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2014/15
STATUS REPORT

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Centre for African Conservation Ecology **Report 63**
Nelson Mandela Metropolitan University **August 2015**

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EXECUTIVE SUMMERY

Through active conservation programmes, Cape mountain zebra (CMZ) numbers increased from their critical status of fewer than 80 individuals in the 1950's to more than 2790 animals in the wild in 2009. This subspecies is currently being down-listed to Near Threatened by the World Conservation Union (IUCN), and is on Appendix 1 of the Convention of International Trade in Endangered Species (CITES). This survey aimed to determine the current status of this subspecies and assess what steps need to be taken to ensure its long term conservation.

The survey showed that the extant population of CMZ stands at a minimum of 4791 individuals, in no less than 75 sub-populations, and a high annual rate of increase has been maintained since 2009, at 9.16% (compared to 8.4% between 1998 and 2002). In terms of numbers, CMZ conservation efforts have therefore continued to be a success. The majority of the population, namely 69%, remains on formally protected land and this proportion has remained stable since 2009. The number of privately-owned populations has grown considerably, however, with at least 56 CMZ populations now on privately-owned land (compared to 35 in 2009). The vital role that private land owners play in increasing the distribution and abundance of Cape mountain zebra within their historic range is therefore highlighted. Maintaining a demand within the private sector is hence crucial.

A key concern for the future conservation of CMZ is the loss of genetic diversity/integrity due to 1) a lack of mixing of the original three relict populations, 2) the large number of small, isolated sub-populations, particularly on private land, and 3) hybridization with plains zebra. More than 50% of sub-populations had a founder population smaller than the recommended minimum of 14 animals, and 62% of the population has been exposed to plains zebra, which are now known to hybridize with CMZ. A Biodiversity Management Plan with a metapopulation management plan, together with appropriate policy and incentives is therefore urgently needed in order to address these threats. This needs to be based on a population viability analysis (PVA) which incorporates a hunting quota, so as to ensure a continued demand within the private sector but enforces management actions which will improve genetic variation in the metapopulation. The impact of predation by lion and cheetah also needs to be considered.

INTRODUCTION

Cape mountain zebra (CMZ) conservation efforts have been very successful in terms of numbers, with the population recovering from a mere 80 individuals in the 1950's to over 2 790 by 2009 (Hrabar & Kerley 2013). The sub-species is currently in the process of being down-listed from 'Vulnerable' to 'Near Threatened' by the World Conservation Union (IUCN; Hrabar *et al*. In prep.) and is on Appendix 1 of the Convention for International Trade in Endangered Species (CITES; https://cites.org/eng/app/appendices.php). The successful growth of the CMZ population is attributable to two key factors, namely (1) the metapopulation approach to the management of the sub-species and (2) the increase in available habitat. In particular, the private sector has played a crucial role in increasing the habitat available and the distribution of Cape mountain zebra within their range, as by 2009 the number of private populations was double that of formally-protected populations (35 versus 17; Hrabar & Kerley 2013).

In terms of numbers and population trends, IUCN Red List Assessment Guidelines (https://portals.iucn.org/library/efiles/documents/RL-2012-002.pdf) suggest that CMZ could potentially be down-listed even further, to Least Concern, yet concerns regarding their conservation status have prevented this. A number of threats were identified from a survey in 2009 (e.g. inbreeding due to a lack of genetic flow between sub-populations) which have not been resolved since, and the larger metapopulation has potentially brought about a new set of challenges/threats to future population growth potential. Sub-populations may now be reaching carrying capacity, for example, which would result in decreased growth rates if translocations from these sub-populations are not encouraged. The demand for CMZ within the private sector is thought to be declining (personal communication with private owners), however, due to the limited (hunting) value and strict regulations put in place to protect the subspecies (TOPS regulations; www.environment.gov.za/sites/default/files/gazetted_notices/nemba10of2004_threaten_protected_species_regulations.pdf). This could have a significant negative impact on the future of available habitat, and hence the population performance.

The urgent need for an updated status report for the sub-species was therefore recognised, in order to assess the performance of the metapopulation in recent years (the previous survey was conducted 5 years ago) as well as identify threats to future conservation efforts. In particular, the need for an assessment of

factors affecting the future growth within the private sector was highlighted. A survey, commissioned by Wildlife Ranching South Africa, was therefore undertaken - the results of which are presented here.

PROJECT AIM:

The aim of this study is to conduct an updated comprehensive survey of the extant Cape mountain zebra population and assess what steps need to be taken to ensure the long term conservation of the sub-species.

QUESTIONS ADDRESSED IN THIS SURVEY:

1) What is the current status of CMZ?
    - What is the number and distribution of CMZ on privately-owned and formally protected land? How does this compare to the situation in 2009?
    - Has the population continued to grow at between 8-10 % per annum and if not, why?
2) What potential is there for further growth of the metapopulation within the current habitat available? - i.e. is the availability of land a limiting factor?
    - How saturated are sub-populations under current regulations?
    - What is the maximum potential population size on habitat available at present? - based on the desired size by owners/managers, as this, rather than ecological carrying capacity is the more relevant limiting factor in the private sector.
    - What effect would an increase in harvesting permits (hunting and translocations) have on the potential carrying capacity of the current available habitat i.e. is it an incentive for higher stocking rates?
3) What effect have TOPS regulations and Provincial legislation had on CMZ conservation – have they been a help or hindrance?
    - What regulations act as a deterrent to private CMZ owners?

- What regulations have affected population growth and population integrity (genetic diversity, hybridization etc.)?
- With current regulations in place, how has the relative value of CMZ changed over time? This reflects the demand for CMZ and hence the potential increase in available habitat.
- What threats do CMZ face at present and how can these be addressed? - to enable sound management actions and possible further down-listing to 'Least concern' by the IUCN?

SURVEY APPROACH

Private owners of CMZ were first identified from permit records, previous survey information and through contact with individuals involved in conservation in the distribution area of CMZ. Formally protected areas were identified through communications with the relevant conservation authorities. A questionnaire regarding the current and historic details of the subpopulation (zebra number, deaths, translocations etc.), the property details (size, location etc.) and owner/manager opinions was compiled and sent to all owners. Similar data was retrieved from subpopulations on formally protected land (provincial reserves and national parks). Questionnaires were completed in person (14 owners/managers) or electronically (58 respondents – but only 42 provided substantial information).

TAXONOMY

The mountain zebra (*Equus zebra* L. 1758) is represented by two geographically separated subspecies, namely the Cape mountain zebra (*Equus zebra zebra* L. 1758) and the Hartmann's mountain zebra (*Equus zebra hartmannae* Matschie 1898). The Cape mountain zebra, the subspecies of interest here, is slightly smaller than the Hartmann's subspecies, generally has wider black stripes and its mane does not extend as far forward between the ears (Novellie *et al*. 2002).

