Monitoring and management of the endangered Cape mountain zebra *Equus zebra zebra* in the Western Cape, South Africa

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Abstract

De Hoop Nature Reserve and a neighbouring conservancy contain the most genetically diverse subpopulation of the Endangered (IUCN) Cape mountain zebra (*Equus zebra zebra* Linnaeus 1758). Although vital for the long-term stability of the meta-population, the population had received limited monitoring post-1999. We summarize data obtained during a population monitoring programme established in 2005. Ninety-nine individuals were identified indicating a decline in annual population growth from 6.6% (1995–1999) to 4.5% (1999–2005). The population was male biased and the deficit of females is likely to have prevented additional breeding herd formation resulting in excess nonbreeding males. These animals are currently of limited reproductive value to the meta-population and may be contributing to the decline in reproductive potential at De Hoop by competing for limited resources. One solution may be to translocate 'excess' males to reinforce existing small populations or establish new populations with females from elsewhere provided that a minimum of 78 animals is maintained at De Hoop to limit genetic loss. Population monitoring and effective management strategies for the De Hoop population and the meta-population are vital to ensure the long-term survival of Cape mountain zebra and for the success of other species recovery programmes.

Key words: Action Plan, De Hoop Nature Reserve, meta-population, population dynamics, sex ratio, translocation

Résumé

De Hoop Nature Reserve et une aire de conservation voisine contiennent la sous-population la plus génétiquement variée du zèbre de montagne du Cap (*Equus zebra zebra* Linnaeus 1758), classé « en danger » par l'UICN. Bien que vitale pour la stabilité à long terme de la métapopulation, cette population a été peu suivie depuis 1999. Nous avons résumé les données recueillies au cours d'un programme de monitoring de la population instauré en 2005. Quatre-vingt dix-neuf individus ont été identifiés, ce qui indique un déclin de la croissance annuelle de la population de 6,6% (1995–1999) à 4,5% (1999–2005). La population est biaisée en faveur des mâles, et c'est probablement le déficit en femelles qui a empêché la formation d'un troupeau reproducteur supplémentaire, qui a abouti à un excès de mâles nonreproducteurs. Ces animaux sont actuellement de peu de valeur de reproduction pour la métapopulation et pourraient contribuer au déclin du potentiel reproducteur à De Hoop par la compétition qu'ils représentent pour les ressources limitées.Une solution pourrait être de déplacer les mâles « en excès » pour renforcer les petites populations existantes ou pour en établir de nouvelles avec des femelles venues d'ailleurs, pour autant qu'un minimum de 78 animaux restent à De Hoop pour limiter l'appauvrissement génétique. Des stratégies pour le monitoring et la gestion efficace de la population de De Hoop sont vitales pour garantir la survie à long terme du zèbre de montagne du Cap et pour la réussite des programmes de restauration d'autres espèces.

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Introduction

Endemic to South Africa, Cape mountain zebra *Equus zebra zebra* Linnaeus 1758 were once widely distributed in the mountains of the Cape Province. By the 1950s, their status was critical; hunting and a greater demand for pasture for livestock had reduced the world population to fewer than 80 animals in five areas of the Eastern and Western Cape (Millar, 1970). Today, as a result of focused conservation initiatives, there are *c.* 1600 Cape mountain zebras (Castley, Lloyd & Moodley, 2002), but the subspecies is still listed as Endangered by The World Conservation Union (IUCN) and is on Appendix I of the Convention on International Trade in Endangered Species (CITES). The objective of the IUCN Action Plan for Cape mountain zebra is to 'build up numbers to a target of 2500 as quickly as possible' (Novellie *et al.*, 2002). This requires that a meta-population strategy, which includes a translocation policy, is implemented to ensure continued population growth and long-term stability.

