

Intervention models to solve the declining problem of swamp buffalo (*Bubalus bubalis*) population in Ubon Ratchathani province of Thailand

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Abstract

Swamp buffalo population in Thailand has dramatically decreased in the last three decades. The present study was conducted to predict trends and future population size of swamp buffaloes and to formulate different interventions to prevent further decline and rejuvenate the existing population. The study is based on a questionnaire survey to access information regarding buffalo husbandry and marketing. Based on derived data, age-structured Leslie matrix population model was constructed to predict the population of the buffalo cows in the coming decades. Three different intervention models were subsequently proposed including Buffalo bank campaign, prohibition of slaughtering buffalo cows and the combination of these two interventions. A total of 398 farmers rearing buffaloes were interviewed and data encompassed information on 1,366 buffaloes (418 buffalo bulls and 948 cows) were retrieved. Initial buffalo cow population in Ubon Ratchathani province was estimated to be 42,766 heads. The number was projected to decline by 36% in the next ten years, with population growth rate estimated to be 0.93. The most feasible and sustainable intervention was to carry out both campaigns simultaneously. This strategy allows the slaughtering prohibition to be successful with the support from the Buffalo bank. These campaigns should be rigorously implemented to maintain this valuable livestock resource. The present model might be implemented for similar studies in different parts of the developing world.

Keywords: buffalo, livestock management; mathematical model; policy

แบบจำลองเชิงนโยบายเพื่อแก้ปัญหาการลดลงของประชากรกระบือปลัก (*Bubalus bubalis*) ในจังหวัดอุบลราชธานี ประเทศไทย

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บทคัดย่อ

จำนวนกระบือปลักในประเทศไทยได้ลดจำนวนลงอย่างรวดเร็วในช่วงสามทศวรรษที่ผ่านมา การศึกษานี้จึงจัดทำขึ้นเพื่อที่จะพยากรณ์แนวโน้มและจำนวนประชากรกระบือปลัก และสร้างแบบจำลองเชิงนโยบายในหลายรูปแบบเพื่อประเมินการป้องกันการลดลงรวมทั้งการเพิ่มจำนวนประชากรที่มีอยู่ให้มากขึ้น ผู้วิจัยได้ใช้แบบสอบถามในการเก็บข้อมูลเกี่ยวกับการเลี้ยงและการตลาดของกระบือ จากข้อมูลที่ได้ ผู้วิจัยได้สร้างแบบจำลองเชิงประชากรแบบ age-structured Leslie matrix เพื่อพยากรณ์จำนวนกระบือเพศเมียในอีกสิบปีข้างหน้า จากนั้น จึงสร้างแบบจำลองเชิงนโยบายสามแบบ ได้แก่ 1) มาตรการกระบือ การห้ามฆ่ากระบือเพศเมีย และการใช้มาตรการทั้งสองแบบร่วมกัน ผู้วิจัยได้สัมภาษณ์เกษตรกรผู้เลี้ยงกระบือทั้งสิ้น 398 ราย และได้ข้อมูลเกี่ยวกับกระบือจำนวน 1,366 ตัว (ตัวผู้ 418 ตัว และตัวเมีย 948 ตัว) จากข้อมูลเบื้องต้นพบว่า ในจังหวัดอุบลราชธานี มีกระบือเพศเมียจำนวน 42,766 ตัว จากการพยากรณ์ จำนวนประชากรนี้จะลดลง 36% ในอีกสิบปีข้างหน้า ด้วยอัตราการเพิ่มประชากรที่ 0.93 มาตรการที่เป็นไปได้และยั่งยืนที่สุดคือการใช้มาตรการทั้งสองแบบไปพร้อมกัน กลวิธีนี้ทำให้มาตรการห้ามฆ่าสัมฤทธิ์ผลด้วยการสนับสนุนจากโครงการธนาคารกระบือ มาตรการเหล่านี้ควรนำมาใช้อย่างจริงจัง เพื่อรักษาชนิดพันธุ์ปศุสัตว์ที่มีค่านี้ไว้ แบบจำลองนี้สามารถนำไปปรับใช้ในการศึกษาที่คล้ายกันในประเทศกำลังพัฒนาอื่นได้