HISTORIC AND CURRENT RANGE

Historically, Cape mountain zebra (CMZ) occurred extensively in the mountainous regions of the south-western parts of South Africa (Boshoff *et al*. 2015; Millar 1970a; 1970b; Figure 1). It is postulated that in historic times they were separated from Hartmann's mountain zebra (which occur mainly in Namibia), by an area devoid of mountainous habitat, the Knersvlakte, which separates the Kamiesberg in the north from the Roggeveldberge in the south (Novellie *et al.* 2002). This broad plain, constituting unsuitable or marginally suitable habitat for mountain zebra, is about 70 km wide at its narrowest point. Mountain zebra also rarely occur in sympatry with plains zebra (*Equus quagga*) as they are adapted for life on rugged terrain and have harder and faster growing hooves, thereby inhibiting their habitation of soft flat plains for long periods (Skinner & Smithers 1990).

Excessive hunting and habitat loss to agriculture left CMZ numbers in a critical status by the 1930's, when the subspecies was confined to just five localities. Two of these subpopulations subsequently went extinct, leaving only three natural populations surviving to the present day. One population, in the Cradock district, was formally protected in 1937 by the proclamation of the Mountain Zebra National Park (Lloyd 1984). The other two, in the Kammanassie and Gamka Mountains, have been protected since 1923 and 1971, since the areas were proclaimed as a State Forest Nature Reserve and a Provincial Nature Reserve, respectively.

During the 1960s and 1970s the Cradock population increased to a point where in 1979, 23 individuals could be translocated to the newly proclaimed Karoo National Park (Karoo NP). During the 1980s and 1990s translocations to 25 other protected areas and game ranches within the subspecies' historic range took place. All of these are from original Mountain Zebra National Park (MZNP) stock, except for the De Hoop Provincial Nature Reserve population, which included individuals from the Kammanassie population. By 2002 the subspecies occurred in no less than six national parks, 10 provincial reserves and 17 private reserves, encompassing most of their historical range (Castley *et al*. 2002). Since then numbers gradually built up through active conservation programmes and by 2009 conservation efforts had been such a success, that the then extant population was in excess of 2 790 individuals (Hrabar & Kerley 2013). The population then consisted of no less than 57 sub-populations.

The important role that the private sector has played in increasing the distribution of CMZ within their historic range became evident during the 2009 survey (Hrabar & Kerley 2013), as at least two thirds of the subpopulations were by then on privately-owned land (38 privately-owned and 19 formally protected).

Since 2009 the number of subpopulations has continued to increase considerably and the extant CMZ population now consists of no less than 75 subpopulations. This increase in the number of subpopulations is solely due to the private sector, as the number of formally protected populations has remained unchanged (19), while privately-owned populations have increased to 56, i.e. 75% of sub-populations are now privately-owned (Figure 1, Figure 2).

Two extra-limital populations exist at present, in the Gariep Nature Reserve and Gariep Eco Reserve in the Free State Province (Boshoff and Kerley 2013).

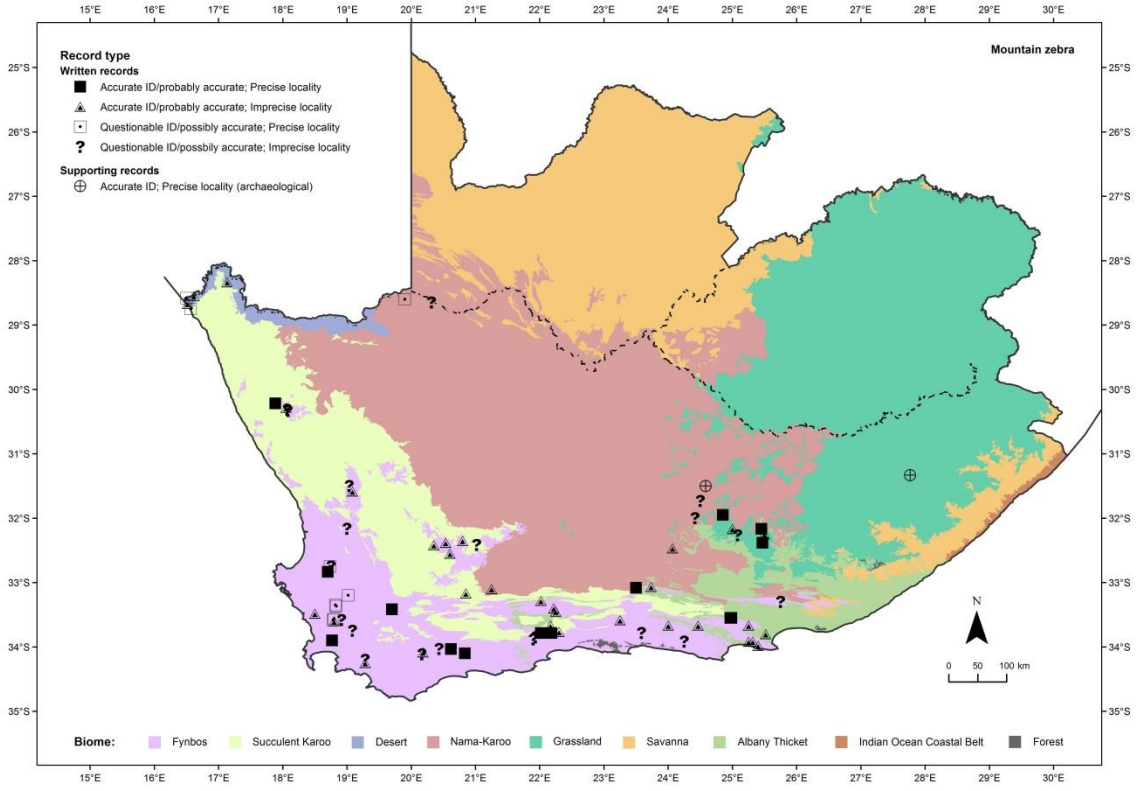

Figure 1. The historical records of the Cape mountain zebra *Equus zebra zebra* (Boshoff *et al*. 2015), reflecting its natural distribution range.

