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REGULAR ARTICLES

Challenges for beef production in smallholder communities with low reproductive management skills: a case study from Northern Lao PDR

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Abstract Improved large ruminant productivity is increasingly acknowledged as a pathway for the alleviation of rural poverty and food insecurity in smallholder communities in Southeast Asia; yet, in much of Laos, bovine reproductive management is practically absent. Large ruminant reproduction skills were studied, using face-to-face surveys (n=60) of the knowledge, attitudes, and practices (KAP) of farmers, plus an extension of an examination of parameters of reproductive efficiency (n = 1786 cattle and 434 buffalo) in the northern provinces of Luang Prabang and Xieng Khouang. The surveys particularly involved female farmers to provide gender-disaggregated data, with females making up 38.3 % of participants. Results confirmed that KAPs of smallholder farmers on bovine reproductive management were low (34–46 %) with trends toward higher KAP scores in male survey respondents. Poor reproductive parameters were identified in both provinces, with low calving percentages of 54–75 and 45–54 % in cattle and buffalo groups, respectively, and prolonged inter-calving intervals of 14.1–19.8 and 26.0 months for the cattle and buffalo groups, respectively. Improving the reproductive efficiency of large ruminants in the northern upland regions would enable smallholder farmers to be more effectively engaged in the dramatic economic growth of the Southeast Asia region, although these findings indicate that intensive training and supportive interventions are required to improve large ruminant reproductive outcomes in communities that have low-level large ruminant husbandry skills.

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Introduction

Laos is a landlocked nation in the Mekong region of Southeast Asia that faces a myriad of poverty and food security challenges to its development and growth. In 2014, Laos ranked 139/186 countries on the United Nations Human Development Index (UNDESA 2014). Infant mortality in children under 5 years of age is 72 out of every 1000 live births (World Bank 2014). Further, evidence for food insecurity is present, with almost every second Lao child having stunted growth (low weight and height for age) (World Food Programme 2010; Campbell et al. 2012).

In Laos, 77 % of the population are involved in agricultural activities (SCAC 2012) dominated by smallholder farmers operating a mixed cropping-livestock system at a subsistence level and owning a variety of livestock, including ~5–10 cattle or buffalo (large ruminants) (Wilson 2007; Nampanya et al. 2010). Large ruminant production is a national priority for the Government of Laos (GOL). However, in upland northern Laos, poverty factors such as lack of road access and food insecurity exist (Millar and Photakoun 2008) with two-thirds of all rural households at risk of food insecurity when challenged with an external shock such as crop failure (Campbell et al. 2012). The GOL's aims for the upland region are to conserve the rainforest ecosystems, aid poverty alleviation, and improve food security by finalizing land allocation and moving farmers away from shifting cultivation (Stür et al. 2002; Ducourtieux et al. 2005; MAF 2010; Campbell et al. 2012; Khounsy et al. 2012).

For the upland smallholder farmer, large ruminants provide a readily marketable cash reserve with minimal price

variability (Stür et al. 2002; Wilson 2007; Nampanya et al. 2010; Windsor 2011). The emerging Lao smallholder beef industry has the potential to benefit from the rising wealth of China, Thailand, and Vietnam (Young et al. 2014). At present, the beef production system in Laos is underdeveloped and unable to meet the demands of domestic and export buyers (Nampanya et al. 2014c). However, increased beef production in Laos requires numerous production constraints to be addressed, including poor livestock nutrition, fascioliosis, toxocariasis, transboundary animal diseases, and low reproductive performance (Stür et al. 2002; Wilson 2007; Windsor 2011; Rast et al. 2014; Rast et al. 2015). Further, a range of best practice education and management interventions are required (Windsor 2011; Young et al. 2015), particularly to engage with smallholders through multi-stakeholder participatory capacity building and to enhance the low levels of general husbandry knowledge (Nampanya et al. 2010).

Upland Lao large ruminants are managed in a combination of free-grazing and semi-housed systems with minimal-to-no additional feed inputs and minimal reproductive management. Estimates are that Lao yellow cattle have a calving percentage of 50–80 % and buffalo have a calving percentage of <50 % (Stür et al. 2002; Rast et al. 2014). A preliminary study recently reported that the inter-calving intervals (ICI's) for northern upland fertile cattle and buffalo were 13.6–15.6 and 18.6–20.6 months, respectively (Nampanya et al. 2014b), and there was a noticeable difference *between* the two provinces surveyed, warranting further investigation (Nampanya et al. 2014b). Studies into similar upland smallholder farming systems in Vietnam recorded ICIs of indigenous yellow cattle to be similar at 16.3 months (Huyen et al., 2011).