คำสำคัญ: กระบือ การจัดการปศุสัตว์ แบบจำลองทางคณิตศาสตร์ นโยบาย

Introduction

Swamp buffalo (*Bubalus bubalis*) has been reared in Thailand for agricultural purposes for many centuries. These buffaloes being native of the land are tolerant to many prevailing diseases and parasites alike (Sanghureyphrai et al. 2013). They were previously used for plowing the paddy fields and other agricultural operations. However, over the years, the mechanization of agriculture has changed the usages of buffaloes as a farm animal. Thus, the swamp buffaloes are now reared primordially for buffalo meat. Reports, from the Department of Livestock Development (DLD) of Thailand, estimated the population of the swamp buffaloes in the year 1982 to be more than six million heads. In the following three decades, the number of these buffaloes dwindled to be around 840,064 heads (DLD 2014). This rapid reduction in the population can erode the genetic base of these buffaloes and may result in higher degree of inbreeding.

Thus, in order to assess the future of these buffaloes, age-structured Leslie matrix population model was used for estimating the population of the buffaloes in the decade to come and age transition was used as the main factor (Leslie 1945). The model was designed to link the population dynamics with the survival rate of the animals (Fieberg and Ellner 2001). The model can be used for predicting the dynamics of the population over a period of time and to assess the chances of the population getting extinct (Morris et al. 1999). The Leslie model has previously been used to assess the population

dynamics in many animal species such as African buffalo and elephant (Wood 1999; Jolles 2007; Leimgruber et al. 2008). However, the Leslie model has been rarely used in the prediction of livestock population in general and swamp buffalo in particular.

Materials and methods

Field data collection

The highest number of swamp buffaloes in Thailand was recorded in Ubon Ratchathani province and the numbers were estimated to be around 82,088 heads (DLD 2014). The province was therefore chosen as a representative site for assessing the population dynamics of the swamp buffaloes. The number of sample respondents was estimated with the method suggested by Krejcie and Morgan (1970). Twenty-five districts of Ubon Ratchathani province were further stratified into three classes according to the size of buffalo population (Fig. 1). Eight districts were purposively chosen and those subdistricts with the highest number of buffaloes were included in this study.

The study was conducted between October to November 2015, a semi-structured cross-sectional questionnaire-based survey was then used to collect data from the buffalo farmers regarding buffalo rearing and trading. The participants were questioned on:

- (1) General demographic data of the respondents;
- (2) Number, sex, and age of the buffaloes reared;
- (3) Age at first calving in buffalo cows;
- (4) History of Buffalo trading (within one-year)

