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(RESEARCH ARTICLE)

POPULATION STRUCTURE ANALYSIS AND INBREEDING EVALUATION IN ENDANGERED GEMBRONG GOATS (*CAPRA HIRCUS*) OF INDONESIA

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ABSTRACT

The Gembrong goats (*Capra hircus*), are one of the Indonesian indigenous goats from Bali Island with very few population numbers. This study was aimed to determine the population structure of Gembrong goats at Beraban Village, Kediri District, Tabanan Regency, Bali Province including of population dynamics analysis and estimation of inbreeding rate (IR) and inbreeding probability (IP) values. The results showed that amount 76 heads of Gembrong goats were recorded for the data analysis and consisting of 43 males (rams) and 33 females (does). The composition of goats under study consisted of 29 rams (67.44%), 27 does (81.82%), 8 young females (18.60%), 1 young female (3.03%), 6 male kids (13.95%), and 5 female kids (15.15%). The NI, IR, and IP values in Gemrong goats were 4.47% (low), 66.90% (high), and 5.20% (high), respectively. Calving rate base on adult female and population were 40.74% and 14.47%, respectively. Therefore, the net replacement rate (NRR) value in Gembrong goats was 161% with the output estimation of 11.84% (± 9 heads). In conclusion, the Gembrong goat population in Beraban Village must be increased with controling the mating system to prevent the inbreeding case.

Keywords: Breeding; Inbreeding Probability; Inbreeding Rate; Natural Increase

1 INTRODUCTION

Goats are one of the small ruminants that easy to raise, have a high adaptability and widely distributed in Indonesia. Among the various local goat breeds, Gembrong goats are the unique breed from Bali Province. The body measurements of Gembrong goats (female/male) according to (Zein and Sulandari, 2014). Were 57.64±5.71 / 65.00±7.55 cm for body length; 53.91±4.74 / 57.67±5.69 cm for withers height and 28.64±1.91 / 31.67±3.51 cm for chest depth. In general, the live weight of adult Gembrong bucks was 29.15 kg for males and 18.20 kg for females (Suyasa and Parwati, 2015). In addition, the Gembrong goats had the body size that similar of a dwarf goat (West African Dwarf) with the presence of horn for male and female goats (Sam, 2024). Moreover, the horn size in the Gembrong bucks can reach about 16-25 cm (Sudarma and Londra, 2020).

The uniqueness of the Gembrong goats is showed in their hair which is thick, soft and covering the body of goat as same as the Angora goat. Due to these characteristics, the government of Indonesia has been registered the Gembrong goat since year 2013 through the decision of Indonesian Ministry of Agriculture No: 696/Kpts/PD.4110/2/2013 (Kementan, 2013). Recently, the population of the Gembrong goats is classified as endangered or critically endangered animal (Mahmilia *et al*., 2004). Zein *et al.*, (2016) reported that in March 2013, the population of Gembrong goats in Karangasem Regency of Bali Island was 20 heads.

The increasing of Gembrong goats can be predicted with the population analysis such as natural increase (NI), inbreeding rate (IR), and inbreeding probability (IP) analyses. Previously, the OE analysis was calculated to evaluate the population of several animals such as goat (Apriliyani *et al.*, 2023), sheep (Astuti *et al.*, 2022), buffalo (Putra and Lestari, 2022), cattle (Widyaningrum *et al.*, 2021; Nurlaila *et al.,*2018) and rhinoceros (Putra *et al.*, 2020). Ridho and Putra (2021) reported that the Gembrong goat population at Tumbu Village (Bali Province) had the inbreeding coefficient of 0.413, indicating of high inbreeding risk. Furthermore, Small population size can increase the inbreeding risk that reduces immunity, fertility, and the oat's ability to adapt to the environment (Leroy, 2014). Putra and Muzawar (2020) reported that the inbreeding in Bali cattle (*Bos javanicus*) can cause the stillbirth case.

Combinating the NI, IR, and IP analyses provide a comprehensive evaluation to the population of Gembrong goats. This study was conducted to evaluate the population of Gembrong goat at Beraban Village, Kediri District, Tabanan Regency, Bali Province. using the NI and IP analyses. The results of this study are important to develop the conservation program for increasing the population and reducing the inbreeding risk of Gembrong goats at Bali Island in the future.

2 MATERIALS AND METHODS

2.1 Animal and Study area

Total 76 heads of Gembrong goat were used for the population analysis. The population structure of Gembrong goat under study was presented in **Table 1**. The phenotype characteristics of Gembrong goat was showed in **Figure 1**. The goats were raised at the breeding station in Beraban Village, Kediri District, Tabanan Regency, Bali Province (**Figure 2**). This place is situated at latitude 8°03’40” to 8°50’48” S and longitude 114°25’53”- 115°42’40” E with 32 m above sea level. The humidity 85% to 90% and the rainfall is 1000-3000 mm/year.