Addressing the generally low level knowledge, attitudes, and current poor practices in reproductive management is likely to improve reproductive outcomes (Nampanya et al. 2014c; Young et al. 2015). This requires provision of management skills that can lead to decreased age of animals at puberty, reduced inter-calving intervals, decreased fertilization failure due to poor nutrition or bull factors such as inbreeding, plus minimizing calf loss from neonatal diseases (Dziuk and Bellows 1983; Burns et al. 2010; Walmsley et al. 2016). Further, it is noted that there is minimal information on the infectious causes of bovine reproductive failure which may be relevant in Laos, such as bovine brucellosis, leptospirosis, bovine campylobacteriosis (vibriosis), plus *Neospora caninum*, and bovine pestivirus (BVD virus) infections (Dziuk and Bellows 1983; Stür et al. 2002; Burns et al. 2010; Fordyce et al. 2014 ; Walmsley et al. 2016).

Environmental, nutritional, and management factors often have a higher net effect on reproductive wastage than infectious and animal effects (Burns et al. 2010). For this reason, our study aimed to investigate the current status of bovine reproductive efficiency in northern Lao, focusing on non-infectious causes of reproductive sub-performance. The study aimed to provide detailed information on smallholder farmer knowledge, attitudes, and practices in relation to bovine reproduction, progressing understanding of the existing knowledge gaps of smallholder farmers. This enables better targeted interventions and improved strategies for capacity building of extension staff, ultimately assisting smallholder communities with poverty alleviation and improved food security through enhanced beef productivity and profitability.

Materials and methods

This study involved two different surveys performed April–July 2014, by a team from the University of Sydney in cooperation with the Department of Livestock and Fisheries (DLF), Laos, and with assistance from students of the National University of Laos (NUOL). Both surveys focused on the northern upland provinces of Luang Prabang and Xieng Khouang. The first survey focused on improving knowledge of large ruminant reproductive efficiency parameters. The second survey focused on smallholder farmer knowledge, attitudes, and practices (KAP) of large ruminant reproduction, enabling trends in KAP and specific knowledge gaps to be identified, assisting future reproductive management initiatives.

Site selection

The reproductive efficiency survey was conducted as a 3-year follow-up to a previously reported 3-year longitudinal survey conducted December 2008 to November 2011 in four villages ($n = 4$) in the two northern provinces of Luang Prabang and Xieng Khouang involving two villages per province (Nampanya et al. 2014b). The new survey reconnected with the villages and farmers from the previous survey and extended the data on calving dates and rates to 6 years (2009–2014) to obtain a more accurate figure for the mean ICI of cattle and buffalo (Nampanya et al. 2014b).

The project villages in the previously published study were selected through consultation between the University of Sydney and DLF research team with officers at the provincial, district, and local village levels. Villages were chosen on selection criteria of the following: high level of cooperation between farmers and local District/Provincial Agriculture and Forestry Officers (DAFO/PAFO); interest in adopting improved livestock animal health and husbandry technologies; evidence for interest in the adoption of forage technology; evidence for interest in intensification of cattle production through practices such as stall feeding; at least 200 cattle or buffalo in each village; year round access; and at least 10 km distance between each village (Nampanya et al. 2014a, b). These same selection criteria were applied for the identification of four ($n = 4$) villages in the provinces of Luang Prabang

and Xieng Khouang for the smallholder large ruminant reproductive KAP survey. For the KAP survey, villages that had not been previously involved in ACIAR-funded projects were chosen to avoid smallholder survey fatigue.

Farmer selection

To assess reasons for differences in previously collected reproductive efficiency data between the provinces (Nampanya et al. 2014b), 15 farmers ($n = 15$) from each of the four new villages ($n = 4$) in Luang Prabang and Xieng Khouang were selected for the reproductive KAP survey through consultation between the research team, village chiefs, and the community as a whole. The survey aimed to have at least 3–5 female respondents per village.

Extension of the longitudinal survey of bovine reproduction parameters involved revisiting smallholder farmers that were previously selected for the reproductive efficiency survey in 2009 (Nampanya et al. 2014a, b). Initial selection involved consultation between the research team staff with village chiefs and the broader community, using criteria of the following: owning at least one cow or buffalo; receptivity to adoption of new technologies; availability of a potential forage plantation area of at least 1000 m^2 per animal enrolled in the study; and finally, farmer willingness to share technologies they have been provided with other villagers not involved in the project (Nampanya et al. 2014b). It is recognized that this approach, while helpful for determining the potential for forage-based fattening, risks marginalizing poorer farmers in the community, who may not have the land access or labor support to grow extra forages (Millar and Photakoun 2008).