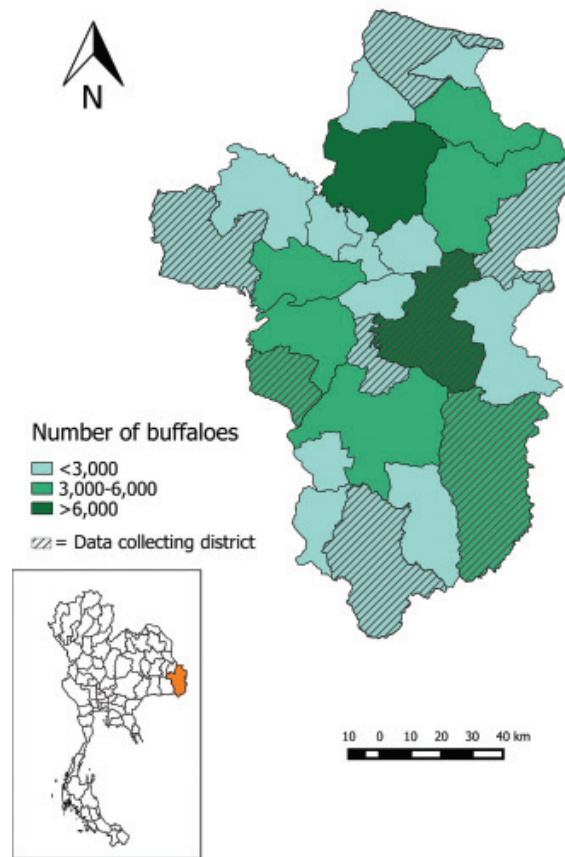


Fig. 1. The population size of swamp buffaloes at the district level in Ubon Ratchathani province and the chosen districts in this study. The map on the bottom-left represents the location of Ubon Ratchathani province within the map of Thailand.

The written consents were signed by all participants prior to the interview. The manuscript does not contain clinical studies or patient data.

Baseline population dynamic model

The data pertained to the secondary data on buffalo population of Ubon Ratchathani province over the last five years (2011-2015). The data was obtained from the DLD and was then averaged (Appendix 1). The information so obtained was considered as the baseline population of the buffalo in the province. The study was based on the buffalo cow population. This is because the numbers of buffaloes as the replacement stock can be correlated with the numbers of breeding

cows. This was in accordance with the present policies of the DLD. The data regarding the population dynamics was then fitted in the Leslie matrix population model (Leslie 1945) (equation 1). The model examined the buffalo cow population on a yearly basis for a decade.

$$N_f(t+1) = A_f(t) \cdot N_f(t) \quad (1)$$

, where $A_f(t)$ represents stochastic projection matrix of buffalo cows in the year t and $N_f(t)$ is population vector of buffalo cows in each age class in the year t . Age class in this model is divided into 17 classes from less than 1 year to over 15 years old. Given that s_f is the proportion of newborn buffalo cow calves (47% as observed in the field study), birth rate is calculated from the equation (2).

$$b_{fi} = b_i \cdot s_f \tag{2}$$

, where b_{fi} is the number of buffalo cow calves born and b_i is the birth rate of all buffalo calves of age i .

Given that;

$$f_{fi} = p_i \cdot b_{fi} \tag{3}$$

, where f_{fi} represents the fecundity of the buffalo cows of age i .

Equation (1) can be written in the matrix form as:

$$\begin{pmatrix} n_{f1}^{(t+1)} \\ n_{f2}^{(t+1)} \\ n_{f3}^{(t+1)} \\ \vdots \\ n_{fi}^{(t+1)} \end{pmatrix} = \begin{pmatrix} p_1 b_{f1} & p_2 b_{f2} & p_3 b_{f3} & \dots & p_i b_{fi} \\ p_1 & 0 & 0 & \dots & 0 \\ 0 & p_2 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & p_{i-1} & \end{pmatrix} \cdot \begin{pmatrix} n_{f1}^{(t)} \\ n_{f2}^{(t)} \\ n_{f3}^{(t)} \\ \vdots \\ n_{fi}^{(t)} \end{pmatrix}$$

, where $n_{fi}^{(t)}$ is the number of buffalo cows of age i in year t . Survival probability of the buffaloes is indicated by p_i in the equation (4).

$$p_i = 1 - f_{si} \tag{4}$$

, where f_{si} represents the number of buffalo cows sold in the given year i . The survivability of the buffalo cows was then stochastically modeled with Poisson distribution in the equation (5).

$$f_{si} \sim \text{Pois}(\lambda_i) \tag{5}$$

, where λ_i is the number of buffalo cows sold at age i in a particular year.

Intervention models

The baseline population dynamic model was considered in the intervention simulations. In this study, three interventions were suggested by the provincial livestock officer of Ubon Ratchathani province. The study included the interventions from the Buffalo bank

campaign, prohibition of slaughtering the buffalo cows and the combination of the two interventions.