Table 1: Population Structure of Gembrong Goats at Beraban Village, Indonesia

Parameter	Male		Female		Total	
	N	%	N	%	N	%
Kid	6	13.95	5	15.15	11	14.47
Young	8	18.60	1	3.03	9	11.84
Adult	29	67.44	27	81.82	56	73.68
Total	43	100	33	100	76	100



Figure 1: The phenotype characteristics of Gembrong bucks (A) and a Gembrong doe with a kid (B)

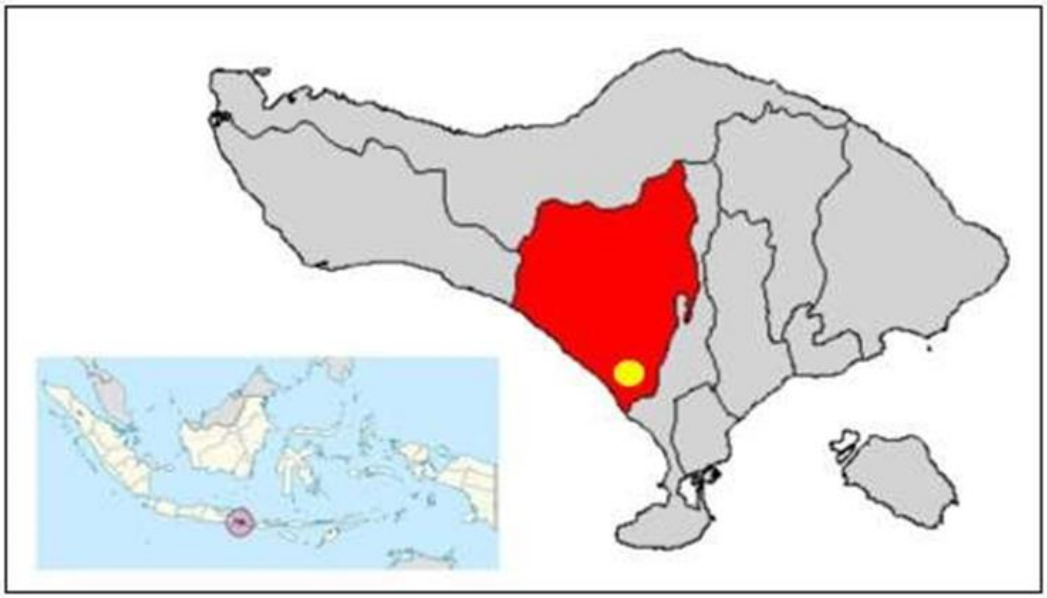


Figure 2: Observation site of the Gembrong goat at Beraban Village (yellow circle) in Tabanan Regency (red area) of Bali Province, Indonesia.

2.2 Management of animal

The goats were kept in the individual cage with natural mating. The goats were released in the pasture land from morning (07.00 am) to evening (14.30 pm). The Leucaena leaves (*Leucana leucocephala*) were given to goats after from the pasture land. The feed ration of goats consisted of Poral concentrate (11.6%), molasses (0.40%), and salt (0.06%). Water was given in goats with *ad libitum*. The regular medical examination and vaccination were managed once every six months.

2.3 Data analysis

The population dynamics analysis was calculated using several mathematical formulas (Samberi *et al.,* 2010) as follow:

$$\text{Number of adult goats (\%)} = \frac{\text{Number of adult goats}}{\text{Number of population}} \text{ x } 100\%$$

$$\text{Calving rate based on adult female (\%)} = \frac{\text{Number of kids}}{\text{Number of adult female goats}} \text{ x } 100\%$$

Calving rate based on population (%) = $\frac{\text{Number of kids}}{\text{Number of population}}$ x 100%

Natural increase (%) = Calving rate based on population (%) – Mortality (%)

Number of young goat (%) = $\frac{\text{Number of young goats}}{\text{Number of population}}$ x 100%

Requirement of goat replacement (%) = $\frac{\text{Number of adult goats}}{\text{Breeding lenght (years)}}$ x 100%

Remains of young goat (%) = Percent of young goat (%) - Requirement of goat replacement (%)

Number of culled goat (%) = Requirement of goat replacement (%)

Output (%) = Number of culled goat (%) + Remains of young goat (%)

Net replacement rate (%) = $\frac{\text{Number of young goats}}{\text{Remains of young goats}}$ × 100%

In this study, we use the mortility rate of 10% for the analysis according to (Makmur *et al.*, 2025). The IR value was calculated using the mathematical formula from (Tave, 1999) as follows:

$$IR = \frac{1}{8N_m} + \frac{1}{8N_f}$$

where, N_m is the number of male animals and N_f is the number of female animals.