Survey design and methodology

Both survey questionnaires were written in English and translated into Lao. The surveys were designed to be succinct, with most questions repeated from previous KAP surveys (Nampanya et al. 2010) to aid facilitator familiarity with the material. Questionnaires were presented to and trialled with facilitators before visiting the villages, to decrease the incidences of miscommunication between facilitators and farmers. The surveys were conducted and recorded face-to-face by a combination of local DAFOs and veterinary students from the NUOL. Two DAFO staff from each province performed the surveys to assist in managing issues surrounding local dialects and farmer familiarity with the survey facilitators. The two students from the NUOL worked in both provinces for the purposes of consistency in question delivery and helping prevent miscommunication between the farmer survey respondents and the survey facilitators. Face-to-face interviews helped reduce non-answer bias, and questions that remained unanswered by a majority of farmers were excluded from statistical analysis.

The reproductive KAP survey was similar to previous KAP surveys performed by the research team (Nampanya et al. 2010) and comprised sections on both the socioeconomic status and reproductive KAP of the respondents. The first section of the questionnaire contained 11 questions on farmer socioeconomic data, employing a majority of open quantitative questions, such as "how many hectares of rice paddy land do you own." There were also some closed dichotomous/multiple choice questions and two open qualitative questions. The KAP survey comprised 23 questions spanning reproductive management with a focus on key areas of reproductive wastage. The KAP survey employed only closed questions, with either a YES/NO response option or a YES/NO/I DO NOT KNOW (IDK) response. IDK responses were considered as incorrect and scored as such and were included to reduce survey bias caused by guessing. The purpose of the KAP study was to find knowledge gaps and post hoc relationships within the data that could be further studied to assist future reproductive development programs. To assist in creating gender disaggregated data for identifying the main large ruminant carer, farmers were asked to record how many hours the "husband," "wife," "children," and "others" worked with large ruminants both during the wet, rice growing season and the dry, non-rice growing season.

The reproductive efficiency survey questionnaire layout was an almost exact copy of that used previously (Nampanya et al. 2014a, b) but with columns for the years 2012, 2013, and 2014 replacing that of 2009, 2010, and 2011. Each year represented a unique calving period and information on whether or not a cow had calved that year; the sex of the calf, the calving month, and the survival of the calf were collected using a closed categorical (e.g., month of birth) and dichotomous questions (e.g., sex of calf). If the farmer did not know the answer to a dichotomous response, it was counted as a 0.

Inter-calving intervals (ICI) were calculated on animals for which ≥4 years of data were available and had ≥2 calves in the survey period, requiring farmers to maintain records on their animals' identification numbers for the calving data from the previous study to be collated with the data collected in this study. This was in response to previous observations (Nampanya et al. 2014a, b) that 3 years of data could produce more favorable ICIs, as only reproductively successful cows would be able to have two or more calves in 3 years.

Data management and analysis

Paper copies of both surveys were completed during the face-to-face interviews and entered into Microsoft Excel. Data analysis was then undertaken using both Microsoft Excel and GenStat© version 16 as detailed below.

Based on the results of the KAP survey, four different marking matrices were created to quantify the status of

reproductive management in the village study. First a traditional knowledge score was recorded from the knowledge-based questions of the survey. To create a more comprehensive picture of farmer reproductive management beyond the knowledge score alone, a combined KAP score was also developed, incorporating questions from throughout the KAP survey that indicated improved reproductive management. This is the first time that more than six questions were dedicated to reproduction and focused upon the areas of bull reproductive management, post-partum cow, and calf management and pregnant cow management, each of which were scored separately to identify farmer knowledge gaps.

Binomial logistic regression analysis determined significant differences in the KAP responses at the province level. Log transformations were performed on hours worked with livestock, total animals owned, and total cultivated area. Analysis of quantitative variables was done with a generalized linear model regression analysis in GenStat© using a backwards stepwise approach. Univariate analysis on farmer reproductive knowledge and management areas against the following variables was undertaken: province, hours worked with livestock during rice-growing season, hours worked with livestock during non-rice-growing season, gender of survey respondent, total no. animals owned, total cultivated area owned, gender of main large ruminant carer, forage growth (dichotomous y/n response), and whether or not the household had multiple main livestock carers. Variables with a $P < 0.25$ were considered for inclusion in the multivariate model, and a $P < 0.05$ was considered significant for both quantitative and categorical data.

Contingency tables from the reproductive efficiency survey were filled out using simple calculations performed using Excel; data for cattle and buffalo were analyzed in separate spread sheets. Mean calving percentages were calculated and grouped by province/species using GenStat©, followed by testing for significant difference in calving percentage between provinces using binomial logistic regression analysis in GenStat©.