Buffalo bank campaign

Buffalo bank is a campaign managed by DLD to replenish the number of buffalo cows in the area by distributing one cow buffalo calf to the rearers with an understanding that the cow-calf will be replaced by at least one of her cow-calf to the bank. The model was designed so as to indicate the survivability of the buffalo cow and the cow-calf, respectively. Equation (4) was then redesigned as:

$$p_i = 1 - f_{si} + f_b \tag{6}$$

, where f_b is increased survival probability due to the addition of the buffalo cow calf to the Buffalo bank. The addition was estimated to increase population growth rate to be 1.00.

Impact of prohibition of slaughtering the buffalo cows

This projection was to investigate the impact of the official order pertaining to the prohibition of the slaughtering of buffalo cows. To assess the threshold of the number of buffalo cows that need to be protected, thus the equation 4 can be rewritten as

$$p_i = 1 - f_{si}' \tag{7}$$

, where f_{si}' is the minimum number of buffalo cows that need to survive so that the population growth rate equals to 1.00.

Combination of the two interventions

Equations (6) and (7) were therefore simultaneously modified to assess the combined effect of the two interventions. The goal of this alteration was to change population growth rate to be 1.00.

All data analysis and model simulations were performed in a statistical computing language R version 3.3.1 (R development core team 2016). Package 'popbio' was used to construct the population projection matrices and to assess the estimated growth of the population.

Results

The surveyed respondents

Number of surveyed respondents was 398 as shown in Table 1. The sex ratio of the interviewees was about 1:1 with an average age of 49.1 years old (standard deviation = 12.7 years). These farmers mostly graduated primary school (77.6%) with over ten-year experience in rearing buffaloes (76.4%).

Demography of the buffalo herds

The herd demographical data pertains to 1,366 buffaloes encompassing both sexes ie. 418 buffalo bulls and 948 buffalo cows. Most of the buffalo bulls were less than 5 years of age, while 50 heads of the buffalo cows were more than a decade old. Age distribution of the buffaloes is presented in Fig. 2.

Predicted swamp buffalo population

The numbers of buffalo heads are presented in Figure 3 and are expected to decrease over time with a negative population growth rate of 0.93. The base population of the buffalo was 42,766 heads while the population is expected to decline by 36% in the following decade and is expected to be around 26,254-28,184 heads.

Impacts of intervention models

In the Buffalo bank campaign, 1,624 buffalo cows need to be transferred to the farmers on an annual basis in order to maintain the growth of the population. This number of buffaloes in the Buffalo bank is equivalent to 3.79% of the initial population (1,624/42,766). With this intervention technique, the expected enhancement in the buffalo population over the decade is 18,330 female buffalo cows. The implementation of only slaughtering prohibition campaign was predicted to increase the number of buffaloes by 20,580 over a ten-year period. With the combination of these two measures, it was expected to accrue 19,605 buffalo cows compared to the baseline prediction (Fig. 4).

Table 1 General demographic data provided by the surveyed respondents (n = 398)

Variable	Number of respondents (%)
<i>Sex</i>	
Male	196 (49.2)
Female	202 (50.8)
<i>Age</i>	
< 20 years	0 (0.0)
20 - 40 years	89 (22.4)
41 - 60 years	237 (59.5)
> 60 years	68 (17.1)
No information	4 (1.0)
<i>Education</i>	
Primary school	309 (77.6)
Secondary school	78 (19.6)
Bachelor's degree	4 (1.0)
No information	7 (1.8)
<i>Buffalo rearing experience</i>	
< 10 years	94 (23.6)
10 - 20 years	118 (29.6)
21 - 30 years	65 (16.3)
> 30 years	118 (29.6)
No information	3 (0.8)

