-country team members. However, perhaps understandably, the local in-country project team wanted to provide farmers with the greatest level of intervention, a desire that outweighed the discomfort they felt distributing different levels of intervention. Although the in-country team members were actively included in project planning discussions and midterm reviews to ensure they share responsibility for the interventions implemented, there remains an issue that a disconnect may occur between the importance of scientific design and the actual implementation of the activities, especially at the district level where the DAFO personnel are responsible for implementing and maintaining the activities yet are still poorly trained in scientific methodology.

9.2.3. Communication improvements

Due to key changes in personnel (e.g. Dr Nampanya leaving mid-project and a suitable in-country replacement was not identified, so this task was conducted by Australian team members) communications between the in-country district, provincial and project staff (in-country and Australian) were occasionally limited, with some confusion on implementation of project activities. This occurred mainly in the provinces that were also involved in the AH-2012-068 project, that is, some confusion emerged that two independent projects were occurring (AH-2012-067 and AH-2012-068). It is recommended that an in-country project officer be replaced by a suitable in-country replacement. However, if the project officer is to be replaced by a foreign team member, a system with more regular communication, such as weekly emails are implemented, where all project members contact the project officer to receive briefings and provide updates. Further, although utilising the same in-country team enabled cost-savings, the increase in the workload of the local team and confusion on project activity implementation in delivering two projects, suggests that when two projects are instigated, it may be better to ensure they are delivered separately (potentially resolving some of the issues identified in section 9.2.2).

9.2.4. Beneficiary target groups

During the inception phase and selection of village locations, efforts were made to ensure there was ethnic diversity amongst the project sites. However, the FGD sessions indicated that in general, there was less ethnic diversity than was intended. This lack of diversity is likely due to the fact that the in-country team members are only able to speak Lao and are unable to communicate effectively with other Lao ethnic groups, such as Hmong. Ensuring more staff from various ethnic groups are included in the project team is desirable in future projects. This inclusion will allow the team to have a better understanding of the culture of these different ethnic groups including their animal husbandry techniques and family dynamics.

9.2.5. Data and personnel management

Efforts were made throughout the project to adopt updated computerised and mobile acquired data techniques. The mobile application CommCare was trialled in the cross-sectional serological survey in February 2019, while KoBo connect was used for the FGDs in May and June 2019. Experiences from this project demonstrate the importance of having appropriate training implemented early in the project and ensuring that all ‘end-users’ are adequately trained to ensure confidence in the system. The adoption of mobile acquired data platforms creates significant time-saving benefits for project activities, reducing the need for data re-entry and long-answer translations, minimising the risk of human error in transcription and providing centralised access to data sets for all team members. Many of these programs have been developed in the human health sphere and have high levels of data security applied so will continue to comply with Human Ethics Council requirements.

Personnel changes may be expected to occur in projects of this duration. The significant personnel changes that occurred in this project required that new roles for project members be developed and required time for team-building opportunities to occur. New personnel changes can provide new opportunities for capacity building within teams and improve autonomy over activities, as occurred with centralising of data and eventually, better communication (Section 9.2.3). It does take time following significant personnel changes for new team members to develop a solid understanding of the aims and deliverables of the project.

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11. Appendixes

11.1. Appendix 1

Table 24. Prevalence data of the large ruminant and goat serum samples collected in February 2019 from the nine northern provinces in Laos that were involved in the STANDZ vaccination program between 2012-2016 (n = 633)

