Full Length Research Paper

Survival and population viability of Fogera cattle (Bos *indicus*, Zenga Type) in North West Amhara, Ethiopia

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The Fogera cattle are among the 27 recognized indigenous cattle in Ethiopia found around lake Tana and its population size decreased from 800,000 in 1980s to 15,000 heads in 2000.Therefore, the objective of the study was to conduct the population viability of the Fogera cattle populations in Denbia, Libo kemkem and Fogera districts as well as Andassa livestock research center. Census and different population viability models were used as methodology. The estimated average population growth rate, λ was 0.9908 with a 95% confidence of 0.9048 to 1.0849. The continuous rate of increase or the rate of growth or decline per year of pure-Fogera cattle population (-0.009) was less than zero (0) and indicated short-term population growth. The probability of the population reaching a lower extinction threshold was extremely very high with long year's mean time extinction. This means that the mean time required for the counts to decline from 9016 to 300 individual pure-Fogera cattle population or to reach to the extinction threshold was extremely high. The mean time to extinction was 162.7 years for 300 individual thresholds. Therefore, appropriate in-situ conservation measures are important for sustainable utilization.

Key words: Extinction, Fogera cattle, Growth rate, PVA

INTRODUCTION

Ethiopia has long been recognized as a center of diversity for domestic animal genetic resources. It appears that the country has served as a gateway to genetic material from Asia to Africa and its diverse ecology gave rise to further diversification and thus contributed to develop the large number of genotypes the country host today (IBC, 2004). Ethiopia is home to large indigenous cattle populations with diverse breeds, ecotypes and characteristics (Rege, 1999; Workneh et al., 2004) and estimated at 55.03 million (CSA, 2014). The cattle are well adapted to the tropical environment producing and reproducing under stresses of high degree of temperature, high disease prevalence and low level of nutritional status. They are categorized into five major breed groups namely, Large East African Zebu, Small East African Zebu, Senga, Zenga and the

Taurine (humpless shorthorn) types (Rege, 1999; Workneh et al., 2004) and are classified into 27 indigenous breeds/eco-types (IBC, 2004).

As compared to other alternatives for making conservation decisions, PVA provides a rigorous methodology that can use different types of data, a way to incorporate uncertainties and natural variability, and products or predictions that are relevant to conservation goals (Akçakaya and Sjögren-Gulve, 2000). Population viability analysis is often oriented towards the management of rare and threatened species to minimize the risk of extinction and to promote conditions in which species retain their potential for evolutionary change without intensive management (Beissinger and McCullough, 2001).
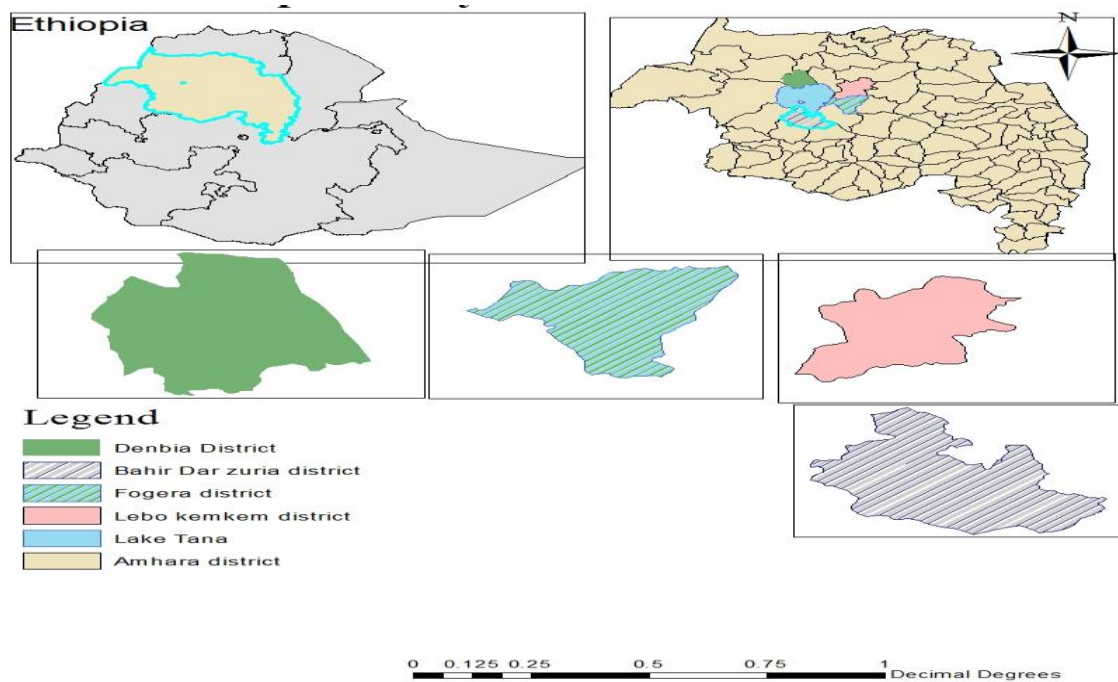
Figure 1. Map of study districts in Amhara region