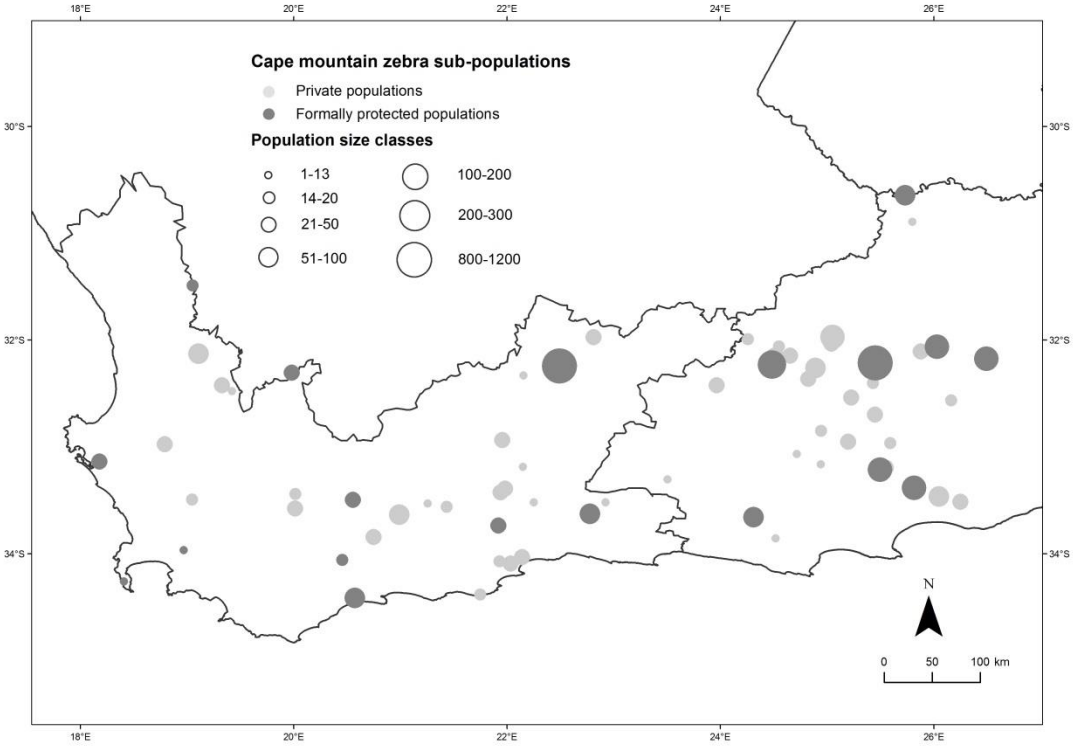

Figure 2. Distribution of all privately-owned and formally protected Cape mountain zebra *Equus zebra zebra* subpopulations in South Africa in 2015.

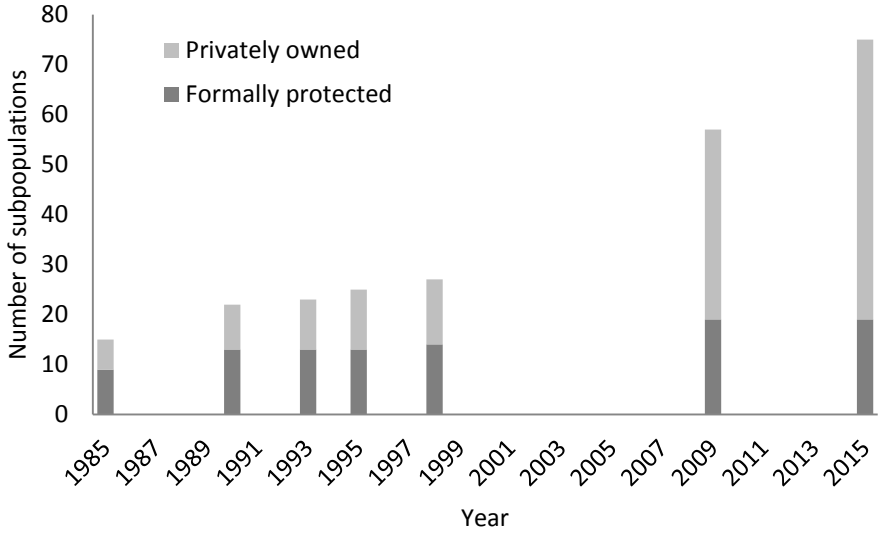

Figure 3. The total number of Cape mountain zebra *Equus zebra zebra* subpopulations on privately-owned and formally protected land in South Africa over a 30 year period from 1985-2015 (data for the period 1985 to 1998 from Novellie *et al*. 2002).

Habitat available to CMZ on privately-owned land has increased by 40% since 2009 and now comprises more than 296 141 ha. The majority of available habitat (65%) still falls within formally protected areas, however, as even though these areas have not increased in number, many have increased in size since 2009 (for example, Anysberg NR increased by 12 000 ha in 2012 and Tankwa Karoo NP has increased by 35 400 ha), thereby resulting in a 20% increase in available formally protected habitat (~ 562 000 ha at present; Table 1). Furthermore the average size of formally protected areas is substantially larger than privately owned areas (~6 000 ha versus ~ 30 000 ha, respectively).

POPULATION INFORMATION

In the 1950s, when the subspecies reached its most critical status, only around 80 individuals remained. The three surviving natural populations all underwent extreme demographic contraction at some stage, with 19 individuals in the Cradock population (now within the Mountain Zebra National Park) and no more than six and five individuals in the Gamkaberg and Kammanassie populations at their respective nadirs (Millar 1970a, b; Lloyd 1984).

While the populations remaining at Gamkaberg and Kammanassie have still not recovered substantially from their more extreme bottlenecks (currently comprising of 42 and 80 animals respectively), the MZNP population increased considerably and allowed for regular off-takes to re-stock other areas. This population now consist of around 1190 animals and is the largest subpopulation.

All CMZ subpopulations are isolated due to fencing and a metapopulation management approach has therefore been necessary, with translocations to ensure continued population growth and genetic diversity. Since the 1960s, numbers gradually built up through such active conservation programmes and in 2009 there were estimated to be more than 2 790 Cape mountain zebra in the wild, exceeding the target size of 2500 set by the 2002 IUCN Action Plan (Novellie *et al*. 2002; Hrabar & Kerley 2013).

In terms of numbers, conservation efforts have continued to be a success, as results from this survey show the total extant population now consists of no less than 4 791 animals (information for four populations is unknown and therefore not included in this total; Figure 4). The annual rate of increase in the population since

2009 has been 9.16%, which is comparable to previous periods - from 1985 to 1995 the annual rate of increase was reported as 8.6 % (Novellie *et al*. 1996), 9.6 % between 1995 and 1998 (Novellie *et al*. 2002) and 8.33 % between 2002 and 2009 (Hrabar & Kerley 2013). The metapopulation approach to management therefore appears to have been successful in ensuring continued population growth.

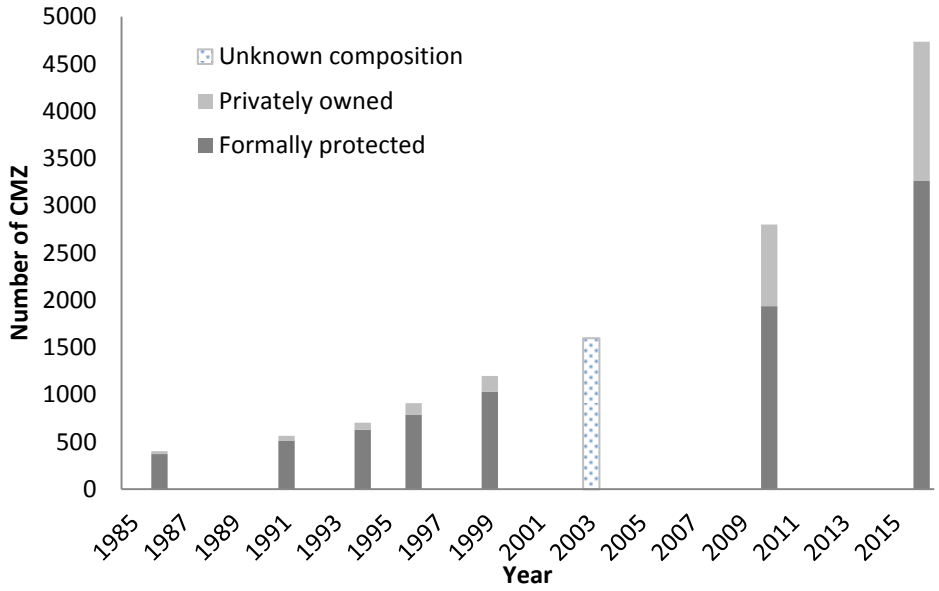

Figure 4. The total number of Cape mountain zebra *Equus zebra zebra* on privately-owned and formally protected land in South Africa over a 30 year period, from 1985-2015 (data for the period 1985 to 1998 from Novellie *et al*. 2002, and 2002 data from Castley *et al*., 2002).