Province	District	Village	Samples tested	Number positive	Apparent Prevalence (95%CI)	True Prevalence (95%CI)
Bokeo			49	6	12.2 (3.1-21.4)	13.0 (4.8-23.7)
	Pha oudom		49	6	12.2 (3.1-21.4)	13.0 (4.8-23.7)
		Somesavang	23	1	4.3 (0.0-12.7)	7.3 (0.5-20.4)
		Phiengtharth	26	5	19.2 (4.1-34.4)	20.7 (7.8-37.4)
Houphan			123	90	73.2 (65.3-81.0)	73.3 (65.1-80.9)
	Add		53	39	73.6 (61.7-85.5)	73.2 (60.9-84.3)
		Kangnamadd	24	16	66.7 (47.8-85.5)	65.7 (46.2-82.6)
		Pha keo	29	23	79.3 (76.2-100.0)	78.0 (61.9-90.8)
	Huameuang		21	20	95.2 (86.1-100.0)	92.0 (77.6-99.4)
		Longang	21	20	95.2 (86.1-100.0)	92.0 (77.6-99.4)
	Viengxay		27	13	48.1 (29.3-67.0)	48.1 (30.4-66.1)
		Chath	27	13	48.1 (29.3-67.0)	48.1 (30.4-66.1)
	Xiengkhor		22	18	81.8 (65.7-97.9)	79.7 (61.4-93.4)
		Sere	22	18	81.8 (65.7-97.9)	79.7 (61.4-93.4)
Luang Namtha			38	5	13.2 (2.4-23.9)	14.3 (5.0-27.0)
	Viengphoukha		17	0	0.0 (0.0-0.0)	5.3 (0.0-15.3)
		Narm Marng	17	0	0.0 (0.0-0.0)	5.3 (0.0-15.3)
	Sing		21	5	23.8 (5.6-42.0)	25.5 (10.0-44.7)
		Nar Leck	21	5	23.8 (5.6-42.0)	25.5 (10.0-44.7)
Luang Prabang			113	37	32.7 (24.1-41.4)	32.6 (24.2-41.6)

	Ngoi		24	2	8.3 (0.0-19.4)	10.7 (1.6-25.4)
		Sobkhan	24	2	8.3 (0.0-19.4)	10.7 (1.6-25.4)
	Nambak		13	1	7.7 (0.0-22.2)	12.6 (1.1-33.4)
		Pongtai	13	1	7.7 (0.0-22.2)	12.6 (1.1-33.4)
	Luang Prabang		26	4	15.4 (1.5-29.3)	17.1 (5.4-33.3)
		Nongtok	26	4	15.4 (1.5-29.3)	17.1 (5.4-33.3)
	Park ou		50	30	60.0 (46.4-73.6)	60.0 (46.2-72.9)
		Khok	20	9	45.0 (23.2-66.8)	45.3 (25.2-66.3)
		Parkjeng	18	17	94.4 (83.9-100.0)	90.7 (74.3-99.3)
		Houypen	12	4	33.3 (6.7-60.0)	35.4 (13.3-61.3)
Oudamxay			59	24	40.7 (28.1-53.2)	40.8 (28.8-53.6)
	Namor		40	15	37.5 (22.5-52.5)	37.8 (26.6-52.9)
		Phukhuea	22	15	68.2 (48.7-87.6)	67.0 (49.6-84.2)
		Pangsar	18	0	0.0 (0.0-0.0)	5.0 (0.0-14.6)
	Xay		19	9	47.4 (24.9-69.8)	47.6 (26.8-68.7)
		Hieyja	19	9	47.4 (24.9-69.8)	47.6 (26.8-68.7)
Phongsaly			77	45	58.4 (47.4-69.4)	58.5 (47.4-69.4)
	May		21	9	42.9 (21.7-64.0)	43.3 (23.9-64.0)
		Noi	21	9	42.9 (21.7-64.0)	43.3 (23.9-64.0)
	Nhot ou		21	1	4.8 (0.0-13.9)	7.9 (0.5-22.0)
		Parng hock	21	1	4.8 (0.0-13.9)	7.9 (0.5-22.0)
	Samphan		35	35	100.0 (100.0-100.0)	97.3 (92.1-100.0)
		Lao san	20	20	100.0 (100.0-100.0)	95.5 (86.6-100.0)
		Oum thurm	15	15	100.0 (100.0-100.0)	93.9 (82.2-100.0)