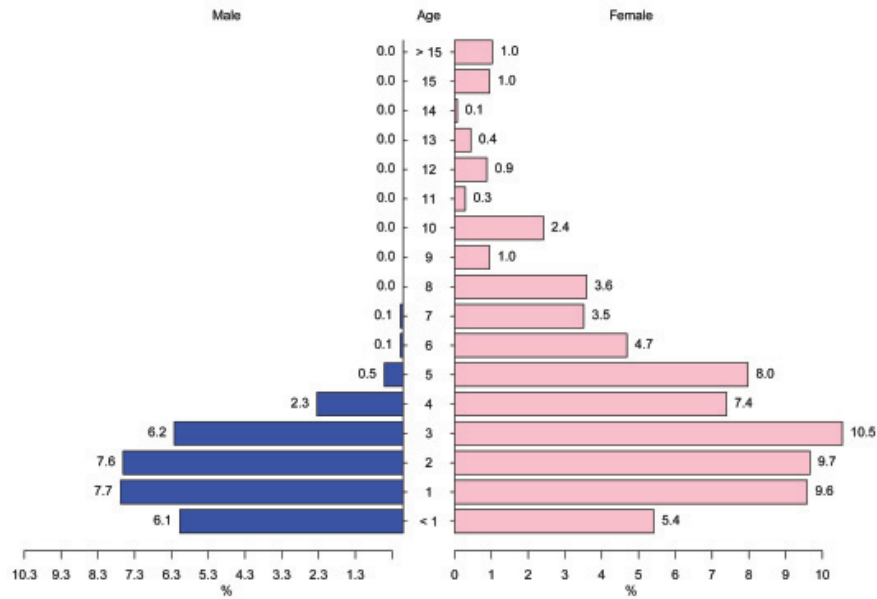


Fig. 2. Age distribution of the surveyed buffaloes in Ubon Ratchathani province.

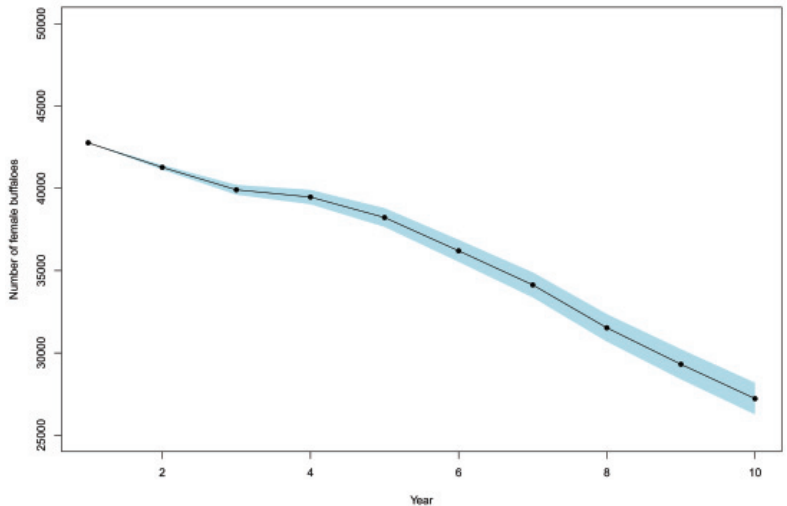


Fig. 3. The predicted number of swamp buffalo cows in Ubon Ratchathani province in the next ten years.