The Fogera cattle are among the 27 recognized indigenous cattle in Ethiopia and it is found distributed around Lake Tana in south Gonder and west Gojjam zone of Amhara region, Ethiopia (Addisu Bitew et al., 2010). Though there is no clear data confirming their utility, they are called triple use; drought, milk and meat (Addisu Bitew et al., 2010). The population of Fogera cattle was estimated to be around 800,000 in 1980s (Alberro and Haile-Mariam, 1982), 636,000 heads in 1998 (IBC, 2004) 86,800 heads in 1999s (Rege, 1999) and 15,000 heads in 2000s (Gebeyehu Goshu et al., 2004). The Fogera cattle is exhibiting a decreasing trend (IBC, 2004). Therefore, the objective of this research was to evaluate the survival and the population viability of the Fogera cattle populations and recommend the conservation measures for sustainable utilization of the breed.

MATERIALS AND METHODS

Study Area Description

The study was conducted in 2014 in three districts (Denbia, Libo kemkem, Fogera) and in one ex-situ conservation site (Andassa research center).

Dembia is one of the districts of North Gondar Administrative Zone. This district covers an area of 148968 ha or 1270 km^2. The altitude of the district ranges between 1750 and 2100 meters above sea level. The topography of the district is 87 % plain, 8 % mountain 2.8 % plateau and 2.2 % covered by water. The district receives an annual rainfall ranging from 700 mm to 1160. Temperature ranges from 18 to 28 ^{0}C. According to Dembia District Agricultural office report 2014 the current livestock population of the district is estimated at 314423 cattle, 58601 sheep, 18659 goats,

58 horses, 20205 donkeys, 269 mules, and 147720 poultry.

Libo Kemkem district is located in the South Gondar Administrative Zone of Amhara Region in North Western Ethiopia. It has an area of 108157 ha or 1,560 square kilometers. The topography of the district consists of plain land (42%), uneven (30%), mountains (21 %), watershed (6%) gorges (1%). it is mountainous with high altitude (1,800 -3,000 meters above sea level). The temperature of the region is medium, ranging from 19ºC to 30ºC. According to Libo Kemkem District Agricultural office 2014 the current livestock population of the district is estimated 115452 cattle, 17939 sheep, 36448 goats, 871 horses, 1220 donkeys, 461 mules, and 327403 poultry.

The Fogera district is found in the South Gondar Zone of the Amhara Regional State. The districts is located at 11°46 to 11°59 latitude and 37°33 to 37°52 longitudes. Altitude ranges from 1774 to 2410 masl. Based on existing digital data, mean annual rainfall is 1216.3 mm and ranging from 1103 to 1336 mm. The average minimum and maximum temperature of the district vary between 10.3°C to 27.2°C. According to Fogera District Agricultural office 2014 report the current livestock population of the district is estimated 182729 cattle, 15575 sheep, 25956 goats, 3 horses, 13782 donkeys, 568 mules, and 379067 poultry.

Andassa livestock Research Center (ALRC) was established in 1964 as the Imperial Fogera Cattle Conservation Centre under the Ministry of Agriculture. It is located in 11°29' N and 37°29'E with 1,730 meters above sea level. It is located in Amhara regional state, western Gojjam zone, Bahir Dar Zuria district. It receives average annual rainfall of 1150 mm with the mean annual temperature varies from 8.8°C to 29.5 °C. In the last years the centre re-initiated pure breeding of the Fogera cattle for genetic improvement. In 2014, the

Figure 2. Matured fogera bull and cow   found in the study districts

Table 1. Total cattle population census including pure Fogera, interbreed and non-fogera

Year	$x = \sqrt{t(j)} - t(i)$	Counts	$y = \ln (N(j)/N(i)/x$
2003		533608	
2004	1	626663	0.160747
2005	1	663533	0.05717
2006	1	665637	0.003166
2007	1	540276	-0.20866
2008	1	415290	-0.2631
2009	1	519539	0.223965
2010	1	534976	0.02928
2011	1	555863	0.0383
2012	1	584968	0.051035
2013	1	522826	-0.11231
2014	1	523039	0.000407

centre maintained herd of 401 pure Fogera, 68 cross Fogera bred cattle and 2 Borena cattle breed.