Vientiane Province			61	27	44.3 (31.8-56.7)	44.3 (32.2-56.5)
	Feuang		21	5	23.8 (5.6-42.0)	25.4 (9.9-44.6)
		Don	21	5	23.8 (5.6-42.0)	25.4 (9.9-44.6)
	Phonhong		20	5	25.0 (6.0-44.0)	26.9 (10.6-47.1)
		Phonhngern	20	5	25.0 (6.0-44.0)	26.9 (10.6-47.1)
	Vangvieng		20	17	85.0 (69.4-100.0)	82.5 (63.8-95.5)
		Namonenuea	20	17	85.0 (69.4-100.0)	82.5 (63.8-95.5)
Xieng Khoung			61	26	42.6 (30.2-55.0)	42.7 (30.6-55.1)
	Kham		42	20	47.6 (32.5-62.7)	47.9 (33.0-62.5)
		Dorkkham	21	10	47.6 (26.3-69.0)	47.9 (27.6-68.1)
		Phosy	21	10	47.6 (26.3-69.0)	47.9 (27.6-68.1)
	Phookood		19	6	31.6 (10.7-52.5)	33.0 (14.4-54.5)
		Nongkung	19	6	31.6 (10.7-52.5)	33.0 (14.4-54.5)
Xayabouli			52	12	23.1 (11.6-34.5)	23.6 (13.0-36.0)
	Hongsa		7	0	0.0 (0.0-0.0)	11.6 (0.0-32.8)
		Kiew mouang	7	0	0.0 (0.0-0.0)	11.6 (0.0-32.8)
	Khop		25	1	4.0 (0.0-11.7)	6.7 (0.4-18.7)
		Don tanh	25	1	4.0 (0.0-11.7)	6.7 (0.4-18.7)
	Xayabuli		20	11	55.0 (33.2-76.8)	54.7 (33.8-74.0)
		Nahai	20	11	55.0 (33.2-76.8)	54.7 (33.8-74.0)
Total			633	272	43.0 (39.1-46.8)	42.9 (38.9-46.8)

11.2.Appendix 2 Student Conference Magazine

Please refer to the attached PDF of the Conference magazine.

11.3.Appendix 3 Student Projects

Student Name (course)	**Project title**
Thomas Boyle (BVSc)	Overview of swine associated viral zoonoses, Japanese encephalitis virus and Hepatitis E virus in Lao PDR
Ran Duan (BVSc)	Pilot study for the use of a vaccination gun for oil-based foot-and-mouth vaccine in field conditions in Lao PDR
Imogen Game (BVSc)	A review of emerging antimicrobial residue and resistance data in the Greater Mekong region of South-East Asia and the need for more research on this issue, with a focus on Lao PDR
Kate Johnson (BVSc)	Investigation of gastrointestinal parasites of goats in Lao PDR
Shan Rixon (BVSc)	Trial of Australian foot-and-mouth disease vaccine guns under field conditions
Ronald Tong (BVSc)	Review of primary poultry diseases and biosecurity practices appropriate for rural smallholders in Lao PDR
Rachael Walton Weitz (BVSc)	The Lao PDR FMD Project: The importance of foot-and-mouth disease
Kate Luk (BVSc)	An evaluation of the data collected from negative disease reporting of eleven important infectious animal diseases in three target provinces in Lao PDR
Mason White (BVSc)	Comparing farmer knowledge, attitudes and practices with regard to vaccination and on-farm biosecurity measures in norther Lao PDR
Janet Nguyen (BVSc)	Review on avian influenza and Newcastle disease in Lao PDR
Georgia Andrews (BVSc)	Biosecurity and preventative medicine principles and practices that can reduce the risks of transboundary animal diseases at the village level for livestock production in Lao PDR
Maria Gerasimova (BVSc)	Nabong Orf Investigation Report
Cameron Grundy (BVSc)	Control of endoparasitism in goats within the Mekong Region – and exploration of control methods for intestinal nematodes namely *Haemonchus contortus*
Brianne Pepper (AVBS)	Assessing the development of smallholder farmer biosecurity knowledge, attitudes and practices in northern Lao PDR
Corissa Miller (MVPHMgt)	Risk factors for emergence of exotic foot-and-mouth disease O/ME-SA/Ind-2001d on smallholder farms in the Greater Mekong Subregion
Francesca Earp (AVBS)	The cost benefit of livestock vaccination and biosecurity programs to mitigate foot-and-mouth disease at the household and village level in Lao PDR
Edwina Leslie (BVSc)	Porcine reproductive and respiratory syndrome in Lao People's Democratic Republic