Three of the natural Cape mountain zebra subpopulations still exist (Fig. 1). The largest of these in Mountain Zebra National Park (MZNP) has provided the founders for *c.* 30 subpopulations (Novellie *et al.*, 2002) and consequently over 91% of the current meta-population derives from MZNP stock (Moodley & Harley, 2005). The other two natural populations, in Kammanassie and Gamkaberg Nature Reserves, which numbered *c.* 64 and 41 animals respectively in 2006 (I. Donian, pers. comm.), are too small to remove individuals as the remaining animals would be highly vulnerable to extinction through demographic and environmental variation (Soulé, 1987; Novellie, Millar & Lloyd, 1996). Only one subpopulation has been founded from individuals translocated from two of the original subpopulations and that is in De Hoop Nature Reserve (DHNR). This makes the DHNR population the most genetically diverse (Moodley & Harley, 2005) and thus vital for the long-term survival of Cape mountain zebra. It is imperative that the population is managed effectively within DHNR and that once it is large enough animals are translocated to both safeguard and improve the genetic diversity of the subspecies.

De Hoop Nature Reserve (34°26′S, 20°30′E) is a 32,300 ha area of coastal fynbos interspersed with limestone hills and grasslands. Six Cape mountain zebra from MZNP and four from Kammanassie Nature Reserve were introduced to DHNR from 1963 to 1975. Animals had access to the neighbouring 28,000 ha conservancy maintained by the Denel Corporation Overberg Toets Baan (OTB) and by 1999 the population had grown to 71 animals. Monitoring of the individual Cape mountain zebras ceased in 1999, however, and by 2004 the total
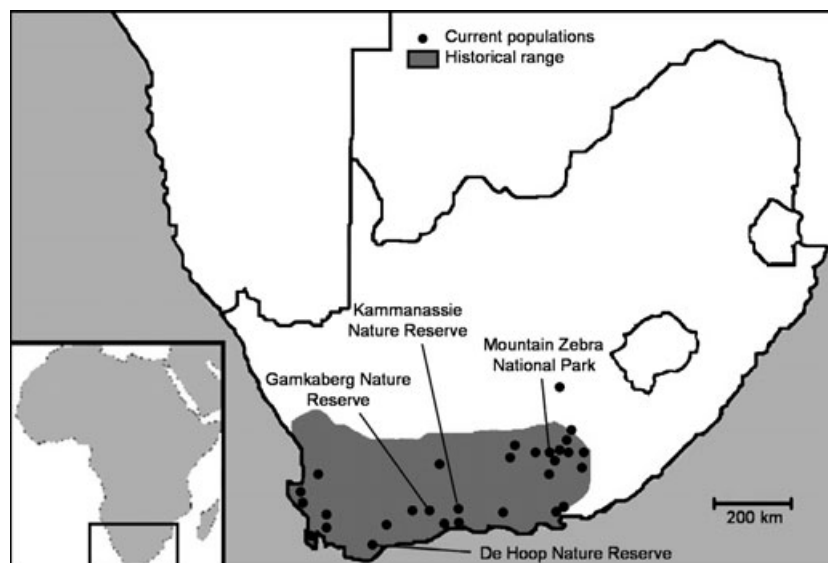
Fig 1 Historic and current distribution of Cape mountain zebra and location of De Hoop Nature Reserve. The locations of the three remaining natural populations, Mountain Zebra National Park, Gamkaberg Nature Reserve and Kammanassie Nature Reserve are also shown

population number was unknown. A reliable population estimate and knowledge of the population composition was urgently needed to allow the development of a long-term management plan for this population and a meta-population strategy to enhance the long-term stability of the subspecies. It has been suggested that once a population of Cape mountain zebras exceeds 90, animals can be removed for translocation (Watson *et al.*, 2005). Although individuals should be removed before a population reaches carrying capacity to ensure continued growth of key populations, it is vital that a minimum population size is reached and that the rate of loss of genetic diversity is kept to a minimum by maintaining an effective population size (N_e). This represents the number of animals that contribute genetically to future generations, taking into account an acceptable level of genetic loss per generation that avoids inbreeding depression. A conservative rate of 1% genetic loss per generation is used for most species, resulting in an effective population size of 50 animals (Soulé, 1980). A sound knowledge of population numbers and dynamics in the genetically diverse DHNR population is thus critical.