The calculation of IP in a natural mating system uses a mathematical formula based on (Putra and Firmansyah, 2020). The formulas are applied in the following sequence:

$$N_{MP} = N_S \times N_D$$

$$N_{MG} = (N_{MP} - 1) \times [(N_S \times N_D)/2]$$

$$N_{MG} = (N_{MP} - 1) \times (N_{MP} \times 0.05)$$

where, N_{MP} is the number of mating combinations among the parents; N_{MG} is the number of mating combinations in the first generation; N_S is the number of males dan N_D is the number of females. The values of N_{MP} and N_{MG} are used to calculate the PI estimate as follow:

$$IP = N_{MI} / N_{MG}$$

$$N_{MI} = [(N_S + N_D) -2] \times (N_S \times N_D) \times 0.05$$

$$N_{MI} = [(N_S + N_D) -2] \times (N_{MP}) \times 0.05$$

where, IP is the inbreeding probability and N_{MI} is the number of inbreeding mating combinations in the first generations.

3 RESULTS AND DISCUSSION

3.1 Population Dynamics

The NI analysis of Gembrong goats under study was presented in **Table 2.** The output estimation and NRR values of Gembrong goat under were 11.84% and 161%, respectively. Previously, several studies obtained the higher of output estimation value than those in Gembrong goat i.e. 24.72% in Saburai (Adhianto *et al.*, 2019); 14.61% in Lakor goat (Harmoko *et al.*, 2022); 29.99% in Rambon (Hasibuan *et al.*, 2023); 23.52% in Ettawa grade (Apriliyani *et al.*, 2023) goats. While, several study also reported the higher NRR value than Gembrong goats under study i.e. 756.23% in Sabari, 191.81% in Boerawa, 636.21% in Rambon, 246.53% in Ettawa grade (Hasri *et al.*, 2018) Furthermore, the NI value of Gembrong goats under study was lower than Kisar (45.65%), Saburai (24.72%), local Gorontalo (14.11%), Ettawa grade (40.92%) and Kacang (51.52%) goat (Tatipikalawan and Hehanussa, 2006; Adhianto *et al.*, 2019; Ilham *et al.*, 2023; Marsudi

et al., 2024; Aka *et al.*, 2024. Samberi *et al.* (2010) stated that the NRR value had two categories of low (<100%) and high (>100%). In addition, the NI can be classified as low (NI<50%), moderate (51<NI<80%), and high (NI>80%) criterion. The low NI value is influenced by the low birth rate. The NI value can be increased by increasing the number of births, and on the other hand, reducing the mortality rate, NRR increases when the number of young goats is higher than the remains of young goats, and the output estimation increases when the number of culled goats and the remains of young goats are high.

Table 2: Natural Increase of Gembrong Goats at Beraban Village, Indonesia

Component	Value
Number of adult goats (%)	73.68
Calving rate based on adult female (%)	40.74
Calving rate based on population (%)	14.47
Mortality (%)	10.00
Natural increase (%)	4.47
Number of young goats (%)	11.84
Requirement of goat replacement (%)	7.37
Remains of young goat (%)	4.47
Number of culled goats (%)	7.37
Output estimation (%)	11.84
Net replacement rate (%)	161

3.2 Inbreeding Rate and Inbreeding Probability

The estimation of IR and IP of Gembrong goats under study was demonstrated in **Table 3.** According to Table 3, the IR value of Gembrong goats was 0.669 than the same goats at Tumbu Village 0.025 as reported by (Ridho and Putra, 2021). This value indicating the high inbreeding risk in Gembrong goat. Putra and Muzawar (2020) reported that the inbreeding coefficient (Fx) of 0.125 in Bali cattle can causing the stillbirth case. Reported that inbreeding which can lead to increased homozygosity, reduce genetic diversity, affecting growth, fertility, and survival of offspring. Despite this, the Gembrong goat at Tumbu Village was 0.025 and higher/lower than the goats under study. In this study, the difference of IR and IP of Gembrong goats at Tumbu and Beraban Villages can be caused by the number of male and females (Ridho and Putra, 2021).

Table 3: Inbreeding probability of Gembrong Goats at Beraban Village, Indonesia

Parameter	Value
Inbreeding rate (IR)	0.669
Inbreeding probability (IP)	0.052

The PI value of 0.052 indicated that amount 5.2% of inbreeding risk was observed in the Gembrong goat population. According to (Salamena *et al.*, 2007), increasing the inbreeding pressure rate less than 1% or more than 1% a can influences the survivability of Gembrong goat population. The high IP value in the Gembrong goat population is caused by small population size. The level of inbreeding is greatly influenced by the number of individuals in a population. Hence, the smaller population had the high of inbreeding pressure (Zahraddeen *et al.*, 2011). To avoid inbreeding case, managing good breeding practices such as feeding management, recording system and the selection are important to implementate in Gembrong goat in the future. Furthermore, the inbreeding depression can occur when the related males are used for the breeding (Asadolahi, 2025).

4 CONCLUSION

The population structure of Gembrong goats in Beraban Village had the >100% of NRR value and indicating this populationis able to produce the seedstock. However, the NI value of Gembrong goat under study was low with high of IR and IP values. These values indicated that the Gembrong goat population in the research area was under the high inbreeding risk. Hence, controling the Gembrong goat population with the good recording system is important to prevent from the extinction.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest in the manuscript.

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