

Short communication

Effective population size and inbreeding rate of indigenous Nguni cattle under *in situ* conservation in the low-input communal production system

O. Tada¹, V. Muchenje^{1#} & K. Dzama²

¹ Department of Livestock and Pasture Science, University of Fort Hare, P. Bag X1314, Alice 5700, South Africa

² Department of Animal Sciences, Stellenbosch University, P. Bag X1, Matieland 7602, South Africa

(Received 19 April 2012; Accepted 24 January 2013; First published online 30 May 2013)

Copyright resides with the authors in terms of the Creative Commons Attribution 2.5 South African Licence.

See: <http://creativecommons.org/licenses/by/2.5/za>

Condition of use: The user may copy, distribute, transmit and adapt the work, but must recognise the authors and the South African Journal of Animal Science.

Abstract

Nineteen rural Nguni cattle enterprises managed at communal and small-scale level were used in a study to determine population genetic parameters, level of Nguni genetic contribution, and risk status of community-based animal genetic resources. Chi-square tests were performed to ascertain the association between enterprise ownership and level of Nguni genetic contribution. Analysis of (co)variance was used to determine significant factors affecting breeding ratio, effective population size (N_e) and inbreeding rate per generation (ΔF). About 75% of the animals in the pooled communities were pure Nguni, and the breed was classified as not at risk of extinction, while the individual enterprises were classified as being endangered-maintained without the exchange of germ plasm among them. There were no significant differences between communal enterprises (0.270 ± 0.0699) and small-scale (0.213 ± 0.0748) in the ratio of breeding males to breeding females. Pooled N_e was 348.14, whereas N_e was 19.5 ± 4.60 for communal enterprises and 14.1 ± 5.03 for small-scale. It was concluded that enterprise ownership had no effect on small population genetic parameters in community-based *in situ* conservation programmes. It is recommended that policies be adopted to integrate enterprises, and increase herd sizes and N_e to preserve within-breed genetic diversity.

Keywords: Breeding ratio, enterprise duration, herd size, *in situ* conservation

Corresponding author: vmuchenje@ufh.ac.za

Animal production contributes significantly to the survival of people through the supply of meat protein and other animal products (Shackleton *et al.*, 2005). Over two-thirds of the 14.1 million cattle in South Africa are found in communal areas (National Department of Agriculture, 2008). The estimated number of cattle in the Eastern Cape was over 3.2 million. The province is known for livestock production and is “home” to the original stock of indigenous Nguni cattle (ECDC, 2011). Nguni cattle have been randomly mated in communal and small-scale enterprises in small herds on land redistribution and development farms in the Eastern Cape (Mapiye *et al.*, 2010). Most cattle in the rural areas are non-descript crossbreds with small populations of local breeds, such as Afrikaner, and locally developed Bonsmara and Drakensberger (Palmer & Ainslie, 2006). Throughout the developing world, countries have placed their indigenous livestock populations at risk by introducing exotic breeds for crossbreeding programmes (Scholtz *et al.*, 2008). This has led to non-descript genotypes, of unknown genetic characterization, being predominant in low-input production systems.

Literature is scarce on community-based and village breeding schemes in developing countries and on risk status classification of indigenous breeds (Wollny, 2003). Bayer *et al.* (2004) suggested that the situation has been made worse by the lack of records and use of uncontrolled mating systems in these areas, with inbreeding leading to several negative effects. It was postulated that these practices threaten the existence of

the local Nguni breed (Ramsay *et al.*, 2000). In response to this situation, the University of Fort Hare (UFH), in partnership with the Eastern Cape Department of Rural Development and Agrarian Reform (ECDRDAR) and Industrial Development Cooperation (IDC), intervened to establish a conservation programme for Nguni cattle. The aim was to empower communal and small-scale enterprises in the rural areas of the Eastern Cape with livestock production skills, and enact a community-based *in situ* conservation programme (Raats *et al.*, 2004). This programme established 72 unrelated nucleus herds managed at communal and small-scale enterprises with 10 in-calf heifers and two bulls per enterprise. Following this intervention, international standards of risk status classification of the breeds (Meuwissen & Woolliams, 1994) have the potential to be applied at enterprise and population level. An intended consequence of this intervention was to reduce the risk of the Nguni breed becoming extinct. This study was carried out with the objective of ascertaining the risk status class of the breed, herd structure and small population genetic parameters.