To facilitate the development of long-term management strategies for Cape mountain zebra we re-established population monitoring of the Cape mountain zebra in DHNR and OTB (referred to as the 'DHNR population'). In this article, we summarize population data obtained between May 2005 and October 2006 to provide a status update for the DHNR population. We also outline emerging management issues for the DHNR population and for the meta-population.

Methods

A population monitoring programme was developed and implemented in DHNR and OTB in May 2005. DHNR field rangers carried out monitoring on 4 days each month by driving existing tracks through DHNR and OTB; animals reported outside the reserve were also monitored. Data were collected using handheld computers with integrated Global Positioning System (Garmin iQue 3600; Garmin International, Inc., Olathe, KS, USA) and CyberTracker software (version 2.79, http://www.cybertracker.co.za). When Cape mountain zebra were sighted, the following data were recorded: herd location, herd size, individual identification code, sex, age class (foal ≤10 months, juveniles 10–30 months, adult >30 months), reproductive status (breeding stallion,

pregnant, lactating, nonbreeding and unknown) and body condition (good, poor and injured). When a carcass was found similar data were recorded, as well as information about possible cause and time since death. Records of the history of each individual were maintained in a photographic database. Population parameters were compared with those obtained during population monitoring up to 1999 and those data were used to estimate the effective population size (N_e). Harris & Allendorf (1989) found that the modified formula of Reed, Doerr & Walters (1986) provided one of the most accurate estimates of N_e for populations with overlapping generations:

$$\frac{1}{N_e} = \frac{1}{(4L_M M_{BR} k_M l_M)} + \frac{1}{(4L_F F_{BR} k_F l_F)},$$

where L_M and L_F are the mean generation lengths, i.e. the mean age of all males and females that reproduce, M_{BR} and F_{BR} are the numbers of breeding males and females, k_M and k_F are the numbers of young sired by a male or born to a female per year and l_M and l_F are the probabilities that a newborn male or female survives to mean age of reproduction (male 7 years, female 5 years; Novellie *et al.*, 1996) and breeds. The accuracy of the formula may increased if the product is multiplied by the following to account for non-Poisson reproductive success (Harris & Allendorf, 1989):

$$\frac{K}{(K + 1) + (V_K/K)},$$

where K and V_K are the mean and variance, respectively, of the total number of offspring produced by an individual female over her lifetime that also survive to reproductive age.