The majority of the population (69%) remains on formally protected land and the proportion on privately-owned land (31%) has not risen since 2009, despite the increase in subpopulation number (Figure 5). The percentage of the population on private versus formally protected land is, however, in proportion to the habitat available within each sector (Table 1). The MZNP and Karoo NP subpopulations continue to make up a significant proportion of the population, namely 25% and 18%, respectively. Interestingly, Karoo NP's contribution to the population has remained stable, at 18%, since 2002 and the proportion on MZNP has steadily increased from 20% in 2002 to 22% in 2009 and now 25% in 2015.

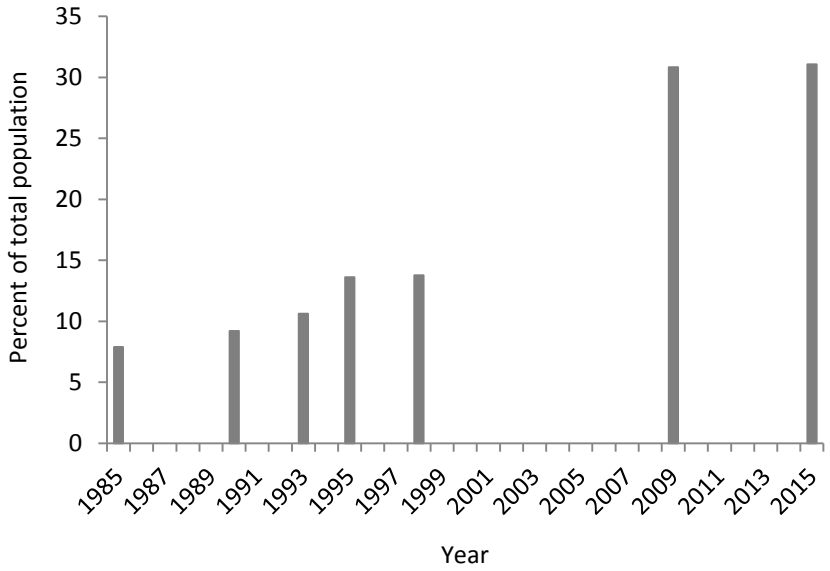

Figure 5. The percent of the total Cape mountain zebra *Equus zebra zebra* population on privately-owned land between 1985-2015 (data for the period 1985 to 1998 from Novellie *et al*. 2002).

The average size of privately-owned subpopulations (29 individuals) has risen slightly since 2009 (25 individuals) and now ranges in size from 5 to 120. Formally protected subpopulations are significantly larger ($t(70) = -3{,}479$, $p < 0.05$), ranging from 4 to 1190 animals (an average of 173). Most formally protected populations (7 out of 19) have more than 100 animals, yet the size of most private populations is between 20-50 animals (23 out of 52, Table 2). Only one private population has more than 100 animals at present and only two additional owners intend to allow their population to grow to this size. Within the private sector, 10 populations have reached their maximum potential size. The total potential (i.e. desired) number on private land is around 2 205 CMZ under current conditions, i.e. an additional 795 animals and a potential 53 % increase. An increase in CMZ value would, however, increase this potential size further, as seven owners indicated that this would be a motivation to increase their desired maximum population size - in total, amounting to an additional 222 animals i.e. a further 10% increase.

In the private sector, conservation of the subspecies was reportedly the most common motivation behind owning CMZ, while hunting was the least common reason (owners could choose more than one motivating factor; Figure 6). Most private owners did not disagree with regulating the possession, translocation and

hunting of CMZ through a permit system (as long as the process is efficient), but around 50% of owners did not agree that the sub-species should be restricted to within their natural distribution range (Figure 7.) This is contrary to conservation best practice, however, and conflicts with claims that ownership is driven by conservation motivations.

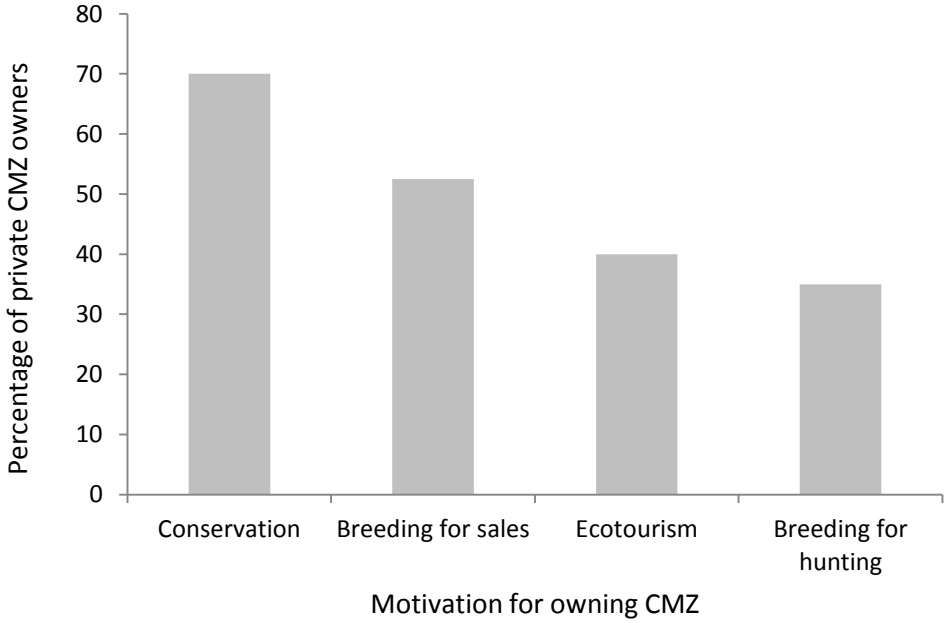

Figure 6. The private sector's motivation behind owning Cape mountain zebra *Equus zebra zebra* (n = 33).