Sampling Technique and Analysis

Burnham *et al.* (1980) and Smart *et al.* (2004) suggested total count and characterizing methods as the most direct way to estimate the abundance or viability of biological population. The study areas were purposely selected based on their potential of Fogera cattle. Besides, twelve year (2003 to 2014) census data obtained from districts and Zonal agricultural offices and from Andassa livestock research centre were considered. To reduce the effect of variable census and characterization   errors on the totals and the annual estimates of the population, the original count totals for all cases where this census data used were transformed using a two-point weighted interpolation model (Norman *et al.*, 2005) as:

$N = 0.67N_t + 0.33N_t + 1$

Where N = adjusted population estimate for male and or female population and N_t = recorded female and or male population count, for year t.

Population growth parameters (μ and σ^2) were estimated based on Dennis et al. (1991) and Morris et al. (1999). Where μ estimates the infinitesimal mean and σ^2 the infinitesimal variance. Based on population growth dispersal estimation model, linear regression will be performed to estimate μ and σ^2 following Dennis *et al.* (1991); Morris *et al.* (1999); Bennewitz and Meuwissen (2005).

Census year variations (X) were estimated as $X = \sqrt{t(I) - t(i)}$

The population size will be defined for each I and i = 1, 2 . . ., p, where I & i were the consecutive census years adjacent I and i censuses performed in years t (I) and t (i) and P is the population size. The population growth rate indicator (Y) will be estimated following Morris *et al.* (1999); Bennewitz and Meuwissen (2005) as:

$$Y = \ln \quad (\frac{N(I)}{N(i)} \div \quad (\sqrt{t(I) - t(i)})$$

The probability of the population reaching a lower extinction threshold (πte), (minimum number of breeding individuals for survival), will be estimated following Dennis et al. (1991) as the extinction probability:-

$$\Pi te = \Pi * \left[\Phi\{\frac{-xd + |\mu|te}{\sigma\sqrt{te}}) + \exp(2x_d|\mu|/\sigma 2)\Phi\{\frac{-xd - |\mu|te}{\sigma\sqrt{te}} \right.$$

The probability of the population reaching a lower extinction threshold (πte) was also estimated using excels computer software program (E) as:

$$E_{22} = (\frac{E_{20}}{E_{19}})^\Lambda (2 * \frac{E_5}{E_{ll}}(\sigma^2)).$$

Mean time to extinction (Π) or the probability (π) that a population will ever become extinct was computed following Dennis et al. (1991) as

Table 2. The Linear regression estimates for infinitesimal mean and infinitesimal variance from variable of census year variations (X) and the population growth rate (Y).

ANOVA

	df	SS	MS	F	Significance F	
Regression	1	0.003267	0.003267	0.162926	0.697051	
Residual	9	0.180478	**0.020053**			
Total	10	0.183745				

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	**0**	#N/A	#N/A	#N/A	#N/A	#N/A
1	**-0.01808**	0.044781	-0.40364	0.695899	-0.11938	0.083226

Table 3. Calculated transformed variable of census year variations (X) and the population size for growth rate for pure Fogerra cattle (Y)

Year	$x = \sqrt{t(j)} - t(i)$	Count	$y = \ln (N(j)/N(i)/x$
2003		9139	
2004	1	11114	0.195655
2005	1	11680	0.049672
2006	1	11585	-0.00817
2007	1	10458	-0.10234
2008	1	7530	-0.32847
2009	1	9484	0.230711
2010	1	9311	-0.01841
2011	1	9530	0.023248
2012	1	10704	0.116173
2013	1	9125	-0.1596
2014	1	9016	-0.01202

$$\Pi = \begin{cases} 1, \mu \leq 0 \\ \exp(-2\mu x_d / \sigma^2), \mu \succ 0 \end{cases} \quad \text{And} \quad \text{as}$$

$$\Pi = \ln(\frac{E_{19}}{E_{20}}) \div \frac{E_{21}}{ABS(E_5)}).$$

In the above equations, Φ (*) denotes for the standard normal cumulative distribution function, π is the probability of extinction (conditional on the fact that the population is sure to eventually become extinct, π = 1). The quantity x_d is the log-scale distance to the threshold population and λ is the parameter value and expressed by the equivalent equation $F(x; \lambda) = 1-e^{-\lambda x}$.