Results

Twenty of the animals alive in 1999 were not found in 2005 and assumed to be dead; half were female. Forty-three new animals were identified in 2005 and assumed to have been born since 1999; 40% were female. An additional thirteen animals were born during the monitoring period. The total number of individuals identified therefore was 107, eight of which subsequently died. The population had thus increased by *c.* 40% since 1999, suggesting a mean annual rate of increase of 4.5%, compared with 6.6% between 1995 and 1999. Despite the fact that more females were born than males during the monitoring period (eight females : five males) the population was
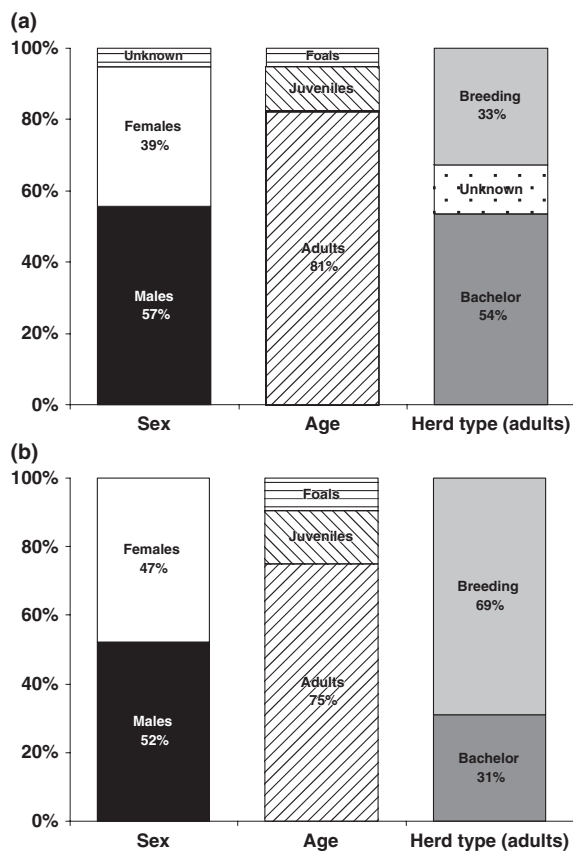
Fig 2 Percentage population composition of Cape mountain zebra in De Hoop Nature Reserve in terms of sex, age class (foals ≤10 months; juveniles 10–30 months; adults ≥30 months) and adults in breeding and bachelor herds in (a) 2006 and (b) 1999. 'Unknown' herd types are fairly stable herds that have formed since the start of monitoring but that have not produced offspring

significantly male biased ($\chi^2 = 3.89$, d.f. = 1, $P < 0.05$; Fig. 2a).

Of the eight animals that died during the monitoring period, five were female including a 23-year-old and her 4-month-old female foal. The other six deaths were animals aged 3–9 years. Causes of death were unknown, although injuries to the head and flank (probably the result of fights) may have caused the death of a herd stallion and bachelor male respectively. Two females and the other male that died were recorded as being in poor condition prior to their death. A further four individuals were recorded as being in poor condition during the monitoring period, two of which recovered.

The proportion of immature animals (foals and juveniles) was 19% (Fig. 2a) compared with 32%, 40% and

25% in 1990, 1995 and 1999 respectively. Although population size had increased since 1999, the number of breeding herds had not (n = 8–10) and the proportion of adults in breeding herds was low (Fig. 2). Just 17% of adult males held herds of breeding females compared with 38% in 1999 although mean breeding herd size (mean ± standard deviation: 3.5 ± 0.8, n = 8) was similar to that in 1999 (3.4 ± 1.0, n = 9). The proportion of bachelors (animals not in breeding herds) was high compared with 1999 (Fig. 2). Mean bachelor herd size was 5.0 ± 4.0 (n = 84) and a herd of 21 males was regularly sighted; the majority of bachelors were male (80–84%). The male bachelor population comprised 18% aged over 12 years that had lost a breeding herd; 23% aged 7–12 years that were not known to have possessed a breeding herd (and may be too old to attain one) and 59% aged 2.5–6 years that were prebreeding (males attain breeding herds from 5 to 6 years: Penzhorn, 1984).

The effective population size was estimated using data recorded up until 1999 as this provided sufficient data for parameter estimates. At that time, there were nine breeding stallions (M_{BR}) and 22 adult females of breeding age (F_{BR}). The mean generation length for males (L_M) and females (L_F) between 1995 and 1999 was 10.4 and 8.6 years respectively. Over the same period, on average, 29.5% of adult males and 33.7% of females produced foals annually resulting in values of 0.373 and 0.337 for k_M and k_F respectively. Of the 82.9% of male offspring that survived to 1 year, 76.5% lived to breeding age, resulting in a value of 0.488 for l_M. For female offspring, 77.5% survived to 1 year and 84.2% of those lived to breeding age and so l_F=0.592. We did not correct for non-Poisson variation in lifetime progeny distribution because our estimated values for K and V_K were 1.21 and 4.12.