A cross-sectional survey was conducted in 19 communities that benefited from the UFH-IDC-ECDRDAR partnership programme. Ten of the communities were communal enterprises managed by an elected project committee composed of local village people. Nine communities were small-scale enterprises managed by a farmer group composed of 4 - 7 individuals or a family trust. The nucleus herd in each enterprise mixed at random with other livestock from the community for 36 - 60 months. Data and information from 2387 animals were collected, which included animal sex, animal class, bull and heifer ages, cow parity, sire breed and dam breed. Relationships among animals were ascertained from the animal records and farmers' memory.

Computations were on the level of Nguni genetic contribution in an animal from its pedigree. Effective population size (N_e) and increase in inbreeding per generation (ΔF) were calculated using the formulas by Wright (1931; 1977):

$$[N_e = \frac{4 \times N_m \times N_f}{N_m + N_f}], \text{ and } \Delta F = 1/(2 \times N_e),$$

where N_m and N_f are the number of breeding males and females, respectively. Risk status classification of the breed was done according to internationally accepted guidelines (Meuwissen & Woolliams, 1994; FAO/UNEP, 1998). Descriptive statistics, chi-square tests of association, analysis of covariance and partial correlation coefficients were computed using GenStat 7.2 (2008). The following model was used to determine significant factors affecting observed variables:

$$Y_{ij} = \beta_0 + T_i + \beta_1 X_1 + \beta_2 X_2 + e_{ij}$$

where:

Y_{ij} = dependent variable (breeding ratio, N_e , ΔF , level of Nguni genetic contribution);

β_0 = intercept;

T_i = fixed effect of ownership pattern (i = communal, small-scale);

β_1 and β_2 = regression coefficients associated with covariates for enterprise duration (X_1) and herd size (X_2);

e = random error.

Herd size was similar between communal enterprises (105.6 ± 10.03) and small-scale (97.4 ± 6.52) ($P > 0.05$). These enterprises operated in the same low-input cattle production system characterized by random mating of animals, rangeland-based feeding systems with minimum dry-season supplementation, and minimum veterinary intervention and disease control. The distribution of cattle across the animal classes, that is, calves (males and females), bullocks, heifers, cows, bulls and oxen, is shown in Table 1. Enterprise duration was significantly correlated with the number of oxen ($r = 0.69$) and negatively correlated with the number of bullocks ($r = -0.41$). The oxen are considered cash-banks of the enterprise (Musemwa *et al.*, 2010) and this is therefore viewed as justification to increase with size of the herd. The bullocks are castrated before one year old and this is evidenced by a negative correlation coefficient with enterprise duration and a positive correlation on the number of oxen. The number of heifers was inversely related to age, with significantly low numbers of four-year-olds and above, as most heifers would have had a calf before attaining four years of age. In most rural areas in sub-Saharan Africa, heifers become cows by the third year (Abeygunawardena & Dematawewa, 2004) and the maximum age at first calving of Nguni cattle, according

to breed standards, is 39 months (Nguni Cattle Breeders Society, 2011). Partial correlation coefficients of cow numbers in different parities with herd size were above 80%. The positive correlation of enterprise duration and the number of heifers and cows tally with programme objectives of increasing the herd sizes through upgrading the community cattle (Raats *et al.*, 2004; Fuller, 2006). The herd size variation was positively correlated with the number of one-year-old bulls ($r = 0.77$). These year-olds are reserved replacement stocks that are not castrated, but inspected after two years and the registered sires undergo progeny testing (Fuller, 2006; Nguni Cattle Breeders Society, 2011). This resulted in significant ($P < 0.05$) positive correlations of enterprise duration with numbers of two- and three-year-old bulls ($r = 0.60$ and $r = 0.58$, respectively).

