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Population viability analysis of the Crioula Lageano cattle

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ADDITIONAL KEYWORDS

Bos taurus.
Conservation of animal genetics resources.
Extinction probability.
Population dynamics modelling.

SUMMARY

The aim of the present work was to perform a population viability analysis of the Crioula Lageana cattle breed to study its demographic and genetic parameters, as well as to verify the interference of factors that may affect the survival and development this population. Population viability was estimated using 128 hypothetical scenarios to assess the risk of extinction of this genetic resource, simulated over a 500 year period. The results showed that the possibility of extinction of this breed over the next 500 years was remote, even in less favourable scenarios. The deterministic growth rate was always positive during the evaluated period, and the mortality of animals up to one year of age was the most important factor that affected this parameter. The population size increased rapidly until the carrying capacity (k) was reached, which was a limiting factor for population growth. The level of retained heterozygosis in the population in the worst scenario was above 80% and the inbreeding coefficient was always below 0.20 at the end of the 500 years of simulation. The analysis of the population viability showed that the Crioula Lageana population has no long-term risk of extinction, and the carrying capacity is the main limiting factor for population growth.

Análise da viabilidade populacional da raça Crioula Lageana

RESUMO

O objetivo do presente trabalho foi realizar uma análise de viabilidade populacional da raça bovina Crioula Lageana, para estudar seus parâmetros demográficos e genéticos, bem como verificar a interferência de fatores que podem afetar a sobrevivência eo desenvolvimento dessa população. A viabilidade da população foi estimada utilizando 128 cenários hipotéticos para avaliar o risco de extinção deste recurso genético, simulada por um período de 500 anos. Os resultados mostraram que a possibilidade de extinção desta raça durante os próximos 500 anos foi remota, mesmo em cenários menos favoráveis. A taxa de crescimento determinística (det.r) foi sempre positiva durante o período avaliado, sendo a mortalidade dos animais de até um ano de idade o fator mais importante que afetou este parâmetro. O tamanho da população aumentou rapidamente até atingir a capacidade de suporte da área (k), sendo este o principal fator limitante para o crescimento da população. O nível de heterozigose esperada (He) da população no pior cenário foi superior a 80% e o coeficiente de endogamia (F) foi inferior a 0,20 no final dos 500 anos de simulação. A análise da viabilidade populacional mostrou que a população de Crioula Lageana não apresentou risco aparente de extinção a longo prazo e que a capacidade de suporte da área é o principal fator limitante para o crescimento da população.

PALAVRAS-CHAVE ADICIONAIS

Bos taurus.
Conservação de recursos genéticos animais.
Probabilidade de extinção.
Modelagem da dinâmica populacional.

INFORMATION

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INTRODUCTION

Cattle arrived in the Americas around 1493 (McManus *et al.*, 2010) and Brazil was the only country in the Americas that received breeds from Portugal, with the first introduction occurring 34 years after the discovery of the country (Primo, 2004). Throughout almost the last five centuries, these breeds were subjected to natural selection in specific environments for adapting to stressful production conditions (Mariante *et al.*, 2009), such as severe winter and blizzards and low food availability.

The introduction of cattle in southern Brazil was carried out by the Jesuits. With the invasion of the Jesuit Missions by the *Bandeirantes* (the Portuguese settlers and the fortune hunters), many of these animals were lost or were taken by the troops northwards the Santa Catarina plateau forests. At the beginning of the colonization of the Sierra fields of Santa Catarina, the settlers brought with them the Franqueiro cattle of origin Franca / SP, who crossed with the Creole cattle in the region, and this crossbred cattle was called as the Crioula Lageana breed (Mariante and Cavalcante, 2006).

From the late nineteenth century and early twentieth century, the exotic breeds began to be imported, most of them kept in the temperate climate regions. Little by little, through crossbreeding, the exotic breed replaced the locally adapted breeds, causing many of the latter to become threatened of extinction (Mariante *et al*., 2009).

Mariante and Trovo (1989) reported that at the end of the 80s, the Crioula Lageana population was reduced to no more than 500 animals of which more than 80% raised by a single breeder. Today, with the creation of the Breeder´s Association in 2003 and the official recognition of the breed by the Ministry of Agriculture, Livestock and Supply in 2008, the current population exceeded 1 400 animals.

The decline of most species is often mediated by human action. However, it is noted that, even if the primary action that caused the decline of species is removed; small populations remain unstable, since they are prone to stochastic random fluctuations such as demographics, environmental variations, genetic drift and disasters. The combination of these random forces can destabilize small populations and lead to their extinction (Shaffer, 1981).

The risk of extinction of a particular breed or species can be evaluated using population viability analysis (PVA) (Daleszczyk and Bunevich, 2009). This method consists in the formulation of hypothetical scenarios in which changes in environmental, demographic and genetic factors can be inserted to predict the size of a population in the future or future chances of extinction (Akçakaya and Sjogren-Gulve, 2000). Furthermore, PVA can also be used to indicate the recommended management strategy to reduce the probability of extinction and to evaluate the effect of different variables on the persistence of small populations (Coulson *et al*., 2001).