Inter-calving intervals were calculated using Excel as the number of months between calvings, e.g., a calving in November 2012 and a calving in November 2013 represented an ICI of 12 months. Mean ICIs were calculated by province and species using GenStat©, followed by testing for significant differences between provinces using a generalized linear mixed model on GenStat©. A P value <0.05 was considered significant in this study.

Results

KAP survey respondent details and socioeconomic data

The number, mean age, and average household size of survey respondents are summarized (Table 1). Women comprised 23/60 (38.3 %) of the farmers interviewed. The mean total and standard error of cultivated land owned by farmers were 2.31 ± 1.73 ha/household in Luang Prabang and 1.52 ± 1.23 ha/household in Xieng Khouang. Mean large ruminant ownership was 10–12 animals (6–8 cattle and 4 buffalo/household).

Table 1 Smallholder farmer knowledge survey respondent details in Luang Prabang and Xieng Khouang

Variate	*LPB**	XK+
Farmers interviewed (*n*=)	30	30
Female farmers interviewed (*n*=; %)	12; 40 %	11; 37 %
Mean age (years)	48.37 ± 12.97	44.00 ± 14.04
Family size (mean ± SD)	5.6 ± 1.85	5.50 ± 1.50
Family size (range)	3-10	3-9
No. female family members	2.52 ± 0.87	3.07 ± 1.23

*Luang Prabang

+ Xieng Khouang

Farmer management styles

The main large ruminant carer in the household was identified as either the husband (63.6 %), wife (16.2 %), other male family members (14.6 %), and children (3.6 %). The proportion of main livestock carers that were female was 13 and 20 % in Luang Prabang and Xieng Khouang, respectively. Survey respondents also demonstrated a huge variation in the time their households spent with their animals, with a range from 1 to 112 h per week. Farmers in Xieng Khouang spent more time with their animals during the non-rice growing period ($P < 0.01$). Farmers worked with their animals for 10.7 and 29.7 h a week in Luang Prabang and Xieng Khouang, respectively. Autonomous forage growth was recorded in 7 % of farms in Luang Prabang and 17 % of farms in Xieng Khouang.

Farmer reproductive management

Farmers in Luang Prabang practised bull castration more than farmers in Xieng Khouang, at 23 and 3 %, respectively ($P < 0.05$). Calf management questions were focused on *Toxocara vitulorum* treatment and weaning attitudes/practices. In both provinces, 13.3 % of farmers weaned their calves. Treatment rates for *T. vitulorum* in young calves were 77 % in Luang Prabang and 40 % in Xieng Khouang.

A greater number of farmers indicated that they would provide extra feed to pregnant cows in Xieng Khouang (70 %) than in Luang Prabang (33 %) ($P < 0.01$). Seven to thirteen percent of respondents confirmed they had knowingly sold a pregnant cow in the 12 months prior to the survey.

Farmer reproductive knowledge

A comparative summary of the farmer reproductive knowledge scores between Luang Prabang and Xieng Khouang is presented (Table 2). It is accompanied by cumulative KAP scores for "improved reproductive practices," "bull management," "pregnant cow management," and "postpartum cow and calf management."

The variables that had a statistically significant impact on the "combined KAP" score and the "pregnant cow management" scores are summarized (Table 3). In both provinces, pregnant cow management scores had the most variance accounted for by variates such as province, forage growth, and hours spent working with livestock during the rice-growing season.

Reproductive efficiency survey

Reproductive parameters from cattle ($n = 558$) and buffalo ($n = 133$) were collected to extend the information on animals used in the previous study (Nampanya et al. 2014b). This required the farmers to have maintained records on the animals identified previously, resulting in many animals being lost between the first and second studies. As extended, ICI figures were not calculated for buffalo in Luang Prabang as only two buffalo cows were re-identified, the second study and the revised buffalo ICI are derived only from Xieng Khouang province. Additional reproductive information on cattle and buffalo is presented (Table 4).

Calving percentages were calculated as raw percentages taken from number of calves born in the survey period ($n =$ 1162 cattle and 204 buffalo) divided by the number of observations made ($n = 1786$ cattle and 434 buffalo) and grouped by province. The cattle calving percentage was 75.4 and 53.9 % in Luang Prabang and Xieng Khouang, respectively, and the buffalo calving percentage was 53.5 and 44.5 % in Luang Prabang and Xieng Khouang, respectively. The mean ICI (taken from raw survey data) of animals observed for 4 or more years ($n = 64$ cattle; 9 buffalo) was 14.1 and 19.8 months for cattle in Luang Prabang and Xieng Khouang, respectively. The ICI for buffalo in Xieng Khouang province was 26.0 months.

