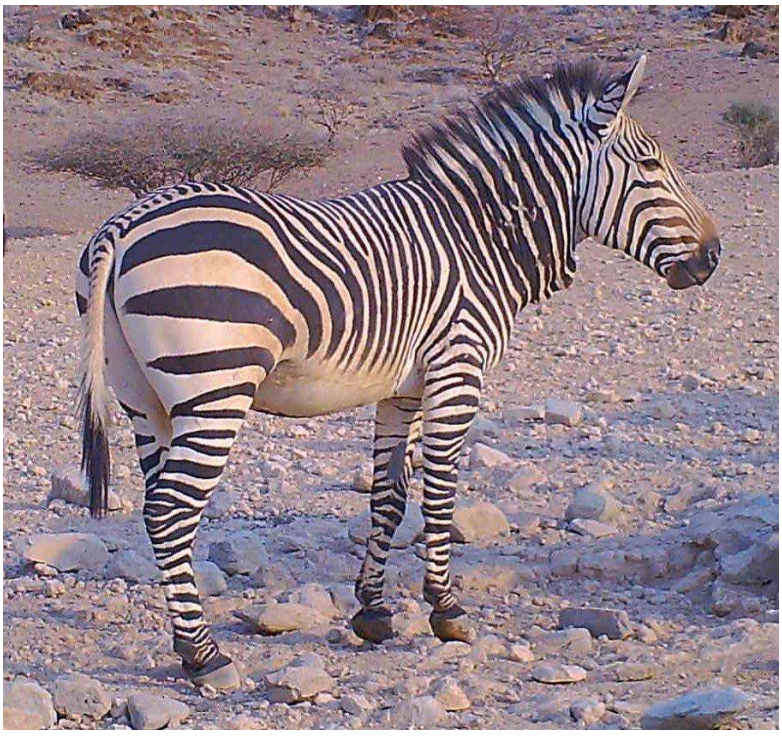
Mountain Zebra Project – 7th progress report

Population ecology of Hartmann's mountain zebra in southern Namibia

2016



Adult male Hartmann's mountain zebra (NPR821m) at Swartberg water hole in the west of the Naukluft estension of the Namib-Naukluft National Park. Note the scars down the side of neck, the result of fighting between males; these start to appear at about 6-7 years of age as males compete for ownership of harem. © L.M.Gosling.

Introduction

This is the seventh progress report on a study of the population ecology and conservation of Hartmann's mountain zebra (*Equus zebra hartmannae*) that has been underway since 2005. The project aims to help support the conservation of mountain zebra in Namibia and to study population processes using an individual-based approach. Hartmann's mountain zebra is a protected species in Namibia and of global conservation importance (Novellie et al, 2002 & 2008; IUCN Red List Category: Vulnerable) and, while locally numerous, they are vulnerable under drought conditions, particularly where seasonal movement is restricted by fences and where they share their range with livestock. They are an important resource in a wildlife-based economy and are valued for both non-consumptive (mainly ecotourism) and consumptive use. They have been extensively reintroduced to support wildlife-based economies, particularly in the communal conservancies in the north-west where off-take quotas are set based on ground counts. Locally, mountain zebra may come into conflict with livestock farmers over grazing and this becomes more critical during droughts. The main issues in their conservation management are of managing a valuable resource, particularly in relation to sustainable consumptive and non-consumptive use (Barnes and de Jager, 1996).

The original proposal to the Namibian Ministry of Environment and Tourism (MET) for research clearance is attached at Appendix A and the study has been carried out under MET research permits, most recently 2100/2015. The longest data series is available from the first study site in Gondwana Canyon Park, a 1,253 km^2 private park established in 1997, and the adjacent Ai-Ais/Fish River Canyon NP but the study has been progressively expanded to additional areas, partly for comparative purposes. Further data have been collected from the northern part of NamibRand Nature Reserve, a 2,150 km^2 private protected area which is open to the Namib-Naukluft NP to the west and has been studied since early 2010 and Geluk Farm which adjoins the NamibRand NR. A large scale study is currently underway in the Naukluft mountain extension (1,148 km^2) of the Namib-Naukluft NP and at Büllsport Guest Farm which adjoins the Naukluft NP. The Naukluft and NamibRand study areas, plus adjoining farms, fall within the Greater Sossusvlei-Namib Landscape scheme and the Gondwana CP study area falls within the Greater Fish River Landscape scheme. If successful, these landscape-scale schemes may have positive significance in the future for the conservation of mountain zebra populations because they are large enough to support genetically-viable mountain zebra populations and to allow the flexibility of movement necessary for population sustainability. The population in the western part of Etosha NP, Otjovasandu, has been monitored since 2012 and, in 2016, the adjacent Hobatere Concession area was sampled for the first time.