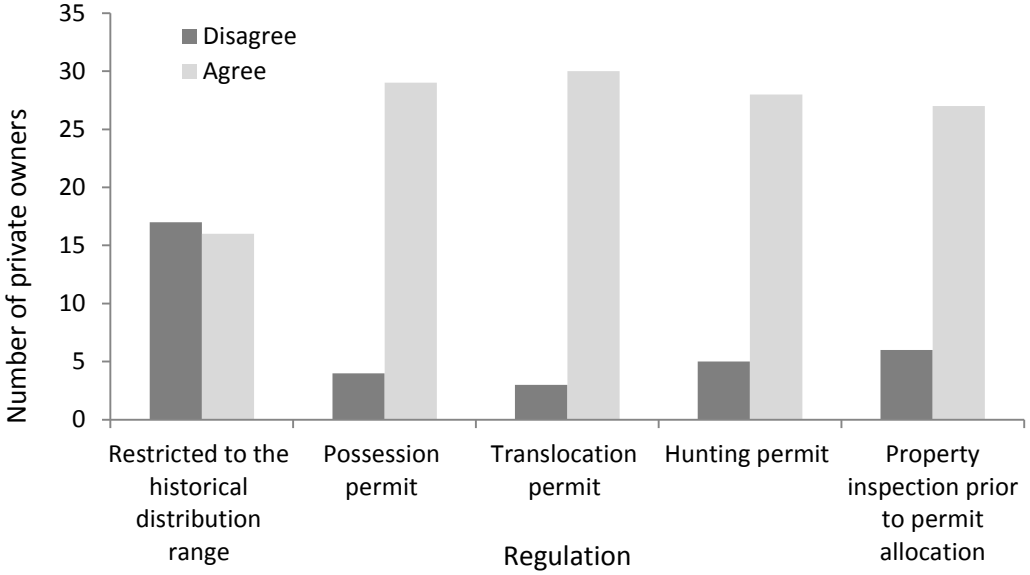

Figure 7. Private owner opinion towards Cape mountain zebra *Equus zebra zebra* ownership regulations.

Table 1. Summary of Cape mountain zebra *Equus zebra zebra* population details in June 2015.

	Formally protected	Privately owned	Total
Population size			
Number of sub-populations	19	56	75
Number of CMZ	3304 (69% of total)	>1487[$] (31% of total)	**4791**
Annual increase since 2009 (%)	9.07	9.47	9.16
Habitat currently available			
Total available land (ha)	562 512 (66% of total)	>296 141 (34% of total)	856 653
Increase in available land since 2009 (ha)	94287 (20% increase)	>86023 (40% increase)	180310
Human induced losses between 2009-2015			
Number hunted	0	12	12
Number culled[^]	50	16	66
Deaths due to translocation etc.	6[*]	>12[#]	18
Total unnatural deaths	56	40	96
No of CMZ translocated between 2009-2015	130 (102 onto private land)	254	384

[$]Data missing from 4 sub-populations. [^]Due to the sarcoid virus. [*]Caught in a kraal or fence. [#] All from translocations.

CONSERVATION CHALLENGES

Previous challenges

In 2009 (Hrabar & Kerley 2013), major threats to Cape mountain zebra were noted as:

- poor population performance of small populations i.e. effect on demographics;
- loss of genetic diversity through inbreeding and genetic drift in small populations, exacerbated by the social structure of CMZ, which tends to reduce effective population size;
- disease; and
- the risk of hybridisation between the two subspecies.

The risk of hybridization with Hartmann's mountain zebra has reduced over time as steps have been taken to remove this extra-limital subspecies from within the CMZ range (personal communication with Cape Nature and East Cape Parks & Tourism). Five Hartmann's populations currently exist within the Western Cape. Plans are in place for one such population within the Eastern Cape to be translocated to the Northern Cape and replaced with CMZ. One Hartmann's/Cape mountain zebra hybrid population has been confirmed within the Eastern Cape (through genetic testing) and attempts are currently underway to outbreed this population back toward pure CMZ (all stallions have been culled and replaced with CMZ stallions). Individuals from this hybrid population have been used to establish at least two additional sub-populations. The need for genetic testing to be a pre-requisite for translocations is therefore highlighted.

All other previous threats (Hrabar & Kerley 2013) persist and are therefore discussed in more detail below.

Current challenges

Current challenges to CMZ conservation have been identified as:

- the loss of genetic diversity through inbreeding and genetic drift in small populations continues to be a primary concern;
- threats to two of the original populations (Gamkaberg and Kammanassie populations), which are genetically invaluable but remain isolated.
- loss of genetic integrity through hybridization;
- a lack of a Biodiversity Management Plan for the subspecies and the lack of effective implementation of a metapopulation strategy;
- a lack of a Population Viability Analysis for the metapopulation and subpopulations;
- conservation in sub-optimal habitat and a poor understanding of habitat suitability;
- limited commercial value;
- disease;
- inability to carry out necessary management actions due to shortfalls in human and financial resources;
- predators

Genetic diversity

Inbreeding depression and genetic drift is a very real threat associated with small populations (Lacy 1993). The adoption of the following policy for the translocation of CMZ was therefore recommended in 1993 (derived at a Population and Habitat Viability Analysis workshop on Cape mountain zebra, Novellie *et al*. 2002):

1) *Reinforcement of existing populations will receive priority over the establishment of new populations, at least until a majority of the existing populations are securely established and increasing.*
2) *In cases where new populations are established, the minimum number introduced should be 14 (either with a one to one sex ratio or up to ten females and four males, Novellie* et al*. 1996).*
3) *New owners will be made aware of the difficulties associated with the establishment of small populations and should understand that they will need to acquire one or two animals once every five to ten years in order to avoid inbreeding depression.*

As the 2009 CMZ survey found, the degree to which these recommendations are being followed is of concern. Fourteen subpopulations had fewer than the recommended minimum 14 founder animals (Novellie *et al*. 1996), 11 of which are privately-owned. The founder population size for 65% of privately-owned subpopulations and for more than 50% of the subpopulations in total have been below the recommended 14 animals (Table 2). Half of privately-owned populations (18 out of 37 - only those with sufficient data considered) have only ever had a single introduction event and of these 18, 16 had a founder population of less than 14, and 15 of these populations are more than five years old i.e. there has been sufficient time for further introductions, and inbreeding risk is in place due to offspring maturing with parents still dominating the breeding individuals. Twenty-seven out of 34 subpopulations (only those with sufficient data considered - private and formally protected populations combined) have had no further reintroductions within the last 10 years. A total of 386 CMZ were translocated from various subpopulations between 2009 and 2015, yet only 72 (18%) individuals were used to reinforce numbers and genetic diversity in existing populations (the remainder were introduced into new areas). Reinforcement of existing populations is therefore not being given priority over establishment of new populations, even though the need clearly

persists. The threat of inbreeding and genetic drift is therefore very real, as minimal gene flow is taking place between subpopulations. Furthermore, an excessively small number of founder individuals tends to result in either failed reintroduction or poor population performance in the long term. Novellie *et al*. (1996), for example, found that the performance of 24 reintroduced populations was strongly influenced by the number of individuals originally re-introduced.

Table 2. Cape mountain zebra *Equus zebra zebra* reintroduction details (size and frequency of introductions) and current size for subpopulations with sufficient data.