With the breeding herd composition (one male : 2.4 females) and age distribution of 1999, we calculated that ten males must breed annually to maintain an effective population size of 50 animals. To maintain this effective population required 78 animals at the end of the breeding season (ten herd stallions, seventeen bachelor males, 24 females of breeding age and 27 immature animals).

Discussion and recommendations

The current Cape mountain zebra population growth rate in DHNR appears to be lower than it was between 1995 and 1999 and lower than the mean annual world population increase of 8.6% between 1985 and 1995 (Novellie

et al., 1996). The proportion of adult males holding herds of breeding females was less than half that in 1999 (17% compared with 38%) and a quarter of that in MZNP (67%: Novellie *et al.*, 1996). The mean breeding herd size of 3.5 was similar to that in 1999 and in MZNP (3.4–3.8: Klingel, 1968; Penzhorn, 1984). Simultaneously, the proportion of bachelors was high compared with 1999 and the MZNP population (17–20%: Penzhorn, 1984) and mean bachelor herd size was twice that in previous years (2.5 ± 1.0: Lloyd & Rasa, 1989). The majority of bachelors were male such that a deficit of females is likely to have prevented the formation of additional breeding herds. This may account for the decline in population growth.

The male bias in the population has occurred since 1999 (Fig. 2). There are two possible explanations; either the sex ratio at birth was biased towards males or mortality rates were higher in females. Whilst the sex ratio of Cape mountain zebra at birth is usually 1 : 1 (Lloyd & Rasa, 1989; Novellie *et al.*, 1996), between 1995 and 1999, 68% of individuals born were male (n = 31, annual range 40–83%). Although the number of births recorded since May 2005 was small, there was no evidence of a male bias (62% of eight births were female) suggesting that past bias may have been due to stochastic variation.

A second explanation for the male bias in the population is that mortality rates were higher in females than in males. Female feral horses over 5 years old have lower survival rates than males, which is thought to result from their greater reproductive costs (Garrott, 1991). During the monitoring period, 63% of carcasses found were female. Between 1999 and 2005, equal numbers of males and females disappeared and were assumed dead, but numbers do not include animals that were born after 1999 but died before 2005. Mortality of immature animals also appears to be higher in females: between 1990 and 1999, 57% of deaths of immature animals were female despite female offspring accounting for just 38% of the births.

High mortality rates of females, or both males and females in this age class would result in the current low proportion of immature animals in the population and would have contributed to the decline in population growth rate. Cape mountain zebra are not predated or hunted in DHNR but foals may be killed by adult zebras (Penzhorn, 1984; Lloyd & Rasa, 1989). Foal mortalities of subordinate females are higher than that of dominant females, partly due to aggression towards subordinates by dominant females (Lloyd & Rasa, 1989), and this may have increased with increasing population density. Infan-

ticide by stallions has also been reported in equids with similar social organization (Pluháček, Bartoš & Víchová, 2006).

Although the cause of the current male bias in the population is not yet fully understood, it has important implications for the population. Due to the deficit of females and the fact that mean herd tenure for stallions is 7.4 years (Lloyd & Rasa, 1989), the majority of the 32 males that have not yet bred may never reproduce. Only one herd takeover by a stallion was observed during the monitoring period. It appears therefore that there are excess nonbreeding males in the DHNR population. The fact that these males are not breeding suggests a loss of reproductive potential and genetic diversity for the Cape mountain zebra meta-population. These males may also be reducing the reproductive potential of the remainder of the DHNR population by competing for limited resources.