The biggest advantage of using PVA is the possibility of detecting problems related to conservation before they are detectable in the field, which enables the development of decision making and management systems suitable for maintaining the genetic diversity of a population. The Crioula Lageana cattle breed, in addition to a small number of animals, has a population concentrated in a single region of the country. The results of this research will provide valuable information for the conservation of this important genetic resource.

The aim of this study was to perform a population viability analysis of the Crioula Lageana cattle breed, to study demographic and genetic parameters, as well as verify the interference of factors that may affect the survival and development this population over a 500-year timespan.

MATERIAL AND METHODS

This study was conducted with the Crioula Lageana cattle breed located in the Southern Plateau of Santa Catarina. This region is located in the central portion of the state of Santa Catarina and reaches altitudes ranging between 700 and 1800 meters above sea level. It is characterized by harsh winters, with frequent frosts and mild summers, with mean annual temperature around 15.7°C (Cordoba *et al*., 2004). Cattle are kept on natural pastures with good dry matter production during the spring and summer, but little or no production during the autumn and winter (Fino *et al*., 2013).

The interaction between population structure, environmental and genetic factors on the Crioula Lageana population was evaluated using the VORTEX software, version 9.3 (Lacy *et al*., 2003), according to the methodology proposed by Lacy (2000). Details of the demographic parameters used in this study were provided by the Brazilian Association of Crioula Lageana Cattle Breeders (ABCCL). There were 128 simulated hypothetical scenarios. The input variables in the program were as follows:

- Initial population: size of the Crioula Lageana population in the Santa Catarina plateau, consisting of 1 408 animals, with 205 males and 1 203 females.

- Number of interactions: number of repetitions performed in each scenario. In this study were performed 100 repetitions (100).

- Evaluated period: simulation time period (100 and 500 years).

- Carrying capacity (k): is the maximum number of individuals that the environment can sustain over time without interfering with the maximum population growth (5000 animals). This number was based on the sum of the agricultural land area of Crioula Lageana breeding properties in the Santa Catarina plateau. It was considered for this study that the carrying capacity of the area would be reached with the stocking of an adult animal per hectare of agricultural land area.

- Animal output: The number of animals that annually leave from the population. For this parameter, two scenarios were constructed. A current scenario, with no removal of animals, and an alternative scenario, with the removal of 100 animals from the population annually. For this analysis only the animals registered by the ABCCL and intended for breeding were considered. According to the ABCCL, the removal of steers and culling cows for slaughter is equal to 40% of the population annually. For this reason, animal output in the current scenario is zero, since this output is already accounted for in the initial population.

- Reproductive parameters: The mating system is polygamous; sexual maturity is on average at two years of age, and the maximum age of animals in reproduction is on average 15 years for both sexes; the likelihood of being born male or female is 50% for each gender; with one offspring per pregnancy; proportion of mating females relative to the total possible females is 55% per year.

• Male: female ratio: Ratio of males to females in a population of 100 animals intended for breeding annually. For this parameter, four different scenarios were considered. A scenario in which the ratio was 5:95; 15:85, 30:70 and 50:50, the latter being regarded as the ideal in natural conditions.

• Inbreeding depression: Probability of deleterious recessive genes in the population as a result of homozygosity. The average inbreeding coefficient of the population was 0.34 (Pezzini, 2011). As this inbreeding coefficient was considered low, it was decided to check if inbreeding depression could be a problem in the future. In this case, it was assumed that the Crioula Lageana responded to inbreeding in a manner similar to that found in Ralls *et al.* (1988), working with 40 species of ungulates and Armstrong *et al.* (2006) when working with the Uruguayan Creole, with a lethal amount of 3.14 equivalents per diploid genome.

• Mortality rate: The percentage of animals that died in the population before the first year of life. In this simulation, three different scenarios were considered: a present scenario, with about 5% mortality at the first year of life and three alternative scenarios, with 10%, 25% and 40%. The mortality rate for animals over one year of age was estimated at 2.5% in all scenarios.

• Catastrophes: Catastrophic events (hurricanes, earthquakes, floods or epidemics) have impact in the survival and / or reproduction of animals in the population. In this simulation, the probability of five catastrophic events were considered, one every 20 years for the scenarios with up to 100 years of simulation, and a catastrophic event every 100 years for the scenarios up to 500 years. Whatever type of simulated disaster, the consequences were always the same, affecting reproduction of 50% of the animals and the survival of 20% in each catastrophe.

The following parameters were calculated using population structure, genetic and stochastic infor expected heterozygosity (He) and inbreeding coefficient (F): The loss of genetic diversity of the population over 500 years was carried out by simulating the parent to offspring transmission of alleles in a hypothetical non-selected neutral locus. At the beginning of the simulation, each animal was given a locus with only two alleles. For each subsequent generation, an original allele from the father and the mother was randomly allocated to each locus. The program calculated how many unique alleles in the population remained after the desired simulation period, and estimated the level of genetic diversity of the herd during the study period.

• Deterministic growth rate (det.r): Corresponds to the difference between the number of births and deaths of the population. The deterministic growth rate is calculated by solving the Euler equation.

where: $$\sum\left(l_x m_x^{-rx}\right)=1$$

lx is the age mortality rate, m_x is the birth rate, and r_x is the interaction between sex and mortality when this rate is different between sexes.

