



# Assessing the Population Structure and Inbreeding Rates of Buffaloes in Batanghari District, Indonesia

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## ABSTRACT

Buffaloes are important in animal husbandry, agriculture, and sociocultural and religious activities in Indonesia. The buffalo population has decreased at the national and regional levels, including in the Batanghari District, Jambi Province, Indonesia. This study analyzed the population structure, effective population size, and inbreeding rate of buffalo populations in the Batanghari District, Jambi, Indonesia, based on secondary data. The data population of 3,149 buffaloes used in this study was sourced from the Integrated National Animal Health System (ISIKHNAS) in the Batanghari District in 2023. The results showed a calf crop of 21.71%, a calving rate of 16.61%, a natural increase of 14.74%, and a net replacement rate of 279.51%. The effective population size was 592 heads, and the inbreeding rate was 0.08%. It can be concluded that the natural increase rate of the buffalo population in the Batanghari District was low, but the number of young replacement animals was sufficient. The effective population size was 592 heads, and the level of inbreeding per generation remained within acceptable limits. Although the buffalo population in the Batanghari District exhibited a negative trend, it still had potential as a source of breeding stock, as indicated by the replacement rate.

**Keywords:** Buffalo, Effective population, Inbreeding rate, Population structure

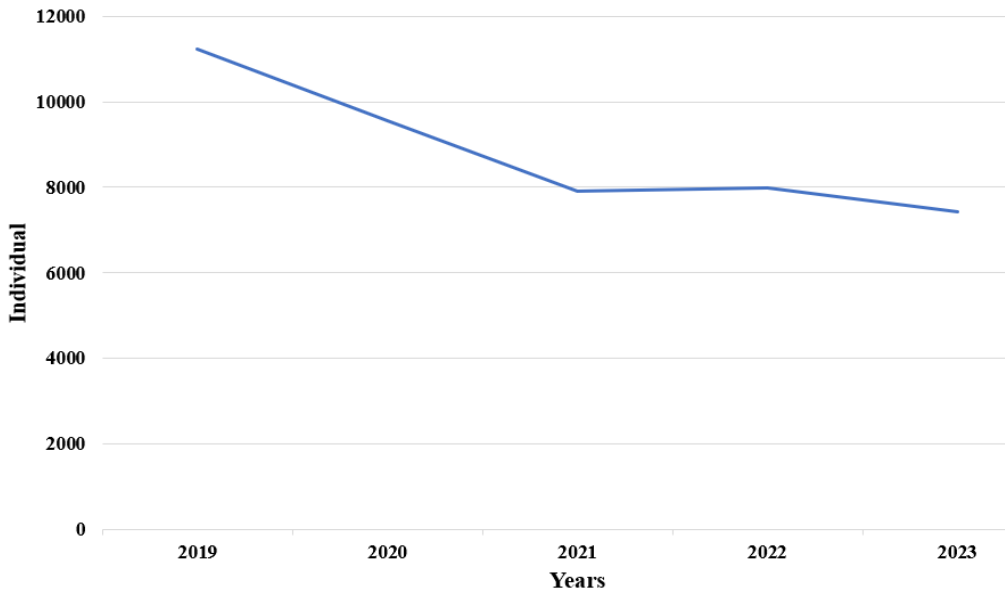
## INTRODUCTION

Buffaloes are adaptable to marginal environments and low nutrition. They can provide high-quality protein through meat and milk, organic fertilizer and fuel in the form of dung, mechanical or draught power (plowing fields and pulling wood), and hides and skins for industrial use. These characteristics enable small, marginal farmers to support their families. Farmers also preserve buffaloes for cultural, religious, and societal reasons (Maulana et al., 2023; Prihandini et al., 2023).

Buffaloes play a notable role in farming in Indonesia; however, their national and regional populations are insufficient. According to the Indonesian Statistics Agency (Badan Pusat Statistik [BPS]) report, the buffalo population in Jambi Province, Indonesia, was 70,154 heads in 2003 and decreased to 47,567 in 2023. Hence, increasing the buffalo population in this region is important to prevent extinction. Carrying capacity, farming skills, and population structure influence buffalo productivity (Reswati and Putra, 2023). The buffalo population in Jambi decreased ten years ago and required mitigation by the government. According to the Indonesian Statistics Agency (BPS, 2024) the buffalo population dynamics in the Batanghari District have decreased over the past five years. In 2019, the buffalo population in Batanghari was 11,221; by 2023, it had decreased to 7,343 (Figure 1). The decline in the buffalo population increases inbreeding risk and reduces productivity traits. The population decline can be attributed to a lack of management systems, diseases such as *Septicaemia epizootica* (SE), foot and mouth diseases, and reduced farmland (Firmansyah et al., 2023).