	Number/percent of formally protected populations	Number/percent of private populations	Total number/percent of populations
Founder population size	(n=17)[#]	(N=37)	(n=54)
<14	5[#] (27%)	24 (65%)	29 (53%)
14-20	6 (33%)	8 (21%)	14 (25%)
>20	6 (33%)	5 (14%)	11 (20%)
Number of introduction/reinforcement events	(n=15)	(n=37)	(n=52)
1	2 (13%)	18[*] (49%)	20 (38%)
2	6 (40%)	11 (30%)	17 (33%)
3-6	7 (47%)	8 (21%)	15 (29%)
Current subpopulation size	(n=19)	(n=52)	(n=71)
<14	3 (16%)	11 (21%)	14 (20%)
14-20	1 (5%)	11 (21%)	12 (17%)
21-50	5 (26%)	23 (44%)	28 (39%)
51-100	3 (16%)	6 (12%)	9 (13%)
>100	7 (37%)	1 (2%)	8 (11%)
Desired population size		(n=45)	
<14		1	
14-20		13	
21-50		19	
51-100		9	
>100		3	

[#] Two of these are original populations.

[*] 16 of these populations have a founder population of <14 individuals and 15 are more than five years old.

Threats to important gene pools

Genetic diversity within the metapopulation has also been restricted due to the continued isolation of two of the original relict populations. All but ~200 animals (the Kammanassie, Gamkaberg and De Hoop populations) originate from just the 19 original animals in MZNP i.e. 95% of the extant population. Low genetic variation within individual populations was confirmed by Moodley & Harley (2005). Only De Hoop NR has a population of mixed origin (Kammanassie/MZNP) and consequently has the highest degree of genetic variation (Moodley & Harley, 2006). Although the recommendation to adopt a management strategy that entails mixing of original populations to halt further loss of genetic diversity has been made (Moodley & Harley, 2006), this has still not taken place.

Importantly, the Kammanassie population (a unique gene pool) is now under threat of hybridizing with plains zebra as the two species periodically co-exist on a neighbouring farm, which the CMZ move onto for access to low lying grazing and water (no fences exist between the properties; personal communication with the property owner). Furthermore, the Gamkaberg population appears to be on the decline as only 42 individuals were sighted during the last aerial survey (May 2015), compared to 47 in 2009. This is thought to be due to a decrease in the availability of suitable vegetation in the habitat since the last significant fire in 1997, as fynbos begins to dominate over grass once again (Watson *et al*. 2005). The potential for future growth and viability of this population is therefore severely threatened by habitat quality as grass forms a crucial part of the CMZ diet (Faith 2011).

Hybridization

Until recently no cases of hybridization between plains zebra and CMZ were known. Hybridization as a threat to CMZ populations was not of great concern as fertile hybrids were thought to be unlikely, due to the difference in the number of chromosomal pairs between the two species being relatively large (44 versus 32 in plains zebra and CMZ, respectively; Ryder *et al*. 1978; Cordingley *et al*. 2009). Plains zebra were therefore introduced into four formally protected areas, including the MZNP in 1999 and Karoo NP in 1998 (i.e. the two largest CMZ populations) and into about 10 private populations.

More recent evidence, however, shows that differences in chromosome number do not constitute a barrier to exchange of genes between equid species

(Jónsson *et al.* 2014) and in 2014 apparent plains/CMZ hybrids were observed in MZNP. This hybridization was confirmed through genetic testing (Taplin *et al*. 2015). One of the individuals was a herd stallion and the other was a young female from the hybrid stallion's family group he was herding. It therefore appears that he may have been fertile, but this was not confirmed (Taplin *et al*. 2015). The fertility of hybrids is therefore still not clear. All plains zebra have since been removed from MZNP but the prevalence of hybridization within the population is unknown as it may not always be expressed phenotypically. Twelve populations (> 1300 CMZ, > 27% of the global population), remain exposed to plains zebra at present and at least 15 populations (> 1600 CMZ) have had previous exposure. In total, 62% of the total population has been/is at risk of hybridization (Table 3). Only 18% of the population has a limited threat of inbreeding (founder populations > 14 animals) as well as no hybridization threat (Table 4).

While hybridization events may occur 'naturally', man-induced environmental changes, particularly fragmentation of habitat and isolation of populations, undoubtedly exacerbate the risk of hybridization between equid species (Hill 2009). Such unintentional anthropogenic hybridization is generally viewed negatively, especially when one of the parent species is protected (Piett *et al*. 2015). In protecting the parent species (CMZ in the case), it is important to consider the demographics of hybridization because if hybrids become very abundant, they can swamp the parent taxa simply due to the probability of finding a mate (Schulte *et al*. 2012). Therefore, the genetic integrity of parent taxa depends on their relative abundance i.e. the abundance of CMZ relative to plains zebra in a population (Piett *et al*. 2015).

Table 3. A summary of the current status of the Cape mountain zebra/plains zebra (*Equus zebra zebra* /*Equus quagga*) hybridization threat.

	Number of populations	Number of CMZ	Percent of total CMZ population
CMZ currently with plains zebra			
Privately-owned	9	320	6.7 %
Formally protected	3	1026	21.5 %
Total currently	12	1346	28.2 %
CMZ previously kept with plains zebra			
Privately-owned	11[#]	317[#]	6.6 %
Formally protected	4[*]	1296*	27.1 %
Total previously	15	1613	34.7 %
Total CMZ with potential hybridization	27	2959	62.0 %

[*]MZNP population included here. [#]Minimum number as information for 17 populations is unknown

Table 4. The Cape mountain zebra *Equus zebra zebra* populations with a reduced threat of inbreeding (due to a founder population ≥14) and no threat of hybridization with plains zebra *Equus quagga*.

Sub-population	Founder population size	Current population size
Oorlogskloof Nature Reserve	26	19
[*]De Hoop Nature Reserve	14	37
Baviaanskloof Nature Reserve	63	51
Gariep Nature Reserve	17	98
Tsolwana Nature Reserve	20	156
Camdeboo National Park	20	236
Addo Elephant National Park	50	120
Touwsberg Private Game and Nature Reserve	16	60
Bushmans Kloof Wilderness Reserve & Retreat	23	67
Shamwari Game Reserve	48	73
Swartberg Private Wildlife Estate	15	21
Bankfontein	>14	32
Leopards Ridge Conservancy	31	32
Total	n.a.	882 (18% of the population)

Metapopulation management plan

Problems associated with the fragmentation of the population are largely due to a lack of management action. A major issue is the lack of an approved national Biodiversity Management Plan for Cape mountain zebra, with a metapopulation management plan. A vital component of a successful management plan in the long term is a sound understanding of population viability. The minimum viable population size for CMZ has not yet been determined (through a PVA) and management actions required to ensure the viability of sub-populations of various sizes are poorly understood (e.g. the number, sex, and frequency of additions/removals required in order to prevent any further loss of genetic variation).