• Population size: The maximum population size was calculated by the initial number of animals multiplied by the growth rate of each deterministic scenario during the study period. However, this parameter is limited by environmental carrying capacity (k) and shows variance according to the stochastic and environmental fluctuations imposed by different hypothetical scenarios.

• Probability of extinction: The interaction of demographic, genetic and environmental factors simulated directly affects the population size at the end of each study period. The persistence or extinction of the breed is based on this parameter, which is considered extinct when there is no longer sufficient males or females for reproduction in the population, according to the criteria established by FAO (2007).

In addition to checking the risk of extinction over 500 years, using the current situation and possible hypothetical scenarios, this study also aimed to determine the population dynamics of the formation of the breed. According to information provided by the ABCCL, the initial population consisted of 291 animals from the Santa Catarina plateau forests in the early 1970s which was the genetic basis of the current population.

Twelve different scenarios were created in order to simulate the development of this population over the course of four decades. So the following conditions were considered: 65% of females suitable for reproduction were in breeding each year and 50% of the population consisted of males in reproduction. The mortality of animals until the first year of life was set at 10% and 25%, which is above the current mortality rate in the first year of the current population. The base scenario considered no animal output, with two other scenarios removing 25 and 50 animals per year.

RESULTS AND DISCUSSION

The analysis of population viability of the Crioula Lageana breed in the Santa Catarina Plateau, based on an evaluation of a total of 128 hypothetical scenarios **(tables I, II, III, IV)**, showed that the probability of extinction of the population was remote. In all investigated scenarios, the population size rapidly increased up to the first 10 years of the simulation period, reaching the carrying capacity of the area **(figure 1)**. After

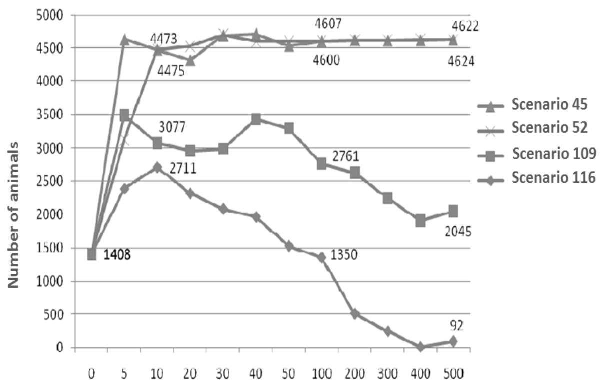

Figure 1. Estimated population size of the Crioula Lageana cattle breed over 500 years (Tamanho populacional estimado da raça bovina Crioula Lageana no decorrer de 500 anos).

Table I. Analysis of population viability in 32 different scenarios, for the Crioula Lageano cattle breed from the Santa Catarina plateau over 100-year period without the occurrence of disasters (Análise da viabilidade populacional, em 32 cenários, da raça bovina Crioula Lageana do Planalto Catarinense ao longo de 100 anos sem a ocorrência de catástrofes).

Scenario	Mort (%)	Males (%)	Ret.	k	Det.r	He	F	P.ext
1	5	5	0	5000	0.158	0.9940	0.0016	0.00
2	10	5	0	5000	0.148	0.9939	0.0015	0.00
3	25	5	0	5000	0.118	0.9939	0.0012	0.00
4	40	5	0	5000	0.084	0.9940	0.0013	0.00
5	5	15	0	5000	0.158	0.9964	0.0000	0.00
6	10	15	0	5000	0.148	0.9964	0.0000	0.00
7	25	15	0	5000	0.118	0.9964	0.0000	0.00
8	40	15	0	5000	0.084	0.9963	0.0000	0.00
9	5	30	0	5000	0.158	0.9970	0.0000	0.00
10	10	30	0	5000	0.148	0.9970	0.0000	0.00
11	25	30	0	5000	0.118	0.9970	0.0000	0.00
12	40	30	0	5000	0.084	0.9969	0.0000	0.00
13	5	50	0	5000	0.158	0.9972	0.0000	0.00
14	10	50	0	5000	0.148	0.9972	0.0000	0.00
15	25	50	0	5000	0.118	0.9972	0.0000	0.00
16	40	50	0	5000	0.084	0.9971	0.0000	0.00
17	5	5	100	5000	0.158	0.9925	0.0015	0.00
18	10	5	100	5000	0.148	0.9960	0.0004	0.00
19	25	5	100	5000	0.118	0.9925	0.0016	0.00
20	40	5	100	5000	0.084	0.9922	0.0018	0.00
21	5	15	100	5000	0.158	0.9960	0.0003	0.00
22	10	15	100	5000	0.148	0.9960	0.0003	0.00
23	25	15	100	5000	0.118	0.9960	0.0000	0.00
24	40	15	100	5000	0.084	0.9959	0.0000	0.00
25	5	30	100	5000	0.158	0.9968	0.0000	0.00
26	10	30	100	5000	0.148	0.9968	0.0000	0.00
27	25	30	100	5000	0.118	0.9967	0.0000	0.00
28	40	30	100	5000	0.084	0.9966	0.0000	0.00
29	5	50	100	5000	0.158	0.9971	0.0000	0.00
30	10	50	100	5000	0.148	0.9970	0.0000	0.00
31	25	50	100	5000	0.118	0.9970	0.0000	0.00
32	40	50	100	5000	0.084	0.9969	0.0000	0.00

Mort.= Animal mortality percentage up to one year of age; Males= Percentage of males on the number of females mating; Ret. = Number of males removed from the population annually; k= area of support capacity; Det. r= Population growth rate; He= expected heterozygosity; F= inbreeding coefficient; P. ext= probability of extinction.