RESULTS AND DISCUSSION

Growth Parameters Estimation

The results were calculated transformed variable of census year variations (X) and the population size for growth rate calculation (Y) and are summarized in Table 1. According to the ANOVA the slope of the linear regression, which provides an estimation of parameter μ and the mean square residual, which is

estimate of σ2 was indicated in bold (Table 2). For the total cattle population estimates indicated that μ is negative and σ2 positive and greater than μ, as is expected given that the counts showed a decreasing trends with great deal of inter-annual variability (Figure 2).

Estimation of Population Parameters (μ and σ²) for pure-Fogera Cattle

According to Kefyalew (2012), when PVA is used as a decision-support tool; it is important that predicted changes in the risks of extinction due to management are reliable, that the relative risks faced by different species are predicted accurately and that the models can be used to help decide the most effective management strategy. Accordingly, the result revealed that the observed the average growth rate and the parameters infinitesimal mean, μ and the infinitesimal variance, σ² shown μ< σ². This indicated that the population of Fogera cattle is in a decreasing trend with a great deal of inter annual variability and has negative growth rate (Table 4).

Accordance to the ANOVA results, the MS number (0.023) represents the value of σ² or infinitesimal variance or the mean squared residual and the coefficients

Table 4. Estimation of population parameters for pure-Fogera cattle in the study district

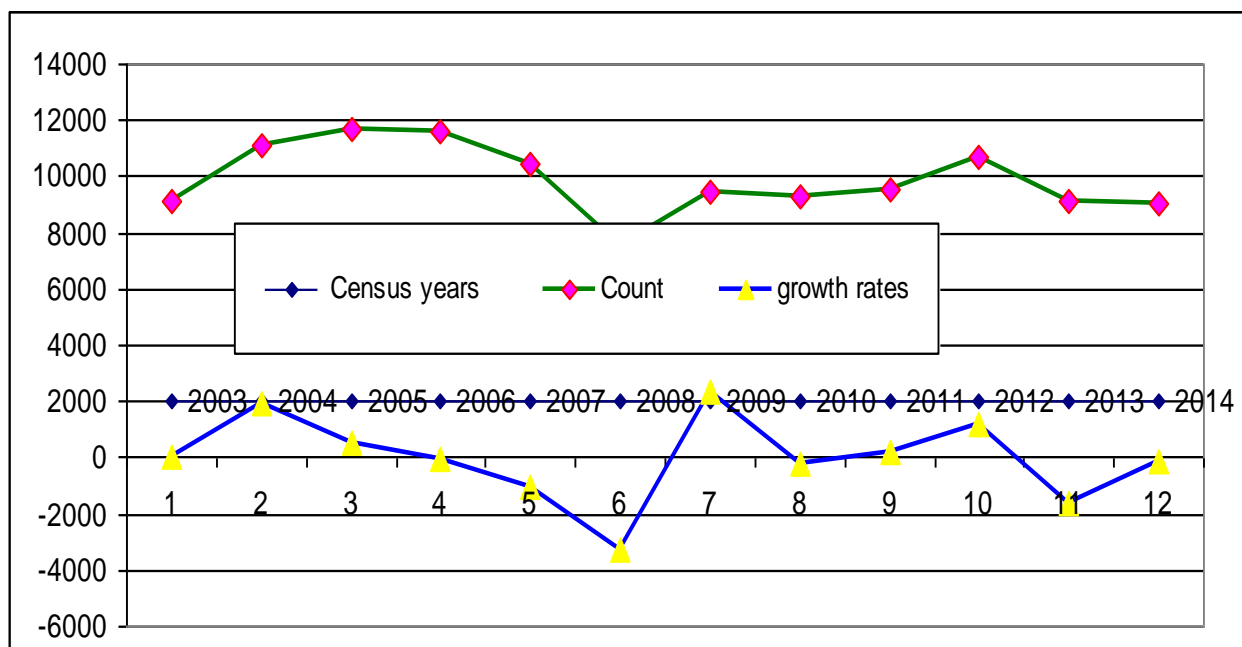| ANOVA					
	df	SS	MS	F	Significance F
Regression	1	0.0044	0.0044	0.189	0.676
Residual	10	-0.021	**0.023**		
Total	11	0.214			

Figure 3. Population size of the year and the population growth rate of Fogera cattle

0 and -0.021 represent the constant and the value of µ or infinitesimal mean. For the Fogera breed, the estimates indicated that µ is negative and σ^2 is greater than µ, and indicated a decreasing trend by a great deal of inter-annual variability.