Efficient management of a population not only requires information about the status of the population, but also an understanding of the ecological processes regulating numbers. Prior to 2005, little was known about how the DHNR population used resources through the year, resources that comprise both natural fynbos and transformed grasslands (transformed to grass for grazing stock). Our data show that Cape mountain zebra select grassland throughout the year, even though grassland covers just 3.4% of the area and grass height was below optimum for Cape mountain zebra (4–8 cm: Grobler, 1983) for half of the year (R.K. Smith, E. Ryan, E. Morley & R.A. Hill, unpublished data). Approximately 13% of the population inhabited farmland outside DHNR and OTB boundaries. In addition, an area covering *c.* 70% of DHNR was not utilized by Cape mountain zebra, possibly because of the age of the vegetation (11–100 years old). Fynbos typically burns at 12- to 15-year intervals but higher frequencies are required to stimulate the grass production favoured by Cape mountain zebras (Watson *et al.*, 2005). As the population increased in size, competition for the limited low quality resources may have also increased. Interspecies competition on the limited grasslands with species such as bontebok, ostrich and eland (which each numbered *c.* 500 animals in 2006) may have exacerbated this problem; only eland have increased in number since 1999. These factors could have contributed to the decline in population growth rate.

The decline in population growth rate, composition of the DHNR population, limited resource availability and observations of animals in poor condition suggest that the

population may be reaching the maximum number that the conservation area can support. Further studies are now urgently needed to determine how these factors are inter-related so as to advance the understanding of the population dynamics of Cape mountain zebra. In the mean time, a solution may be to translocate some of the 'excess' bachelor males to maximize reproductive potential of the remaining DHNR population. This should not negatively affect population growth within DHNR, provided that males in the process of forming bonds and potentially new breeding herds with females are not removed as females take time to form new bonds (Novellie *et al.*, 2002). Similarly, it should not put the population at risk by increasing the rate of loss of genetic diversity. Calculations suggested that 78 animals were required to maintain an effective population size of 50 where no more than 1% of the genetic diversity is lost per generation (Soulé, 1980). The population composition required was similar to the composition present at the end of 1999 (nine herd stallions, fifteen bachelor males, 22 females of breeding age and 25 immature animals) and to a model for an unmanaged island population of feral horses (Goodloe *et al.*, 1991). In 2006, the population consisted of sufficient breeding adults (eight to ten herd stallions and 30 females of breeding age), over twice the number of bachelor males (40–42), but fewer immature animals (19) than required. If either mortality rates of immature animals have increased or reproductive rates have decreased since 1999, a larger minimum population would be required to maintain an effective population of 50. Estimates of effective population size must, therefore, be used cautiously and must be revised with changes in population parameters (Goodloe *et al.*, 1991). This further highlights the urgent need for continued monitoring and research and, if excess males are contributing to the decline in population growth, the translocation of some of these animals.

If males were translocated from DHNR, they could reinforce existing small populations as recommended in the IUCN Action Plan (Novellie *et al.*, 2002). Alternatively, males could be translocated to new conservation areas to found populations with females introduced from elsewhere (at least four males and ten females are required: Novellie *et al.*, 1996). Either would result in increased genetic diversity and thus improved stability of the meta-population. Unfamiliar individuals may take time to form breeding herds causing slow population growth over the first 3–5 years after re-introduction (Novellie *et al.*, 1996). It is not recommended that any females are removed from DHNR at this time.

By re-establishing a monitoring programme for the DHNR Cape mountain zebra population, we have improved the knowledge of its status. Data collected have highlighted potential problems for the continued growth of this and other Cape mountain zebra populations. Information obtained has facilitated the development of management strategies for the long-term survival of the DHNR population and due to its genetic diversity, the stability of the meta-population. Effective management of the meta-population requires that similar monitoring programmes are implemented for other populations and monitoring and management strategies developed during this study have been made available to conservation managers. This is particularly the case for the natural populations in Gamkaberg and Kammanassie Nature Reserves. It is only by monitoring and managing subpopulations effectively that conservation managers can ensure that populations continue to grow and that animals can be translocated to found new populations. This is vital if the IUCN's target of 2500 animals is to be achieved (and exceed) and genetic variation improved to secure the long-term survival of the Cape mountain zebra. This study has highlighted the importance of monitoring in species recovery programmes.

Acknowledgements

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