Cattle calving percentages and ICIs differed between the provinces ($P < 0.01$), with Luang Prabang demonstrating higher calving percentages and lower ICIs. The calving percentage was 22 % higher in cattle from Luang Prabang than cattle from Xieng Khouang, accompanied by a mean reduction in 5.7 months of calving interval. For buffalo, no significant difference was found between Luang Prabang and Xieng Khouang province in calving percentage, and only Xieng Khouang province was recorded for ICI. Both cattle and buffalo had distinct peaks in calving during the early dry season, as illustrated (Fig. 1). The calves born in November accounted for 22.4 % of all large ruminant calves born.

Discussion

Previous studies of reproductive efficiency in the northern upland provinces potentially misrepresented true intercalving intervals (Nampanya et al. 2014b), and no survey of Lao smallholder large ruminant KAP to date asked more than 6 questions on reproduction. This study provides more comprehensive baseline information on the current status of bovine reproductive efficiency in northern Laos at the provincial level, and more detailed information about corresponding smallholder farmer KAP on bovine reproduction.

Although mean large ruminant ownership was 10–12 cattle and buffalo, variation both within and between species was high. Households in the study owned a mean of 6–8 cattle and 4 buffalo. These figures are only slightly higher than the 2011 national average of 5.3 cattle and 3.4 buffalo (SCAC 2012). This is in line with concerns that upland provinces such as Luang Prabang and Xieng Khouang have been bypassed by much of the recent economic growth experienced in Laos (World Food Programme 2010; Campbell et al. 2012). Road inaccessibility, differing ethnic groups, and low land availability are common in northern upland Laos and are all known risk factors for poverty and food insecurity (Millar and Photakoun 2008; World Food Programme 2010; Campbell et al. 2012). It is also possible that differing levels of education and economic development between the provinces studied and other provinces in northern upland Laos are present. The outcomes of this study should therefore be interpreted with discretion and should not be considered predictive of outcomes in other upland contexts.

Table 2 Smallholder farmer estimated mean knowledge, attitude, and practice scores by province

Test score	Luang Prabang	Xieng Khouang	*p*	r^2
Reproductive knowledge score (/10)*	3.40 ± 0.28	4.57 ± 0.40	<0.01	11.2
Combined reproductive KAP[§] score (%)*	23.52 ± 1.16	28.57 ± 1.64	<0.01	12.6
Bull management KAP[§] (%)*	47.50 ± 3.17	47.08 ± 4.49	0.93	–
Post-partum cow and calf KAP[§] (%)*	58.79 ± 1.99	56.97 ± 2.81	0.52	–
Pregnant cow KAP[§] (%)*	27.92 ± 2.55	60.00 ± 3.60	<0.001	57.1

NB: **Generalized linear model estimate ± standard error; [§] KAP = knowledge, attitude, and practice

Table 3 Variables modeled to have a positive impact on smallholder farmer knowledge, attitude, and practice test scores

Test score	Intercept	Independent variables	r^2
Knowledge score (/10)	1.57 ± 0.57	+1.90 ± 0.46 (LOG Hours spent working with cattle outside of the rice growing season) + 2.03 ± 0.59 (Farmer grows forages)	31.7
Combined KAP* score (%)	6.97 ± 3.47	+7.76 ± 1.81 (LOG Hours spent working with cattle outside of the rice growing season) + 6.08 ± 1.50 (Gender = male) + 6.93 ± 2.69 (Farmer grows forages)	41.1
Pregnant cow management KAP* score (%)	10.03 ± 6.02	+24.90 ± 4.04 (Province = Xieng Khouang) + 13.24 ± 4.04 (LOG Hours spent working with cattle outside of the rice growing season) + 8.39 ± 3.65 (Gender = male) + 13.14 ± 5.81 (Farmer grows forages)	65.4

NB: * KAP = knowledge, attitude, and practices

Smallholder large ruminant reproductive management

Bull husbandry is a key factor in reproductive management largely missing in Lao smallholder farming systems (Nampanya et al. 2014b; Rast et al. 2014). The survey showed that 97 % of respondents from Xieng Khouang believed that bull selection could produce better calves, a result significantly higher than the 67 % of Luang Prabang ($P = 0.01$). However, Xieng Khouang had a significantly lower number of farmers that requested DLF officers to castrate their calves ($P < 0.05$), with only 3 % indicating that they requested castration and 7 % indicating that they practised any form of bull calf segregation at all. Although castration services were offered to villages via their local DLF in the previous project (Windsor 2006), the results demonstrate farmer reticence in the uptake of bull castration. When further questioned on their attitudes toward the practice, 36–57 % of smallholders believed that castration would cause a bull to have a poor sale price and 37–40 % believed that castration would bring bad karma, most likely connected to a mixture of Buddhist and animistic belief systems (ADB 2010).