Analyzing the structure of the livestock population is an effort to address the issue of mitigating the decline in the buffalo population in the Batanghari district. Many studies have examined the population structure of livestock, including cattle (Widyaningrum et al., 2021), buffaloes (Yendraliza et al., 2021a), ducks (Rusfidra et al., 2012), and rhinoceroses (Putra et al., 2020). However, studies of population structure, inbreeding rate, and effective population size in buffalo populations in the Batanghari district have not been reported. The present study aimed to determine buffaloes' population structure, inbreeding rate, and effective population size in the Batanghari District, Jambi Province, Indonesia.

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**Figure 1.** The population dynamics of Buffalo at Batanghari District, Jambi, Indonesia, from 2019 to 2023



**Figure 2.** Research location at Batanghari District, Jambi, Indonesia

## MATERIALS AND METHODS

### Ethical approval

This study was approved by the Animal Ethics Commission of the Faculty of Medicine, Universitas Andalas, Indonesia, with license number 588/UN.16.2/KEP-FK/2023.

### Data collection

The population data of 3,149 buffaloes were obtained from a secondary source, the Batanghari District ISIKHNAS database in 2023, including data at the beginning and end of the year in Batanghari District, Jambi, Indonesia (Figure 2). These data were collected to calculate the calf crop, the calving rate based on population, natural increase, requirement of animal replacement, remains of young animals, the number of culled animals, the net return rate, output estimation, effective population size, and inbreeding rate per generation. Additionally, population dynamics from 2019 to 2023 were analyzed based on BPS data from 2019 to 2023. The data collection included buffalo calves (0-1 year), young buffalo (1-3 years), and adult buffalo (> 3 years).

### Data determination

These data were used to calculate the calf crop, calving rate based on population, natural increase, requirement of animal replacement, remains of young animals, number of culled animals, net return rate, and output estimation, according to the methods described by [Samberi et al. \(2010\)](#) using the following formulas (Formulas 1-8).

$$\text{(Formula 1) Calf crop (\%)} = \frac{\text{Number of calf (heads)}}{\text{Number of adult female (heads)}} \times 100\%$$

$$\text{(Formula 2) Calving rate (\%)} = \frac{\text{Number of calf (heads)}}{\text{Number of population (heads)}} \times 100\%$$

$$\text{(Formula 3) Natural increase (\%)} = \text{Calving based on population (\%)} - \text{Mortality (\%)}$$

$$\text{(Formula 4) Requirement of animal replacement} = \frac{\text{Number of adult animal (\%)}}{\text{Breeding length (years)}}$$

$$\text{(Formula 5) Remains of young animal} = \text{Number of young animal (\%)} + \text{Requirement of animal replacement (\%)}$$

$$\text{(Formula 6) Number of culled animal (\%)} = \text{Requirement of animal replacement (\%)}$$

$$\text{(Formula 7) Net return rate} = \frac{\text{Number of young animal (heads)}}{\text{Remains of young animal (heads)}} \times 100\%$$

$$\text{(Formula 8) Output estimation (\%)} = \text{Remains of young animal (\%)} + \text{Number off culled animal (\%)}$$

The Effective population size and inbreeding rate per generation were calculated using [Hamilton \(2009\)](#) according to the following formulas (Formulas 9 -10), the obtained data were then analyzed using descriptive statistics.

$$\text{(Formula 9) } Ne = \frac{(4 Nm Nf)}{Nm + Nf}$$

$$\text{(Formula 10) } \Delta F = \frac{1}{2Ne}$$

In this equation, Ne represents the effective population, F represents the inbreeding rate per generation, Nm represents the number of adult males, and Nf represents the number of adult females.