Habitat suitability

Population performance (measured as the percent annual growth) is highly variable between sub-populations and this may be due to confinement within sub-optimal habitat. For example, Strauss (2015) and Weel *et al*. (2015) found the CMZ populations in Bontebok NP and the Baviaanskloof, respectively, are limited by both poor resource quantity and quality in dystrophic fynbos ecosystems. Re-introduction into areas confined within such habitat could then be a wasted effort, as are efforts to grow existing sub-populations within these areas (unless there is potential for habitat expansion incorporating more suitable habitat). In particular, this becomes a threat to CMZ conservation where genetically valuable sub-populations become vulnerable to decline due to confinement within such habitats (such as the Gamkaberg population). A more thorough understanding of habitat suitability is therefore needed in order to guide future metapopulation management plans.

Commercial value

The average price of CMZ has remained stable for the last 26 years (with the mean price per animal at ZAR16 000 between 1998-2008, ZAR16 500 between 2009-2011 and ZAR13 125 between 2012-2014), despite inflation i.e. their value has decreased over time. This is a reflection of a decrease in demand, which is largely due to their limited hunting value, as the private sector is reluctant to invest in a species with limited income potential – due to the lack of an export quota for Cape mountain zebra hunting trophies. In accordance with CITES Resolution Conf. 2.11 (Rev.) (https://cites.org/eng/res/02/02-11.php), however, a quota is allowed for Appendix I

species when a Scientific Authority of the State of export has advised that such export will not be detrimental to the survival of that species. In the last year, steps towards a national hunting quota have taken place and the price of CMZ has materially increased and individuals are now selling for up to R45 000 (the mean price for 2015 is double that of previous periods, at R33 000; Figure 8). Any decline in the demand for CMZ within the private sector could have a significant negative impact on future expansion of the population and availability of habitat, as this survey once again highlights the important role the private sector plays in purchasing available animals from existing subpopulations, thereby ensuring continued population growth of these populations by reducing density dependent effects.

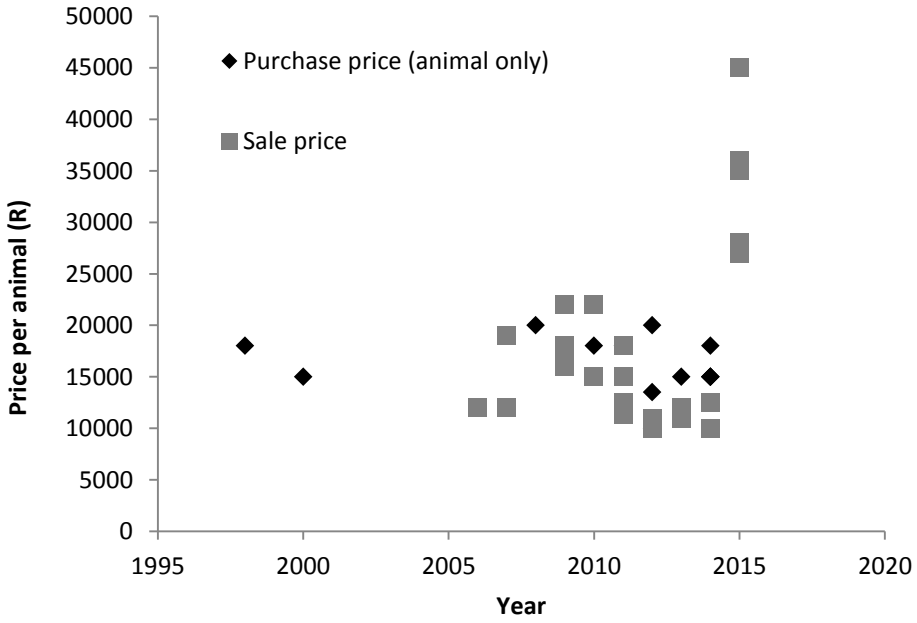

Figure 8. The sale and purchase price (for the animal only; South African Rands) for Cape mountain zebra *Equus zebra zebra* between 1998 -2015.

Disease

Equine sarcoids (the most common cutaneous neoplasm of Equids) is a widespread disease of Equids that has also been found in CMZ and inbred populations are more susceptible to this disease (Sasidharan 2006). Although only the odd case has been reported from some populations, the virus reached epidemic proportions in two

populations, namely in the Gariep Nature Reserve and Bontebok National Park where 22% and 53% of the population was infected respectively. Treatment of sarcoids is difficult at the best of times and almost impossible to manage in a free ranging population of wild equids. The management approach at present is to euthanase animals with visible lesions and between 2009-2015, 66 animals were culled from the metapopulation for this reason (Table 1). In 2010 the entire Bontebok NP population was chemically immobilized and 22 of the 48 animals had to be euthanased. Monitoring of the incidence of sarcoids in the various sub-populations is ongoing and until such time that we have a better understanding of the epidemiological factors that result in sarcoids, it is recommended that animals with visible lesions be euthanased as they are thought to act as a source of infection (Zimmerman et al. 2010).

Predators

Lions *Panther leo* have been reintroduced into one privately-owned and three formally protected areas which have CMZ, namely Kuzuko, Karoo NP and MZNP i.e. the two largest CMZ populations are exposed to lions. Cheetah *Acinonyx jubatus* have also been reintroduced MZNP, as well as into the areas of three additional sub-populations. At least 13 CMZ were killed by the two lion in MZNP over a two year period (2013-2014) and in Karoo NP, lion showed a preference for CMZ during the initial post-release period when their movements were concentrated within the high CMZ density area on the mountain tops (their prey preference has since shifted to kudu, red hartebeest and gemsbok; personal communication with SANParks). Cheetah are thought to be limiting the population growth in at least one private property where 13 partially consumed CMZ carcasses were found over an 18 month period. The cause of death could not be confirmed for these individuals, but cheetah numbers exceeded 21 individuals during that time.

CONSERVATION MEASURES

1) The urgent need to eliminate the threat of hybridization with plains zebra has been recognised by SANParks and plans are in place to remove all remaining plains zebra from areas with CMZ (personal communication with SANParks). Furthermore, all individuals captured for translocation from affected SANParks

populations will be subject to DNA testing and will be kept in holding camps until confirmed as pure. Hybrid individuals will be euthanased to prevent any further gene contamination (Dalton *et al*. In prep.).

2) A population viability analysis (PVA) for the metapopulation and sub-populations is currently underway. The South African National Biodiversity Institute (SANBI) is the scientific authority leading this process and two modellers employed by SANBI will be responsible for developing the models in collaboration with Cape Nature, SANParks and ourselves at the Nelson Mandela Metropolitan University. The most current data is being used for the PVA (i.e. from this survey) and will be used to develop management plans for various-sized subpopulations (e.g. introductions/removals necessary) in order to prevent any decrease in genetic variation and population performance.
3) SANParks and Cape Nature have been in the process of developing a Biodiversity Management Plan for CMZ since mid-2013, after all stakeholders were included in initial discussions at a BMP workshop. While progress has been slow to date, current data and findings from this survey can now be included, which will strengthen the BMP substantially. The urgency to complete the BMP is recognised by all conservation bodies/stakeholders and is of high priority.
4) A study linking variation in habitat quality with population performance is currently underway, which will help future conservation planning.
5) The process of increasing the value of CMZ through greater hunting potential began back in 2013 with a non-detrimental finding (NDF) workshop. The outcome of this workshop was that an international trade in CMZ under the prevailing conditions would be detrimental to the subspecies and trade was therefore not recommended by the Scientific Authority. The current management system for the subspecies was mainly responsible for the negative NDF. It was recommended that 1) a Species Biodiversity Management Plan (a gazetted regulatory tool) for CMZ needs to be developed focusing on the metapopulation management plan, and 2) a PVA be done, advising the hunting quota and the management thereof. Both the BMP and PVA are currently being developed - both requirements for the implementation of a small hunting quota and international trade in CMZ.