The importance of calf management within a herd is in providing high-quality young stock, plus assisting dams to return to estrus by removing the source of lactational anestrus through weaning. Weaning was practised by 13.3 % of farmers, and many farmers (60–67 %) believed that weaning a calf at or before 6 months was bad for its health. Consistent with previous studies (Rast et al. 2014; Nampanya et al. 2014a), 40–77 % of farmers reported treating for *T. vitulorum*; yet, very few farmers in both Luang Prabang and Xieng Khouang used the correct treatment for young calves. The lack of effective treatment in the new villages may be caused by a combination of low farmer knowledge of calf disease, a lack of localized and adequately trained animal health personnel, plus low disease diagnostic capacity (Rast et al. 2014).

Of the farmers surveyed, ~7–13 % indicated that they had knowingly sold a pregnant cow in the past 12 months. In a study of slaughterhouses in northern Laos, 44–47 % of cows were pregnant at slaughter (Nampanya et al. 2014c). Due to the difficulties in determining accurate pregnancy diagnosis, with farmers using visual assessment only (skills in pregnancy

Table 4 Surveyed smallholder farmers' cattle and buffalo reproductive performance in 2009–2014 in northern Laos

Cattle			Buffalo	
Variate	Luang Prabang	Xieng Khouang	Luang Prabang	Xieng Khouang
No. of cows	291	267	42	91
≤3 years of data	258	238	39	74
≥4 years of data	35	29	2	9
No. of cows that calved	289	258	42	87
1 calf	49	107	17	53
≥2 calves	240	151	25	34
Calving percentage	75.38 %	53.86 %	53.52 %	44.52 %
Inter-calving interval*	14.10 ± 4.21 (13.27,14.93, <0.01)	19.82 ± 8.38 (17.60, 22.04, <0.01)	–	26.03 ± 8.38 (15.41, 26.13, <0.01)

*Mean calving interval (months) ± standard deviation (95 % CI, F probability)

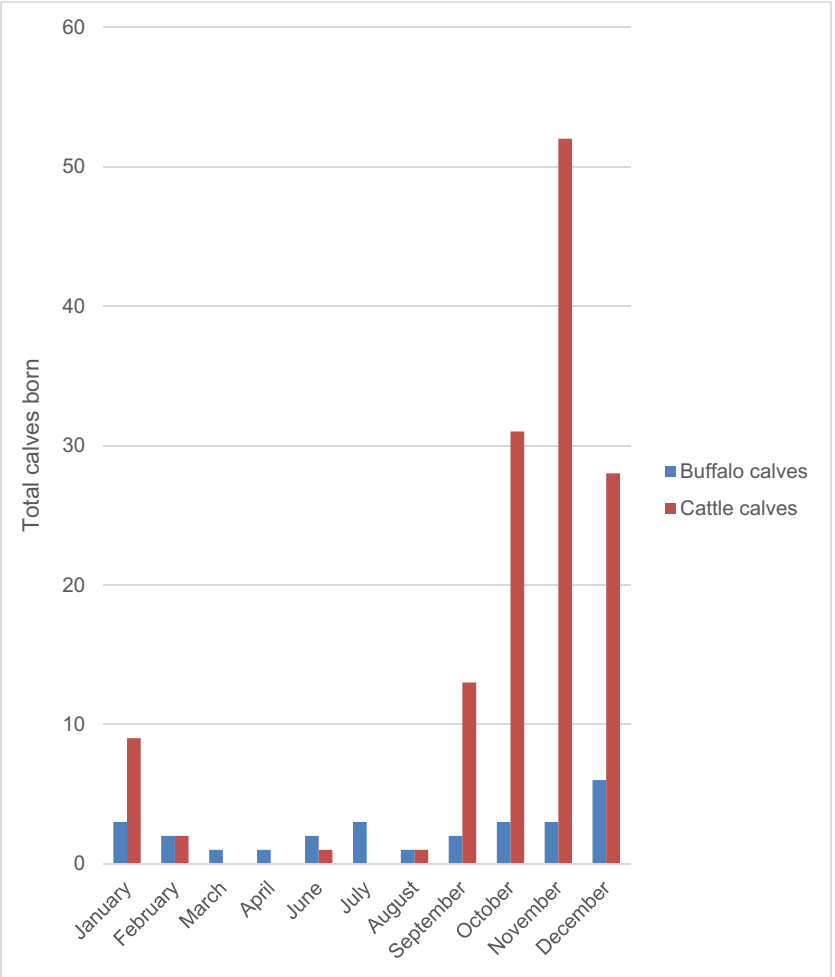

Fig. 1 Total number of cattle and buffalo calves born for each calendar month reported by surveyed smallholder farmers