Table 1 Animal class distribution of Nguni cattle and correlation with herd size in rural low-input enterprises of the Eastern Cape

Animal class	Communal enterprise	Small-scale enterprise	Herd size correlation
Female calves	3.4 ± 1.0^a	4.2 ± 1.0^a	0.49
Male calves	3.1 ± 1.3^a	4.7 ± 1.4^a	0.60
Bullocks (bulls <2 years)	4.7 ± 1.1^a	1.7 ± 1.2^a	0.75
Heifers	25.1 ± 2.5^a	31.7 ± 2.6^a	0.91
Cows	33.4 ± 2.7^a	35.3 ± 2.3^a	0.96
Bulls	5.8 ± 1.6^a	5.0 ± 1.7^a	-0.11
Oxen (young and old steers)	21.5 ± 2.5^a	14.5 ± 2.7^a	0.84

Values with the same superscript letter in each row are not significantly different ($P > 0.05$).

In line with the goal of the programme to upgrade community stock (Raats *et al.*, 2004; Fuller, 2006), the majority (74%) of the rural cattle in both enterprises had undiluted Nguni blood. The enterprise ownership pattern significantly affected the level of Nguni genetic contribution, with a high number of 50% crosses in communal enterprises ($P < 0.05$). Herd size and duration of the enterprise also had significant effects on the level of Nguni genetic contribution (Table 2). Cattle with 50% and 100% Nguni blood are aligned with the programme goals and many non-descript animals were upgraded from use of Nguni bulls and non-Nguni females. The positive increase in 25% Nguni blood animals with herd size is retro-progressive, as evidenced by the presence of non-Nguni and non-descript cattle constituting 10% of the community cattle. A negative correlation between herd size and cattle with 75% Nguni blood is owing to a lesser number of crossbred animals being available to upgrade. The farmers substituted sire breeds with the Nguni as its popularity in terminal beef crossbreeding lines in South Africa is increasing (Scholtz & Theunissen, 2010).

Table 2 Distribution of animals and correlation with herd size and enterprise duration of different levels on Nguni genetic contribution in rural areas of Eastern Cape, South Africa

Level of Nguni genetic contribution	Overall proportion	Correlation with enterprise herd size	Correlation with enterprise duration
0%	10%	0.01	-0.22
25%	0%	0.70	-0.48
50%	14%	0.66	0.14
75%	2%	-0.02	0.35
100%	74%	0.98	0.42

The small population genetic parameters were similar across enterprise ownership patterns (Table 3). The average breeding male : female ratio of 0.24 was high compared with the recommended 0.05 under commercial beef herds (Mapiye *et al.*, 2009). The high number of bulls in the communal areas offers a chance to effect selection and to minimize the inbreeding rate as low bull fertility was reported by Mapiye *et al.* (2007). Average N_e of 17 observed across enterprises was below the recommended 50 in most species under risk of extinction owing to inbreeding (Wollny, 2003). Similarly, Nomura *et al.* (2001) reported an inbreeding N_e value of 17.2 over a 48-month period in the indigenous Japanese Black beef breed using pedigree records. A low N_e value can be attributed to the unequal breeding sex ratio in favour of females and overlapping generation from random mating with no defined breeding season (Felsenstein, 1971). The enterprise duration had a significant effect on the increase in inbreeding per generation with a negative correlation coefficient of $r = -0.58$. Although small population genetic parameters have been generalized under community-based management of animal genetic resources in Africa (Rege & Gibson, 2003; Wollny, 2003), they determine the strength of genetic drift, and are important in evaluating conservation status and threats to the genetic health of populations (Hare *et al.*, 2011).

Table 3 Small population genetics parameters ($\mu \pm$ s.e.) of pooled data, communal and small-scale enterprises in the rural areas of Eastern Cape, South Africa

Small population genetics parameter	Communal enterprise	Small-scale enterprise	Pooled data (overall)
Breeding male to breeding female ratio	0.27 ± 0.07^a	0.21 ± 0.08^a	0.10
Inbreeding effective population size (N_e)	19.50 ± 4.60^a	14.10 ± 5.03^a	348.14
Increase in inbreeding per generation (ΔF)	0.05 ± 0.01^a	0.07 ± 0.01^a	0.00

Values with the same superscript letter in each row are not significantly different ($P > 0.05$).