## RESULTS AND DISCUSSION

The population structure of buffalo in the Batanghari District in 2023 consisted of 3,149 heads (Table 1), with the following proportions: Calves 523 heads (230 males and 293 females), young buffalo 932 heads (346 males and 586 females), and adults 1,694 heads (164 males and 1,530 females). The results showed that the natural increase (NI) in Batanghari buffaloes was 14.74%, as presented in Table 2. A natural increase refers to the growth of a population over time, calculated as the difference between the number of live births and the number of deaths within that population. The natural increase observed in this study was classified as a low category. According to [Samberi et al. \(2010\)](#), natural increase (NI) is categorized as high if  $NI > 30\%$ , medium if  $15.01\% < NI \leq 30\%$ , and low if  $NI < 15\%$ . The results of this study were lower than the natural increase in the buffalo population in the Malang District, reported as 16.1% ([Budiarto and Ciptadi, 2018](#)), 20.18% buffaloes in Sumbawa ([Putra and Lestari, 2022](#)), and 55.59% for Kuntu buffalo ([Yendraliza et al., 2021a](#)). The natural increase in the buffalo population in the Batanghari District was low, consistent with the decline observed in the buffalo population in the Batanghari District over the past five years. A large number of slaughters of productive females to meet consumer demand and mortality due to diseases such as *Septicaemia epizootica* (SE) can reduce the buffalo population ([Marsudi et al., 2017](#)). Additionally, the low natural increase (NI) value of buffaloes may be attributed to the presence of non-productive buffaloes on the farm ([Kgosikoma and Bastisani, 2014](#)).

**Table 1.** Population structure of buffalo in Batanghari District, Jambi, Indonesia, 2023

Sex	Group	Calf	Young	Adult	Total (N)
Male		230	346	164	740
Female		293	586	1,530	2,409
Total (heads)		523	932	1,694	3,149

N: Individual

**Table 2.** The technical coefficient in population structure analysis of buffaloes in Batanghari District, Jambi, Indonesia, 2023

Parameters		Value
<b>Variable</b>	Calf crop (%)	21.71
	Calving rate (%)	16.61
	Mortality (%)	1.87
	Natural increase (%)	14.74
<b>Adult animals (%)</b>	Male	5.21
	Female	76.50
<b>Breeding length (years)</b>	Male	2
	Female	8
	Sex ratio (Male/Female)	1/2
	Number of population observed (N)	3,149

N: Individual

**Table 3.** The analysis of the buffaloes population structure in Batanghari District, Jambi, Indonesia, in 2023

Parameters		N	(%)
<b>Young animal</b>	Male	346	10.99
	Female	586	18.61
	Total	932	29.60
<b>Requirement of animal replacement</b>	Male	82	2.60
	Female	191	9.56
	Total	273	12.17
<b>Remains of young animals</b>	Male	264	8.38
	Female	395	9.05
	Total	549	17.43
<b>Culled animal</b>	Male	82	2.60
	Female	191	9.56
	Total	273	12.17
<b>Output estimation</b>	Male	346	10.99
	Female	586	18.61
	Total	932	29.60
<b>Net replacement rate</b>	Male	-	131,06
	Female	-	148,45
	Total	-	279,51

N: Individual

**Table 4.** The Effective population and inbreeding rate of buffaloes in Batanghari District, Jambi, Indonesia, in 2023

Sex	Total
Number of males breeding ( <i>NM</i> )	164
Number of females breeding ( <i>NF</i> )	1,530
Total	1,694
Effective population	592
Inbreeding Rate (%)	0.08

**Table 5.** Population dynamics of buffaloes in Batanghari District, Jambi, Indonesia, from 2019 to 2023

Year	Actual			Prediction			
	N	Deviation	Percentage	Year	N	Deviation	Percentage
2019	11,221	0	0	2024	6,770	664	9.808477
2020	9,560	-1661	-17.3745	2025	6,105	-664	-10.8814
2021	7,921	-1639	-20.6918	2026	5,441	-664	-12.2101
2022	7,991	70	0.875985	2027	4,777	-664	-13.9083
2023	7,434	-557	-7.4926	2028	4,112	-664	-16.1552
-	-	-757,4	-8.94	-	-	-399	-8.67