diagnosis by rectal palpation or ultrasonography are rare in Laos), or possibly even because of the known illegality of this practice, many farmers responded to this question with "I do not know." There is also a possibility that some of the respondents in the "I do not know" category actually did sell pregnant animals but were unaware of having done so. Beef uterus-and-fetus soup is believed to be a delicacy in Laos, potentially attracting a premium price at sale and has been implicated as a cause of the high number of pregnant cows found at slaughter (Nampanya et al. 2014c). Until smallholder livestock service capacity and infrastructure can support routine pregnancy diagnosis, plus law enforcement in particularly at slaughter facilities, there may be little that can be done to improve this situation, other than to educate farmers on identification of pregnant cattle and the importance of maximizing calving percentages.

Smallholder large ruminant reproductive knowledge, attitudes, and practices

The mean reproductive knowledge score for Luang Prabang smallholders was 34 and 46 % for smallholders from Xieng Khouang ($P < 0.01$; $r^2 = 11.2$). These reproductive knowledge scores were lower than those previously reported at ~50 % in 2013 (Nampanya et al. 2014a).

Pregnant cow management practices are crucial to ensuring the health of the neonatal calf and a quick return to estrus in the dam. Very little information about Lao pregnant cow management has ever been reported. This study found that estimated mean pregnant cow management KAP scores were 28 and 60 % in Luang Prabang and Xieng Khouang, respectively ($P < 0.001$, $r^2 = 57.1$). Due to the open quantitative nature of many of the questions, the variance accounted for was low, despite significant differences being identified between the provinces. Because of this, province should be considered to have a small impact upon reproductive knowledge score and combined KAP score. Overall, higher scores were estimated to come from Xieng Khouang province, from farmers who spent more time with their cattle (during the dry season), from male farmers, and from farmers who grew forages ($P < 0.05$).

Male respondents were found to have estimated higher scores for the combined KAP and pregnancy KAP questions, a disappointing outcome reflecting ongoing gender imbalances in Lao education and agriculture (Rex and Tanaka

2013). Early literature on Lao livestock raising identified caring for large ruminants as a job primarily undertaken by men (Stür et al. 2002). However, the percentage of families that identified a female large ruminant carer in this study was 13–20 % and was most recently reported at 22 % (Nampanya et al. 2016). In 7/60 respondents, no main large ruminant carer was identified, and the hours spent undertaking work with large ruminants were split equally between both male and female family members. In the 2011 agricultural census, two-thirds of all farming households were jointly managed, usually by a husband and wife (SCAC 2012). Because of this, gender imbalances in KAP scores should be addressed when implementing rural community programs, particularly as literacy rates in Lao adults are 82 % for men and 63 % for women (World Bank 2014).

The significance of forage growth in these studies is unsurprising as most recent reporting of forage growth in the provinces of Luang Prabang and Xieng Khouang showed that after a suite of management and educational interventions were introduced and maintained through multi-stakeholder involvement, forage plantation rose from 52 to 87 % in Luang Prabang and 16 to 30 % in Xieng Khouang (Nampanya et al. 2010; Nampanya et al. 2014a). However, this study approached villages in these provinces that had not yet been involved in ACIAR-funded projects and found autonomous farmer forage plantation to be low (7–17 %). Improved feeding is crucial to all aspects of beef production, and reproduction cannot be successful if the dry season feed gaps are not filled (Senger 2012). The provision of cut-and-carry forages has been shown to significantly improve average daily gains in Lao cattle (Nampanya et al. 2014b) and is a promising indication for the potential of forage provision to improve reproductive outcomes.

Hours worked with large ruminants were not significantly different between the provinces during the rice-growing season. However, during the non-rice growing season, farmers worked 10.7 ± 7.2 and 29.7 ± 27.2 h/week with large ruminants in Luang Prabang and Xieng Khouang, respectively, with seasonal free-grazing combined with overnight shelter and opportunistic fattening either on cultivated forages or communal areas occurring in both provinces (Nampanya et al. 2010; Nampanya et al. 2014b). Communal grazing involves a rostered rotation of farmers caring for the animals, reducing the individual workload and hours per week of management. The lower hours/week in Luang Prabang could be attributed to the higher proportion of farmers that communally graze their animals compared to Xieng Khouang, although as the questions on management were asked separately in this survey, caution is advised on conclusions made from these observations of hours spent on specific management tasks.