The pooled data indicated that Nguni breed is not at risk of extinction. With regard to individual enterprises, the breed is classified as endangered-maintained in both communal and small-scale enterprises. This is because there are fewer than 1000 breeding females and more than 20 related breeding males, as well as active conservation strategies in place. Institutionalization and continued implementation of Nguni conservation and improvement strategies using production knowledge of these genetic resources are encouraged in this low-input agriculture production system. Though it can be argued that indigenous breeds are largely unpopular owing to lack of commercialisation of their invaluable traits (Mapiye *et al.*, 2010), Nguni cattle are greatly in demand in the large-scale commercial sector whereby farmers exploit their mothering ability, and tick and disease resistance (Muchenje *et al.*, 2008; Marufu *et al.*, 2009).

Though ΔF was approximately zero for pooled data, in the individual enterprises it was only marginally less than the maximum recommended level for conservation in most intensive high-input production systems. For individual enterprises, the Nguni breed under low-input production is classified as endangered-maintained in both communal and small-scale enterprises. However, when the conservation programme is viewed as a whole, the Nguni breed is not at risk of extinction. Further, exchanges of germ plasm, particularly breeding bulls, between enterprises has the potential to at least partially negate effects of accumulated inbreeding in each enterprise. Indiscriminate crossbreeding, potentially resulting from other livestock development initiatives, may pose a greater risk to the Nguni breed than inbreeding.

Acknowledgements

The authors are grateful to the beneficiaries of the Eastern Cape Nguni Cattle Programme, and the support of the UFH-IDC-ECDRDAR partnership, and Department of Livestock and Pasture Science of UFH. The project was funded by Adam Fleming through Nguni Project Operations (P329) of UFH.