N: Individual

**Table 6.** The output estimation of buffaloes in Batanghari District, Jambi, Indonesia, from 2024 to 2028

Component	Years	2024	2025	2026	2027	2028
	<b>Number of animals (N)</b>	Male	2,675	2,912	3,129	3,346
	Female	5,350	5,824	6,259	6,693	4,956
	Total	8,025	8,737	9,388	10,039	7,434
<b>Number of young animals (N)</b>	Male (10.99%)	882	960	1,032	1,103	817
	Female (18.61%)	1,493	1,626	1,747	1,868	1,383
	Total	2,375	2,586	2,779	2,972	2,200
<b>Number of culled animals (N)</b>	Male (4.94%)	396	432	464	496	367
	Female (13.13%)	1,054	1,147	1,233	1,318	976
	Total	1,450	1,579	1,696	1,814	1,343
<b>Remains of young animals (N)</b>	Male (6.72%)	539	587	631	675	500
	Female (13.86%)	1,112	1,211	1,301	1,391	1,030
	Total	1,652	1,798	1,932	2,066	1,530
<b>Output estimation (N)</b>	Male	936	1,019	1,095	1,171	867
	Female	2,166	2,358	2,534	2,710	2,006
	Total	3,102	3,377	3,628	3,880	2,873

N: Individual

The net replacement rate (NRR) was 279.51, comprising 131.06 males and 148.45 females, as shown in Table 3. The Net Replacement Rate (NRR) is calculated by comparing the number of young replacement cattle to the annual replacement livestock requirements, multiplied by 100%. The NRR is used to assess whether the number of livestock births is sufficient to meet the replacement needs and maintain a stable population (Kusuma et al., 2017). Batanghari District is one of the areas that can be used as a source of feedstock owing to its high NRR value. Samberi et al. (2010) classify an area as a seed source area if the net replacement rate (NRR) is greater than 100%. Previous research has reported higher NRRs than the results of this study. Previous studies reported the NRR of buffalo in Sumbawa was 414.41, with 259.54 females and 154.88 males (Putra and Lestari, 2022), in Kuantan Regency, it was 455.71 with 310.60 females and 145.10 males (Yendraliza et al., 2021b), and in Ulukan Regency it was 279.02, with 121.97 females and 157.31 males (Putra et al., 2018). The effective population size of the buffalo population in the Batanghari District was 596 individuals (Table 4). The effective population size was considered adequate if it exceeded 100 Individuals. It is an important parameter in many population genetic models (Elsadina et al., 2021). The effective population size represents the number of breeding individuals in an ideal population that exhibits the same allele frequency distribution under the pressure of random genetic drift (Setiawati et al., 2020). Table 4 presents that the inbreeding rate of Batanghari buffaloes was 0.08%. The results of this study indicated that inbreeding did not yet occur at the crossbreeding level in buffaloes in the Batanghari District. A population is considered to be in good condition when the inbreeding rate is  $\leq 1\%$  per generation (Steensma et al., 2024). However, an increase in the inbreeding rate of 1% per generation can reduce productivity traits (Rusfidra et al., 2012).

Data from the Central Bureau of Statistics of Batanghari District from 2019 to 2023 showed that the average annual growth rate of the buffalo population in Batanghari District was -8.94% (Table 5). The growth rate in population size can be determined by estimating the net increase based on the data collected over the last five years (Widyaningrum et al., 2021). This population growth value can be used to predict the buffalo population. Based on the same coefficient calculation, the estimated buffalo population in 2028 will be 4,112 heads, and the average remains of young animals is -24 per year (Table 6). It can be concluded that the growth rate of the buffalo population in the Batanghari District showed a negative trend. Therefore, various mitigation efforts and policies must be implemented by the government as policymakers and by farmers as business actors. These efforts should address issues such as the slaughtering of productive females, improved reproductive management, health management, and farm management to reduce mortality and increase birth rates.

## CONCLUSION

The natural rate of increase in the buffalo population in the Batanghari District was low (14.74%), with an effective population size of 592 individuals. The inbreeding rate per generation was 0.08, indicating that the population was in relatively good condition. Nonetheless, the buffalo population in the Batanghari District showed a negative trend.

However, the animals under study have potential as a breeding stock resource based on their NRR value. Therefore, the government and farmers should implement policies to increase the buffalo population and prevent this livestock from becoming extinct.

## DECLARATIONS

### Availability of data and materials

The data used in this study can be accessed through the Department of Agriculture and Livestock of the Batanghari District in 2023 (unpublished data).

### Funding

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### Authors' contributions

This research was made possible by the contributions of all authors. Panca Andes Hendrawan collected information and drafted the manuscript. Jakaria, Cece Sumantri, and Sony Hartono Wijaya revised the manuscript. All authors have read and approved the final version of the manuscript.

### Competing interests

The authors have not declared any conflict of interest.

### Ethical considerations

The authors confirmed that plagiarism checks have been carried out, and there is no copy and data falsification.

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