Reproductive efficiency of large ruminants in northern upland Laos

The cattle calving percentage was 54–75 %, and the buffalo calving percentage was 45–54 % and was consistent with the precursor study conducted previously (Nampanya et al. 2014b) when calving percentages of cattle and buffalo were at ~70 and 50 %, respectively. The mean ICI (taken from raw survey data) of animals observed for 4 or more years was 14.1–19.8 months for cattle, and the ICI for buffalo in Xieng Khouang province was 26.0 months. The precursor study also recorded ICIs of 13.6–15.6 and 18.6–20.6 months for cattle and buffalo, respectively, but added the caution that these parameters would likely to be higher if data was collected over more years so that less fertile animals were not excluded (Nampanya et al. 2014b). This concern has been confirmed by the addition of data from 2012 to 2014, despite the poor rate of re-identification of animals between the first and the second study that meant that fewer animals ($n = 64$ cattle and $n = 9$ buffalo) could be used to calculate the extended ICIs.

Relevance and aims for improved reproductive efficiency in northern upland Laos

This study confirmed previous reports that large ruminant reproductive efficiency is poor (Stür et al. 2002; Nampanya et al. 2014b; Rast et al. 2014). Improved reproduction requires efforts to improve nutritional and disease management, particularly as feed gaps in the dry season lead to suboptimal large ruminant reproductive outcomes due to diversion of energy resources away from cycling or lactation into more vital physiologic functions (Senger 2012; Nampanya et al. 2014b). Reproductive efficiency indicators including calving percentage and ICI enable baseline comparisons for measuring the success of introducing reproductive management interventions.

Based on the farmer's responses and the current literature, future reproductive interventions that could improve reproductive performance include the following:

1. Bull management, sex segregation, and early weaning. Improving bull management requires farmer education on the importance of bull selection in improving production outcomes and fertility, plus prevention of inbreeding. Education on husbandry practices including castration, sex separation, and selling bull calves before puberty is also required. Concurrent with or prior to the education program, early adopters should be targeted to trial castration and fattening of bull calves and these animals evaluated.
2. Instigation of a controlled breeding period. Strategic adjustment of the current parturition period (January–February mid-dry season) so that cows calve in the wet

season (July–August) and well prior to the onset of the early dry season (October–November) needs to be explored in areas where extensive grazing occurs. Calving in the wet season will enable a higher plane of nutrition from the natural ground cover in the important early-mid lactation period when a cow has maximum drain on her metabolic reserves, with improved BCS increasing the likelihood of a return to estrus during the lactation. The possibility of supplementary feeding in the final trimester of the pregnancy to provide a moderate BCS at birth also deserves consideration for improving post-partum anestrus and pre-weaning calf gains (Dziuk and Bellows 1983; Houghton et al. 1990; Short et al. 1990; Walmsley et al. 2016).

3. Introduction of forage technology. Forage provision is crucial to improving reproductive outcomes, particularly to fill the dry season feed gap. A previous USyd-DLF project saw dramatic uptake of forage growing among farmers in LPB and XK between 2009 and 2013 (Nampanya et al. 2014a).
4. Production disease management. Production limiting diseases identified as priorities in Laos (Foot and Mouth Disease and Hemorrhagic Septicaemia) have a secondary impact upon successful reproduction due to the nutritional strain that a severe illness places on the animal. Control of these TADs is crucial to the prevention of reproductive wastage and in future outbreaks, studies into the effect of these outbreaks on subsequent reproductive efficiency could provide valuable insights into the ongoing financial impacts of TADs on the smallholder farmer.

Conclusion

This study confirms that currently, beef productivity is constrained by low calving percentages of 54–75 and 45–54 % and extended inter-calving intervals of 14.1–19.8 and 26.0 months for the cattle and buffalo groups, respectively. Further, farmer knowledge, attitudes, and practices on reproductive management is low in all aspects and future improvements need to consider issues with farmer beliefs and attitudes. However, the introduction of simple management and educational interventions, such as forage provision and bull selection training, can address these constraints and assist the transition of smallholders from livestock keepers to a livestock producers. Improved beef breeding provides opportunities to enhance food security and reduce rural poverty by facilitating the engagement of smallholder farmers in the dramatic economic growth of the Southeast Asia region. For smallholder farmers, extra income from improved beef reproduction can be spent on improved agricultural technologies, buying more livestock, educational expenses, and retention for emergency funds, creating a buffer against climatic or disease shocks and increasing smallholder farmer financial resilience.

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