10 years, in the scenarios with no disasters, the number of animals presented a low growth rate until the end of the evaluated period. This is in agreement with Armstrong *et al.* (2006) who studied the population viability of the Uruguayan Creole cattle breed over 100 years They found that the population reached its maximum size in about 10 years, period in which the carrying capacity of that area was reached and the population remained stable until the end of the evaluated period.

For the scenarios with no disasters **(figure 1)**, the difference between the most optimistic situation (Scenario 45: mortality rate of 5% in the first year, male:female ratio of 50:50 and no annually animal output), was minimal compared to the worst case scenario (Scenario 52: mortality rate of 40% in the first year, 5:95 male:female ratio and annual output of 100 animals). This suggests that, for long-term viability of the population without the occurrence of disasters, the main limiting factor for the development of the population is the carrying capacity. So the factors such as high mortality, male:female ratio and animal output did not significantly affect the development of the population.

As for the scenarios where disasters were inserted, the population size decreased considerably by the end of 100 and 500 years simulation period the study period. The reason for the sharp drop in population size

Table II. Analysis of population viability in 32 different scenarios, for the Crioula Lageano cattle breed from the Santa Catarina plateau over 500-year period without the occurrence of disasters (Análise da viabilidade populacional, em 32 cenários, da raça bovina Crioula Lageana do Planalto Catarinense ao longo de 500 anos sem a ocorrência de catástrofes).

Scenario	Mort (%)	Males (%)	Ret.	k	Det.r	He	F	P.ext
33	5	5	0	5000	0.158	0.9817	0.0024	0.00
34	10	5	0	5000	0.148	0.9827	0.0029	0.00
35	25	5	0	5000	0.118	0.9800	0.0025	0.00
36	40	5	0	5000	0.084	0.9817	0.0019	0.00
37	5	15	0	5000	0.158	0.9879	0.0010	0.00
38	10	15	0	5000	0.148	0.9872	0.0016	0.00
39	25	15	0	5000	0.118	0.9871	0.0008	0.00
40	40	15	0	5000	0.084	0.9856	0.0011	0.00
41	5	30	0	5000	0.158	0.9880	0.0010	0.00
42	10	30	0	5000	0.148	0.9883	0.0012	0.00
43	25	30	0	5000	0.118	0.9880	0.0007	0.00
44	40	30	0	5000	0.084	0.9877	0.0007	0.00
45	5	50	0	5000	0.158	0.9893	0.0006	0.00
46	10	50	0	5000	0.148	0.9890	0.0006	0.00
47	25	50	0	5000	0.118	0.9889	0.0007	0.00
48	40	50	0	5000	0.084	0.9883	0.0010	0.00
49	5	5	100	5000	0.158	0.9810	0.0018	0.00
50	10	5	100	5000	0.148	0.9810	0.0038	0.00
51	25	5	100	5000	0.118	0.9812	0.0019	0.00
52	40	5	100	5000	0.084	0.9778	0.0054	0.00
53	5	15	100	5000	0.158	0.9858	0.0017	0.00
54	10	15	100	5000	0.148	0.9873	0.0013	0.00
55	25	15	100	5000	0.118	0.9868	0.0013	0.00
56	40	15	100	5000	0.084	0.9848	0.0019	0.00
57	5	30	100	5000	0.158	0.9883	0.0010	0.00
58	10	30	100	5000	0.148	0.9988	0.0009	0.00
59	25	30	100	5000	0.118	0.9879	0.0012	0.00
60	40	30	100	5000	0.084	0.9868	0.0012	0.00
61	5	50	100	5000	0.158	0.9890	0.0009	0.00
62	10	50	100	5000	0.148	0.9888	0.0009	0.00
63	25	50	100	5000	0.118	0.9887	0.0011	0.00
64	40	50	100	5000	0.084	0.9881	0.0007	0.00

Mort.= Animal mortality percentage up to one year of age; Males= Percentage of males on the number of females mating; Ret.= Number of males removed from the population annually; k= area of support capacity; Det. r= Population growth rate; He= expected heterozygosity; F= inbreeding coefficient; P. ext= probability of extinction.

over the years was due to the severity of the disasters, since they caused the death of 20% of the population and reduced the number of animals by half in the 100 years simulation.

In case of disasters, the difference in population size when comparing the most optimistic scenario (scenario 109) and the worst case scenario (scenario 116) at the end of 500 years of simulation is considerable. This suggests that, in case of severe disasters, such as those simulated in the present study, the Crioula Lageana population size may become twenty times smaller if factors such as mortality rate, male:female ratio, animal output and number of animals in breeding are not controlled.