The average population growth rate λ: was computed based on Dennis *et al*. (1991) and Morris *et al*. (1999) models, λ of the breed and other related parameters. According to the Table 5 the estimated average population growth rate, λ was 0.9908 with a 95% confidence of 0.9048 to 1.0849. This estimate indicates that the average of the possible population realization will decline since the estimated average population growth rate, λ is less than one. The continuous rate of increase or the rate of growth or decline per year of pure-Fogera cattle population (-0.009) was less than zero (0) and indicated short-term population growth. The probability of the population reaching a lower extinction threshold was extremely very high with long year's mean time extinction. This means that the mean time required for the counts to decline from 9016 to 300 individual pure-Fogera cattle population or to reach to the extinction threshold was extremely high. Threatened species are adversely affected by changes in landscape that cause habitat loss and fragmentations and theses changes can be brought by short-term human impacts and long-term impacts of global climate change (Kefyalew, 2012).

T**he probability of the population reaching a lower extinction threshold**: The estimated probability that the extinction threshold is eventually reached was E_{22}= IF (E_5<0,1,(E_{20}/E_{19}) ^(2*E_5/E_{11})=100/9016^(2* -0.0209/0.0212=1=100% and hence using the current population size of 9016 (the last counts of 2013) and according to FAO 2007 livestock species are classified in to high productive (their extinction threshold is 100 individual) and low productive (their extinction threshold is 300 individual). Since indigenous cattle of Ethiopia are grouped under lower productive species and their extinction threshold is three hundred (300), the estimated probability of ultimate extinction is 100%. Thus, the available data suggest that the risk of extinction faced the endangered Fogera cattle is extremely high.

The mean time to extinction: The mean time to extinction was computed by [LN (E_{19}/E_{20})/ (E_{21}/ABS (E_5)] which is equal to 162.7 years for 300 individual threshold. Hence, the estimating population parameter µ indicated negative or less than 0 and the mean time required for the census counts to decline from 9016 which is now to 300 individual cattle were 162.7 years with 0 lower confidence limits and 162.7 years upper confidence limit.

Unless faced by stochastic factors such as demographic instabilities, environmental and genetic variation as well as deterministic factors such as

Table 5. Computed results of average growth rate and related parameters of population viability of Fogera cattle population.

Measures	Value
Estimated μ, (E_5)	-0.0216
Estimated $\sigma2$, (E_8)	0.023
Continuous rate of increase, r, (E_{12})= E_5+E_8/2	-0.009
Lower 95% confidence limit for r (E_{13})= E_{12}+NORNSINV(0.025)*SQRT (E_8* ((1/E_3) +(E_8/(2*(E_4-1)))))	-0.1000
Upper 95% confidence limit for r, (E_{14})= E_{12}-NORNSINV(0:025) * SQRT(E_8* ((1/E_3)+(E_8/(2*(E_4-1)))))	0.0815
Average finite rate of increase, λ, (E_{15})= EXP(E_{12})	0.9908
Approximate lower 95% confidence limit for λ, (E_{16})= EXP(E_{13})	0.9048
Approximate upper 95% confidence limit for λ, (E_{17})= EXP(E_{14})	1.0849

unstable age distribution; inconstant birth and death rates; inbreeding depression, the Fogera cattle population will survive for about 162.7 years with the minimum 300 breeding individuals.

Within livestock species, the prediction of the loss of genetic diversity within a given future time period due to putative extinction of breeds requires reasonable estimates of extinction probabilities (Simianer *et al.*, 2003). Therefore, an attempt was made to estimate the extinction probability of Fogera cattle breed using the population growth diffusion approximation PVA model of Dennis *et al.* (1991). This procedure would result in sets of extinction probabilities, one for every cumulative distribution function year. It is also important to note that the estimation of the expected loss of diversity should be conducted for every estimated set of extinction probabilities (i.e., for every cumulative distribution year) in order to obtain an impression of the pattern of the loss with increasing cumulative distribution year.

CONCLUSIONS

Population viability analysis of this result indicated that the pure-Fogera cattle are not viable and the population growth is at decreasing trends by the reason of feed shortage, cross-breeding with other indigenous breeds, disease and parasites. The mean time required for the counts to decline from the existing population size to 300 individual animal extinction thresholds is 162.7 years, unless faced by stochastic and deterministic disturbances. However, unless we will apply practical breeding and conservation strategy within short period of time the population will be reach their extinction threshold before 162.7 years. Therefore, appropriate in-situ conservation measures are important for sustainable utilization.

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