References

- Abeygunawardena, H. & Dematawewa, C.M.B., 2004. Pre-pubertal and postpartum anestrus in tropical Zebu cattle. *Anim. Rep. Sci.* 82-83, 373-387.
- Bayer, W., Alcock, R. & Gilles, P., 2004. Going backwards? – moving forward? – Nguni cattle in communal KwaZulu-Natal. “Rural poverty reduction through research for development and transformation”. A scientific paper presented at a conference held at Agricultural and Horticultural Faculty, Humboldt-Universität zu, Berlin. pp. 1-7. <http://www.tropentag.de/2004/abstracts/full/326.pdf>
- ECDC, 2011. Eastern Cape Development Cooperation. <http://www.ecdc.co.za/livestock> Accessed 12 Dec. 2011.
- FAO/UNEP., 1998. Primary guidelines for development of national farm animal genetic resources management plans. Food and Agriculture Organisation of the United Nations (Environmental Program), Rome, Italy.
- Felsenstein, J., 1971. Inbreeding and variance effective numbers in populations with overlapping generations. *Genetics* 68, 581-597.
- Fuller, A., 2006. The sacred hide of Nguni; the rise of an ancient breed of cattle is giving South Africa new opportunity. Miracles that are changing the Nation. Industrial Development Corporation (IDC) Newsletter. pp. 3-4.
- GenStat Release 7.2.2., 2008. Discovery Edition 3, VSN International Ltd, UK.
- Hare, M.P., Nunney, L., Schwartz, M.K., Ruzzante, D.E., Burford, M., Waples, R.S., Ruegg, K. & Palstra, F., 2011. Understanding and estimating effective population size for practical application in marine species management. *Conservation Biology* 25 (3), 438-449.
- Mapiye, C., Chimonyo, M., Muchenje, V., Dzama, K., Marufu, M.C. & Raats, J.G., 2007. Potential for value-addition of Nguni cattle products in the communal areas of South Africa. *Afr. J. Agric. Res.* 2 (10), 488-495.
- Mapiye, C., Chimonyo, M., Dzama, K., Raats, J.G. & Mapekula, M., 2009. Opportunities for improving Nguni cattle production in the smallholder farming systems of South Africa. *Livest. Sci.* 124, 196-204.
- Mapiye, C., Chimonyo, M., Dzama, K. & Marufu, M.C., 2010. Protein status of indigenous Nguni and crossbred cattle in the semi-arid communal rangelands in South Africa. *Asian-Aust. J. Anim. Sci.* 23, 213-225.
- Marufu, C.M., Chimonyo, M., Dzama, K. & Mapiye, C., 2009. Seroprevalence of tick-borne diseases in communal cattle reared on sweet and sour rangelands in a semi-arid area of South Africa. *Vet. J.* 184, 71-76.
- Meuwissen, T.H.E. & Woolliams, J.A., 1994. Effective sizes of livestock populations to prevent a decline in fitness. *Theor. Appl. Genet.* 89, 1019-1026.
- Muchenje, V., Dzama, K., Chimonyo, M., Raats, J.G. & Strydom, P.E., 2008. Tick susceptibility and its effects on growth performance and carcass characteristics of Nguni, Bonsmara and Angus steers raised on natural pasture. *Animal* 2, 298-304.
- Musemwa, L., Mushunje, A., Chimonyo, M. & Mapiye, C., 2010. Low cattle market off-take rates in communal production systems of South Africa: Causes and mitigation strategies. *J. Sust. Dev. Afr.* 12 (5), 209-226.
- National Department of Agriculture (NDA), 2008. Directorate: Agricultural Statistics of the National Department of Agriculture, Republic of South Africa. pp. 58-73. <http://www.nda.agric.za>: accessed 04 April 2011.
- Nguni Cattle Breeders Society, 2011. Nguni Society By-Laws. www.nguni.co.za
- Nomura, T., Honda, T. & Mukai, F., 2001. Inbreeding and effective population size of Japanese Black cattle. *J. Anim. Sci.* 79, 366-370.
- Palmer, T. & Ainslie, A., 2006. Country pasture/forage resource profiles: South Africa. Department of Agriculture, Republic of South Africa.
- Raats, J.G., Magadla, A.M., Fraser, G.C.G. & Hugo, A., 2004. ‘Re-introducing Nguni Nucleus Herds in 100 Communal Villages of the Eastern Cape Province’. A proposed co-operative project between the University of Fort Hare, Agricultural and Development Research Institute (ARDRI) and the Eastern Cape Department of Agriculture and the Kellogg Foundation.

- Ramsay, K., Smuts, M. & Els, H.C., 2000. Adding value to South African landrace breeds: conservation through utilisation. *FAO/UNEP Animal Genetic Resources Information Bulletin*, 27, 9-16.
- Rege, J.E.O. & Gibson, J.P., 2003. Animal genetic resources and economic development: issues in relation to economic valuation. *Ecol. Econ.* 45, 319-330.
- Scholtz, M.M. & Theunissen, A. 2010. The use of indigenous cattle in terminal cross-breeding to improve beef cattle production in Sub-Saharan Africa. *Anim. Genet. Res.* 46, 33-39.
- Scholtz, M.M., Bester, J., Mamabolo, J.M. & Ramsay, K.A., 2008. Results of the national cattle survey undertaken in South Africa, with emphasis on beef. *Appl. Anim. Husb. Rural Dev.* 1, 1-9.
- Shackleton, C.M., Shackleton, S.E., Netshiluvhi, T.R. & Mathabela, F.R., 2005. The contribution and direct-use value of livestock to rural livelihoods in the Sand River catchment, South Africa. *Afr. J. Range Forage Sci.* 22 (2), 127-140
- Wollny, C.B.A., 2003. The need to conserve farm animal genetic resources in Africa: should policy makers be concerned? *Ecol. Econ.* 45 (3), 341-351.
- Wright, S., 1931. Evolution in Mendelian populations. *Genetics* 16, 97-159.
- Wright, S., 1977. Evolution and the Genetics of Populations. vol. 3. Experimental Results and Evolutionary Deductions. University of Chicago Press, Chicago.