RECOMMENDATIONS

The following broad recommendations arise from the findings of this survey:

- Mixing of the original populations to ensure increased genetic variation in the metapopulation should be top priority.
- Conservation actions should focus on the genetically valuable sub-populations identified in this survey (see details for formally protected populations in Appendix A). For example, the De Hoop NR population has the greatest degree of genetic variation and has had no exposure to plains zebra. Performance of this population is, however, poor due to habitat suitability and competition with other grazers.
- Subpopulations which have failed to grow on sub-optimal habitat should be translocated to more suitable habitat (not removing the entire population from areas where they never went extinct, however, e.g. Gamkaberg NR).
- Subpopulations with a founder population smaller than the recommended minimum 14 animals need supplementation (see details for formally protected populations in Appendix A).
- Sub-populations which have not had any further introductions within the last ten years need reinforcement with new animals.
- Plains zebra urgently need to be removed from all areas with CMZ to prevent further hybridization.
- The prevalence of plains/CMZ hybridization needs to be determined for populations at risk, or with an unknown risk (i.e. when the source of the animals is not known). The option of DNA testing from dung samples needs to be investigated. Only populations testing positive for hybridisation would then need individual based DNA testing.
- DNA testing for hybridization should be a pre-requisite for reintroductions. Any hybrid individuals should then be euthanased.
- A research project should be in place to monitor the effects of management actions recommended by the PVA (hunting, translocations, introductions etc.).
- Once the minimum viable population size has been determined for CMZ (for the total metapopulation), the amount of habitat required to support this population should be determined in order to set conservation goals.

- The BMP needs to include an Action Plan with an indication of resource requirements, as well as “resource mobilization strategies” i.e. how human and financial resources will be utilized.
- Impacts of reintroduced predators needs to be monitored and if this is shown to be a problem, appropriate management interventions developed.
- Possession, translocation and hunting of CMZ should continue to be regulated in order to ensure sound metapopulation management. Issuing of permits needs to be efficient, however, and needs to be in accordance with standard recommendations for the subspecies, across provinces.
- The global CMZ population should be subject to regular (every 5 years) surveys, such as the current survey.

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APPENDIX 1: Notes and management recommendations for individual formally protected Cape mountain zebra populations - 2015

Formally protected population	**2014/15 Pop size**	**Desired number**	**Founder population size**	**With plains zebra now**	**With plains zebra before**	**Property size (ha) in 2015**	**Comments**	**Recommendations**
Gamkaberg NR	42		6	no	no	10 431	Genetically important relic population, but declining in poor habitat.	**Urgent action needed to grow population** - improve habitat suitability/availability or translocate part of the population to better suited habitat.
Anysberg NR	23		17	no	no	74 500	Genetically sound with low inbreeding threat or hybridization. Habitat expansion may allow for growth into a significant sized population.	Monitor population performance in this habitat.
Kammanassie NR	80		5	yes	n.a.	21 532	Genetically vital relic population which is now exposed to plains zebra	**Urgent removal of plains zebra on adjoining property** - preferable over cutting off the CMZ's access to water and grazing on this neighbouring property.
Hottentots Holland NR	6		14	no	no	20 000	Population has declined to below 14 CMZ due to unsuitable habitat	Perhaps translocate this population to more suitable habitat
De Hoop NR	100		14	no	no	33 800	Most genetically diverse population - genes from two relic populations and no hybridization threat (horses?). Only 16 on DH though, suitable habitat limited and	**Growth and conservation of this population should be a priority - not necessarily in-situ**.

							high competition with other grazers.	
Mountain Zebra NP	1190		11	no	yes - 1999-2014	21 340	Largest population but with hybridization	**Assess degree of hybridization**, start process of testing and eliminating hybrids.
Karoo NP	843		76	yes	n.a.	93 000	Second largest population but with plains zebra	**Urgent removal of all plains zebra** and assess whether hybridization in the population
Tankwa Karoo NP	41	260	28	no	between 1995 & 1999	146 400	Potentially valuable population due to potential for population expansion and good founder number, but hybridization unknown (very small chance).	Test for hybridization in a sample of the population to confirm whether pure. Plains removed in 1999 so greatest chance in old individuals >15yrs.
West Coast NP	42	>50	11	no	yes - in KRNP	3 000	Population performance has been very good in the last 5 yrs (11.38% p.a.) suggesting a favourable habitat. Therefore worth addressing possible hybridization and inbreeding.	**Increase the founder population** and test for hybridization.
Bontebok NP	14		24	no	no	3476	Started with a good founder population but has since been reduced to less than 10 animals. Inbreeding therefore now possible issue. Sarcoids prevalent in past. Limited suitable habitat available and not the priority focus species for the Parks' conservation?	Decide what the future aim for the population is as intro of more CMZ needed to boost 'founder' population after culling/translocation in 2010.
Addo NP (Zuurberg)	120	500	50	no	?	65000	Potentially genetically valuable population if no	none

							previous exposure to Plains.	
Camdeboo NP	236		20	no	no	19370	Valuable population due to founder pop size, current size and lack of hybridization threat.	none
Table Mountain NP	4		7	no	no	?	Poor performance -population more than 30 years old and not viable	Removal of remaining CMZ
Kuzuko	103	100		yes -200	n.a.	11000	Good population performance post drought (12.8% p.a.) i.e. suitable habitat in large area, but hybridization a threat. Good scope for large population once Plains zebra removed.	**Urgently remove all plains zebra** and test for hybridization.
Baviaanskloof NR	51		63	no	no	15000	Genetically sound due to large founder population and no hybridization threat. Limited population growth, however, due to limited suitable available habitat.	Monitor growth more closely. Decide what future potential/plan is for this genetically sound population.
Commando Drift NR	150		8	no	no	5983	No hybridization threat and good size but founder pop small. Growth rate has slowed in recent years suggesting CC is being reached under current herbivore numbers.	Remove a portion of the population to enable an increased growth rate. Introduce new individuals to increase founder population size.
Tsolwana NR	156		20	no	no	7803	Genetically sound population, both in terms of inbreeding and hybridization. Growth rate reduced in recent years though (only 3.44% p.a. between 2010-2013). May	Remove a portion of the population to enable an increased growth rate.

							therefore be nearing CC.	
Oorlogskloof NR	19		26	no	no	5577	Large founder population and no hybridization threat, but previous performance poor? Still unclear how population performance is at present (data not obtained).	Close monitoring of performance in this habitat.
Gariep NR	98		17	no	no	5300	Genetically sound population but has history of sarcoids prevalence.	