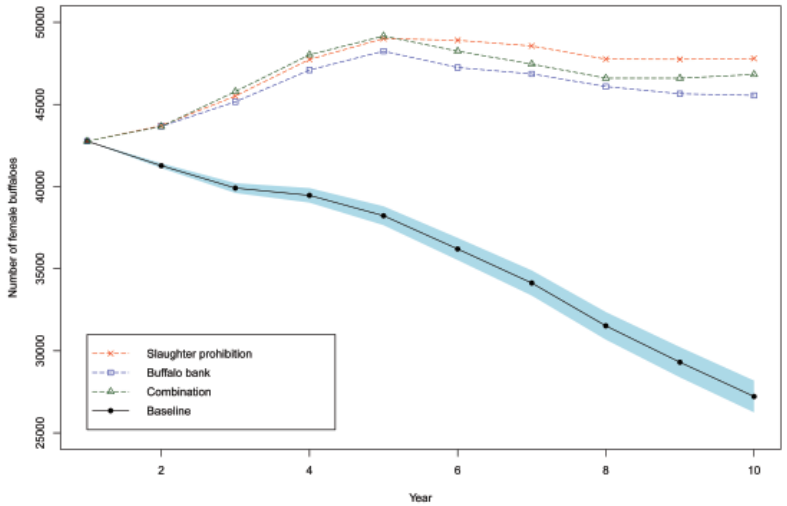


Fig. 4. Comparison of intervention models to increase buffalo cow population in Ubon Ratchathani province.

Discussion

The present study tried to assess the trend of swamp buffalo population over a decade. Data and trading behavior were employed to forecast trends and a future number of buffalo cows in Ubon Ratchathani province in the next ten years. Subsequently, the predictive model was used as a baseline to assess different interventions proposed by local livestock office.

Based on our empirical data, the number of buffalo cows was twice compared to the bulls (948/418). It was noticeable from age distribution that the buffalo bulls died at a younger age than the cows. The bulls were slaughtered when they reached the desired size whereas cows were still kept for reproduction. This finding insists that performing population dynamic model on cow part is sound and sufficient as cows considerably direct future population.

In our predictive model, the number of buffalo cows tended to diminish by more than one-third in a decade. The DLD previously observed this tendency but not any quantitative studies were carried out (DLD, 2014). Changing on agricultural technology does affect population dynamics of buffaloes in Thailand. The declining pattern of buffalo populations has been reported in other agriculture-based countries, for examples, Iran, Sri Lanka, and Turkey (FAO, 2005). This problem seems to be a global threat to genetic security and should be more concerned in the international arenas.

The most effective intervention is to prevent buffalo cows slaughtering (Fig. 4). Nonetheless, a complete ban of buffalo slaughtering is almost impossible to achieve. Farmers are still able to kill animals without official notifications. On the other hand, Buffalo bank is far more practical. However, this program required massive subsidies and investments. A previous study criticized the Buffalo bank campaign as a high-risk program in terms of investment. Donated buffaloes may die or unable to produce offspring resulting in low return rate to the bank (Kaboski and Townsend, 2005). The most likely and sustainable practice is to simultaneously

implement both campaigns even though some more buffaloes are required from the Buffalo bank.

Like other predictive models, we assumed that all parameters are constant and never alter throughout the course of modeling. Indeed, multiple factors do affect these parameters which are unpredictable. Therefore, the model should be periodically re-evaluated and re-parameterized to obtain the most up-to-date guidelines. Due to limited budgets, we conducted our project at a provincial level. The extension of the study to the regional or national level is recommended.

In conclusion, our study provides a framework for population dynamic modeling which is adaptable to such studies in other livestock species especially ones that were expected to decrease over time. Regarding interventions, the combination of slaughtering prohibition and Buffalo bank is strongly recommended. These campaigns should be rigorously implemented to maintain this valuable animal population.

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Conflict of interest

The authors declare that they have no conflict of interest.

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Appendix 1

Age distribution of five-year average buffalo populations in Ubon Ratchathani province, Thailand and number of surveyed and sold buffaloes in each age in this study.

Age (year)	Provincial population	Surveyed population	Sold buffaloes
less than 1	3,270.4	74	5
1	5,789.5	131	13
2	5,833.7	132	21
3	6,364.1	144	24
4	4,651.6	101	27
5	5,020.1	109	23
6	2,947.6	64	12
7	2,210.7	48	4
8	2,256.7	49	3
9	598.7	13	0
10	1,519.8	33	1
11	184.2	4	0
12	552.7	12	0
13	276.3	6	2
14	46.1	1	1
15	598.7	13	1
over 15	644.8	14	1