The probability of persistence of a population over time depends directly on the population growth rate as well as environmental, genetic and demographic factors (Miller and Lacy, 2005). The Crioula Lageana population growth rate decreased as the mortality of one year old animals increased **(figure 2)**. In their study, Lopes *et al.* (2009) also reported an inverse relation between mortality and population growth rate.

Although the population growth rate is directly influenced by the mortality rate within the first year,

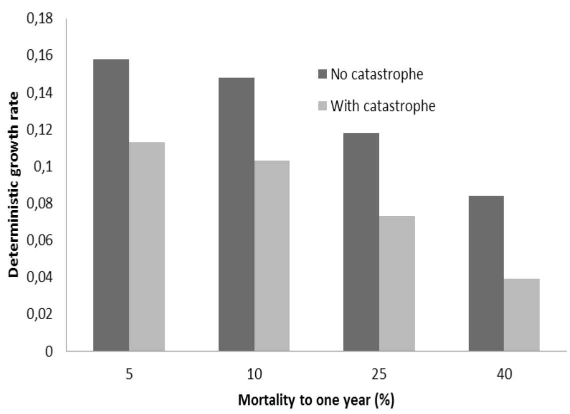

Figure 2. Deterministic growth rate of Crioula Lageana cattle in relation to the mortality of animals up to one year of age (Taxa de crescimento determinística da raça bovina Crioula Lageana em relação à mortalidade de animais até um ano de idade).

the difference in population growth with a 5% (Det.r = 1.58) and 10% (Det.r = 1.48) mortality rate was only 6.3%, suggesting that a mortality rate within the first year of up to 10% will not stop a rapid population growth.

The Crioula Lageana genetic variability was high in the 128 simulated scenarios. The expected heterozygosity was above 65% and the inbreeding coefficient below 35% in all simulated scenarios. Even in the worst case scenario (scenario 116), the expected heterozygosity over 100 years was above 0.95 **(figure 3)**. According to Ballou (1997), a management program which can predict a 90% retention of genetic variation for the next 100 years can be considered a success.

For scenarios where no disasters were considered, the difference between the most optimistic (Scenario 45) and the worst-case scenario (Scenario 52) was minimal, suggesting that male:female relationship did not significantly affect the genetic variability. According to information from the genealogical record of ABCCL, male:female ratio currently found in the population is 15:85. Thus, in a no disaster scenario, the current male:female ratio would not compromise the genetic diversity of the population over the next 500 years. On the other hand, a low number of breeding males relative to the number of females could significantly reduce the effective population size, leading to the so-called bottleneck effect (Kantanen *et al.*, 2000).

When scenarios with disasters were compared to those without disasters, there was no significant difference in the expected heterozygosity. This finding can be attributed to a significant decrease in population size after catastrophic events, which may lead to an increase in inbreeding rates in subsequent generations.

However, even in the worst-case scenarios, the evaluation of population viability showed high genetic diversity. Studies with Crioula Lageana using molecular markers also found a high genetic diversity in the population. A genetic characterization of Crioula Lageana, using RAPD molecular markers, observed that there was no loss of genetic diversity across generations in animals from the Santa Catarina plateau (Spritze *et al.*, 2003). Studies evaluating the genetic similarity of Crioula Lageana to other locally adapted breeds reported that the Crioula Lageana formed an in-

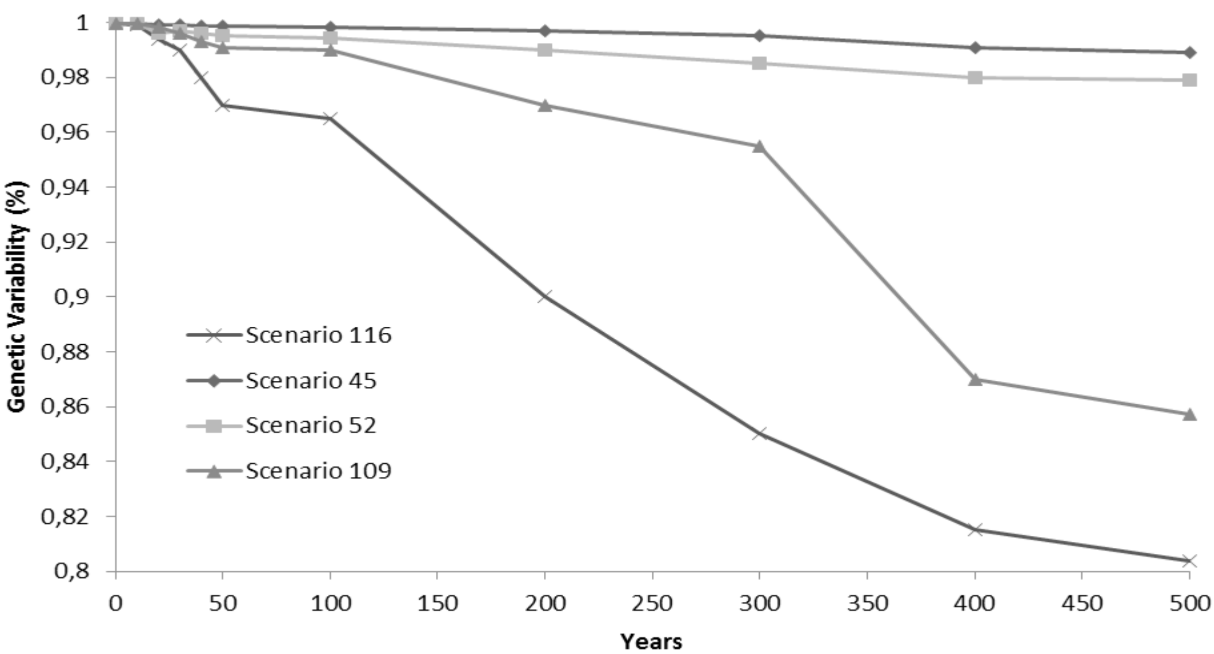

Figure 3. Expected heterozygosity (He) of the Crioula Lageana cattle population (Heterozigose esperada (He) da poupulação da raça bovina Crioula Lageana).

Table III. Analysis of population viability in 32 different scenarios, for the Crioula Lageano cattle breed from the Santa Catarina plateau over 100-year period with the occurrence of disasters (Análise da viabilidade populacional, em 32 cenários, da raça bovina Crioula Lageana do Planalto Catarinense ao longo de 100 anos com a ocorrência de catástrofes).

Scenario	Mort (%)	Males (%)	Ret.	k	Det.r	He	F	P.ext
65	5	5	0	5000	0.113	0.9602	0.0580	0.00
66	10	5	0	5000	0.103	0.9550	0.0536	0.00
67	25	5	0	5000	0.073	0.9568	0.0415	0.00
68	40	5	0	5000	0.039	0.9246	0.1007	0.00
69	5	15	0	5000	0.113	0.9744	0.0381	0.00
70	10	15	0	5000	0.103	0.9655	0.0546	0.00
71	25	15	0	5000	0.073	0.9624	0.0454	0.00
72	40	15	0	5000	0.039	0.9268	0.1409	0.00
73	5	30	0	5000	0.113	0.9752	0.0354	0.00
74	10	30	0	5000	0.103	0.9662	0.0602	0.00
75	25	30	0	5000	0.073	0.9610	0.0601	0.00
76	40	30	0	5000	0.039	0.9447	0.0811	0.00
77	5	50	0	5000	0.113	0.9607	0.1189	0.00
78	10	50	0	5000	0.103	0.9710	0.0887	0.00
79	25	50	0	5000	0.073	0.9519	0.1139	0.00
80	40	50	0	5000	0.039	0.9454	0.0852	0.00
81	5	5	100	5000	0.113	0.9553	0.0780	0.00
82	10	5	100	5000	0.103	0.9729	0.0348	0.00
83	25	5	100	5000	0.073	0.9462	0.0714	0.00
84	40	5	100	5000	0.039	0.9066	0.1238	0.00
85	5	15	100	5000	0.113	0.9705	0.0459	0.00
86	10	15	100	5000	0.103	0.9644	0.0531	0.00
87	25	15	100	5000	0.073	0.9586	0.0689	0.00
88	40	15	100	5000	0.039	0.9223	0.1086	0.00
89	5	30	100	5000	0.113	0.9711	0.0416	0.00
90	10	30	100	5000	0.103	0.9668	0.0756	0.00
91	25	30	100	5000	0.073	0.9487	0.1049	0.00
92	40	30	100	5000	0.039	0.9331	0.0765	0.00
93	5	50	100	5000	0.113	0.9727	0.0545	0.00
94	10	50	100	5000	0.103	0.9706	0.0510	0.00
95	25	50	100	5000	0.073	0.9588	0.0671	0.00
96	40	50	100	5000	0.039	0.9562	0.0586	0.00

Mort.= Animal mortality percentage up to one year of age; Males= Percentage of males on the number of females mating; Ret.= Number of males removed from the population annually; K= area of support capacity; Det. r= Population growth rate; He= expected heterozygosity; F= inbreeding coefficient; P. ext= probability of extinction.

dependent group, therefore proving the uniqueness of this population (Rangel *et al*., 2004, Serrano *et al*., 2004).

In the present work, when analysing the current population structure **(table V)**, a clear predominance of females above 3 years of age was observed. The Crioula Lageana cannot be considered threatened due to the high number of breeding females and males (FAO, 2007). However, despite the large number of breeding animals, the difference in the number of males and females is significant and can lead to losses in the genetic diversity of the population over the years. In a previous study on indigenous cattle in Jordan concluded that if no conservation action was taken, the breed would be extinct in 10 years. According to the authors, the factor that aggravated this situation was the difference between the number of male and female since in a population of 1 880 animals, there were only ten breeding males (Raed and Atiyat, 2009). Thus, the ABCCL should encourage breeders to increase the number of breeding males in order to avoid the risk of extinction.

In addition to studying the risk of extinction of the Crioula Lageana breed over 500 years, the present study also aimed to determine the population dynamics of the breed. Therefore, 12 hypothetical scenarios were considered, simulating 40 years of population growth in natural conditions **(table VI)**. The deterministic growth rate (Det. r) of the founding population ranged from 0.178, in scenarios where the mortality rate of

Table IV. Analysis of population viability in 32 different scenarios, for the Crioula Lageano cattle breed from the Santa Catarina plateau over 500-year period with the occurrence of disasters (Análise da viabilidade populacional, em 32 cenários, da raça bovina Crioula Lageana do Planalto Catarinense ao longo de 500 anos com a ocorrência de catástrofes).

Scenario	Mort (%)	Males (%)	Ret.	k	Det.r	He	F	P.ext
97	5	5	0	5000	0.113	0.7210	0.1841	0.00
98	10	5	0	5000	0.103	0.7323	0.1753	0.00
99	25	5	0	5000	0.073	0.7897	0.1064	0.00
100	40	5	0	5000	0.039	0.6655	0.0000	0.00
101	5	15	0	5000	0.113	0.8208	0.1204	0.00
102	10	15	0	5000	0.103	0.8277	0.1964	0.00
103	25	15	0	5000	0.073	0.8209	0.0425	0.00
104	40	15	0	5000	0.039	0.8080	0.0000	0.00
105	5	30	0	5000	0.113	0.8099	0.1599	0.00
106	10	30	0	5000	0.103	0.8991	0.0446	0.00
107	25	30	0	5000	0.073	0.8536	0.0799	0.00
108	40	30	0	5000	0.039	0.7312	0.1017	0.00
109	5	50	0	5000	0.113	0.8572	0.1276	0.00
110	10	50	0	5000	0.103	0.8976	0.0919	0.00
111	25	50	0	5000	0.073	0.8433	0.1321	0.00
112	40	50	0	5000	0.039	0.9595	0.0000	0.00
113	5	5	100	5000	0.113	0.8324	0.1243	0.00
114	10	5	100	5000	0.103	0.7762	0.1100	0.00
115	25	5	100	5000	0.073	0.8525	0.0091	0.00
116	40	5	100	5000	0.039	0.8039	0.0000	0.00
117	5	15	100	5000	0.113	0.6635	0.1783	0.00
118	10	15	100	5000	0.103	0.8737	0.0936	0.00
119	25	15	100	5000	0.073	0.7868	0.1534	0.00
120	40	15	100	5000	0.039	0.7241	0.0000	0.00
121	5	30	100	5000	0.113	0.8900	0.644	0.00
122	10	30	100	5000	0.103	0.9191	0.0306	0.00
123	25	30	100	5000	0.073	0.8819	0.0652	0.00
124	40	30	100	5000	0.039	0.8439	0.949	0.00
125	5	50	100	5000	0.113	0.9193	0.0320	0.00
126	10	50	100	5000	0.103	0.8178	0.2070	0.00
127	25	50	100	5000	0.073	0.8202	0.1129	0.00
128	40	50	100	5000	0.039	0.6666	0.2639	0.00

Mort.= Animal mortality percentage up to one year of age; Males= Percentage of males on the number of females mating; Ret.= Number of males left from the population annually; k= area of carrying capacity; Det. r= Population growth rate; He= expected heterozygosity; F= inbreeding coefficient; P. ext= probability of extinction.

Table V. Current population structure of the Crioula Lageana cattle breed in the Santa Catarina plateau (n = 1 408) (Estrutura populacional da raça bovina Crioula Lageana no Planalto Catarinense (n=1 408)).

Age (years)	Males	Females
0-1	57	164
1-2	53	152
2-3	38	145
3-4	24	131
4-5	19	128
>5-14		483
Total	205	1 203

animals under one year of age was 10%, to 0.146 in scenarios of 25% mortality rate. Although the population growth rate is directly influenced by the mortality rate of the animals until the first year of life, it was verified in this study that the differences in population growth rates with mortality of 5% (Det. r = 1.58) was only 6.3% lower than the 10% mortality rate (Det. r = 1.48). This suggests that a first-year mortality rate of up to 10% would not be detrimental to the maintenance of high growth rates for the Crioula Lageana breed.

Higher growth rate of the founding population can be attributed to the fact that a greater proportion of females were considered to be mating since in the past the animals were not subjected to a breeding season as

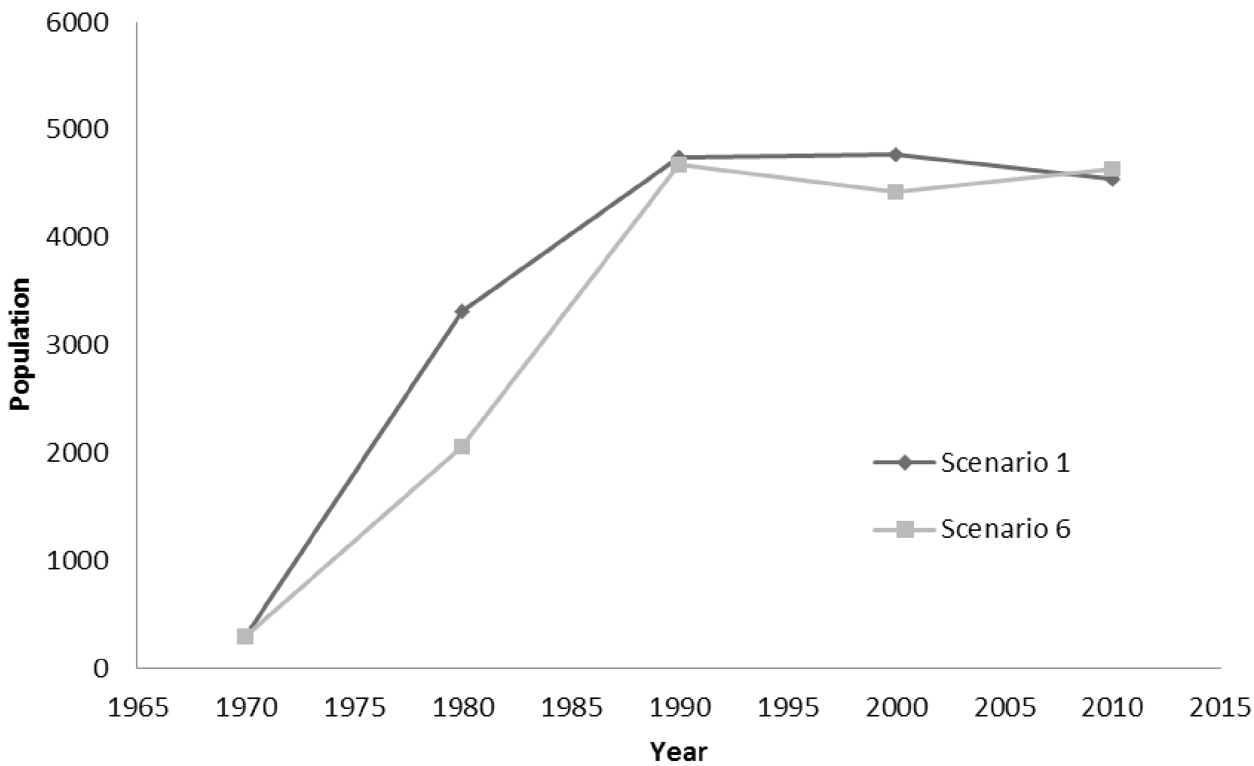

Figure 4. Estimated growth rate of the Crioula Lageana founders in a carrying capacity (k) equal to 5000 animals (Estimativa de crescimento populacional dos fundadores da raça Crioula Lageana em uma capacidade de suporte da área (k) igual a 5000 animais).

currently occurs. So, the rise in birth rate led to a higher population growth.

The estimated population growth of the Crioula Lageana founders in a carrying capacity (k) equal to 5000 animals was higher than the growth of the current population. In the most optimistic scenario (Scenario 1), with a 10% mortality rate in the first year and without animal output, as well as in the worst case scenario (Scenario 6), with a mortality rate of 25% in the first year and the removal of 50 animals per year, the population reached the number of more than 4 500 animals **(figure 4)**.

Considering that the current population is a commercial herd and 40% of the animals are sold annually for slaughter for generating income for the farmers, the difference between the potential size (over 4500

Table VI. Population viability analysis of the Crioula Lageana cattle breed in the Santa Catarina plateau, from its formation, in 12 different scenarios (Análise da viabilidade populacional da raça bovina Crioula Lageana do Planalto Catarinense, a partir de sua formação, em 12 cenários distintos).

Scenario	Mort (%)	Males (%)	Ret.	k	Det.r	He	F	P.ext
1	10	50	0	5000	0.178	0.9953	0.0005	0.00
2	25	50	0	5000	0.146	0.9942	0.0005	0.00
3	10	50	25	5000	0.178	0.9917	0.0020	0.00
4	25	50	25	5000	0.9918	0.146	0.0016	0.00
5	10	50	50	5000	0.9929	0.178	0.0008	0.00
6	25	50	50	5000	0.9927	0.146	0.0010	0.00
7	10	50	0	5000	0.178	0.9883	0.0011	0.00
8	25	0	50	5000	0.146	0.9892	0.0012	0.00
9	10	50	25	5000	0.178	0.9859	0.0025	0.00
10	25	50	25	5000	0.9853	0.146	0.0024	0.00
11	10	50	50	5000	0.9876	0.178	0.0012	0.00
12	25	50	50	5000	0.9877	0.146	0.0012	0.00

Mort.= Animal mortality up to one year of age; Males= Percentage of males on the number of females mating; Ret.= Number of males removed from the population annually; k= carrying capacity; Det.r= Population growth rate; He= Expected heterozygosity; F= Inbreeding coefficient; P. ext= probability of extinction.

animals) and the current population (1408 animals) can be justified by the fact that only breeding animals remain in the herd.

Even with a growth below the potential, assessment of population viability showed that the Crioula Lageana population has no apparent risk of extinction according to the criteria established by FAO (2007). However, the population should be spread to different regions because in an event of a disease, such as foot and mouth diasease, in which the entire herd would be sacrificed, the population would be extinct. Also, acording to Lindenmayer *et al*. (1993), the separation of the population in sub-populations is an important tool of conservation of genetic resources, enabling better forward planning and a more effective genetic improvement. So, the allocation of animals, semen and embryos to other regions of the country can reduce the risk of extinction and conserve the genetic material.

CONCLUSIONS

The assessment of population viability showed that the Crioula Lageana population has no long-term risk of extinction, and the carrying capacity is the main limiting factor for population growth. However, in order to avoid extinction in case of disasters, the farmers should adopt measures to ensure a low mortality rate in the first year, a balanced male:female ratio and a high number of breeding males.

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