Feedback has been provided about the results of the study to all landowners and other stakeholders involved and to the Rufford Foundation and Montpellier Zoo who were the main sources of external funding.

Methods

The study employs an individual-based approach (e.g. De Angelis & Gross, 1992) and the main practical techniques are camera trapping at water holes plus field observations of wild groups when possible; all individuals are identified from photographs using a bar-code approach which I developed for this study. Water hole sampling takes advantage of the fact that mountain zebra are water dependent and must drink every day, and sometimes more often in dry weather. The Individual-based approach allows the

investigation of key population processes and the short-term enumeration of 'source populations', the animals that visit a particular area over a defined period (usually a calendar year) but who may not be present at any one time and these populations are the focus for this report. Previous reports have shown how source populations can be predicted for any current year using historical data and such information can then be compared with conventional estimates of populations present at any one time which are obtained either from sample counts (air or ground) and using known individuals for mark-recapture estimate; the latter follow standard procedure (see Seber, 1982 and others) and details have been given in previous Progress Reports.

Etosha National Park and the Hobatere Concession Area

The mountain zebra population, in western Etosha NP, in an area called Otjovasandu, has been studied since 2012 and is carried out in parallel and in co-operation with a study by Kenneth Uiseb of the ecological interaction between mountain and plains zebra which overlap in this area. The site was visited and sampled twice, in November 2015 and November 2016. The presence of elephants would make camera trapping difficult in Etosha and so normal photography from a car (using a 500mm zoom lens) has been used throughout. This works well because the mountain zebra visit waterholes frequently and because the animals are approachable due to habituation to tourist vehicles.

In November 2015 I spent 7 days in the field and visits to water holes were planned to achieve balanced sampling in each half of the study period to allow mark-recapture estimates of population size. The total number of individuals identified over the 7 days was 361 and of these 248 (69%) were new. Only 35 (14%) of the new animals were under two years old so the new animals were mainly adults. In the first mark-recapture estimate carried out in 2012 (Gosling, 2012), I used the first 4 days of my visit as the 'mark' period and the last 3 days as the 'recapture' period. This procedure was repeated for the November 2015 data: 211 individuals were seen in the 'mark' period, '170' in the 'recapture' period and 22 in both. Using a modified Lincoln-Peterson method (Seber, 1982) these values yielded an estimate of 1,576+/-283 (mean +/- SE) which is surprisingly large. A number of other permutations of the mark and recapture days were tried and these all yielded similar results.

The new estimate of 1,576+/-283 in November 2015 is substantially larger than my estimate of 802+/-116 mountain zebra in 2012. And also larger than the estimate of 685+/-158 from the MET air survey in 2012 (Kolberg, 2012). I have not yet seen the results of a more recent MET air survey but one of the participants told me that the estimate was between 6 and 7 hundred. At present the difference between the 2012 and 2015 individual-based estimates is unexplained and further work is need to address this problem. And if the 2015 estimate is accurate there is a much larger difference between the population estimated from the ground and in air counts than in 2012. Areas for future investigation include problems of sampling in the mark-recapture process and questions about the accuracy of the mark-recapture estimate in comparison with that of the air survey. As discussed previously it seems likely that the air survey underestimates mountain zebra when in mixed groups with plains zebra (as often happens in Otjovasandu) but these new results suggest that this effect could sometimes be larger than previously suspected.

If the population did increase from 802 in 2012 to 1,576 in 2015 this is unlikely to be by reproduction alone: a population of 802 growing by 10% over 3 years reaches 1,067 but it seems unlikely that the Otjovasandu mountain zebra could grow at this rate under quite intense predation by lions. The alternative is immigration, either from outside, or from an area within the Park that was under-sampled in 2012. One possibility is that mountain zebra could move between Otjovasandu and the Hobatere

Concession Area and some work was started in Hobatere in 2016, partly to test this possibility (see below).

In a shorter, 3 day visit to Otjovasandu in November 2016, a total of 178 animals were identified and, of these 108 (61%) were new. The visit was too short to carry out a mark-recapture estimate but the high proportion of new animals suggests large numbers. The total number of individuals identified in Etosha since 2012 is now up to 749 with the addition of the new animals seen in 2016. Six adult female mountain zebra have been collared by K. H. Uiseb as part of his study of the ecology of mountain and plains zebra in Etosha NP and only one of these was seen in the sample of 178 animals identified in November 2016.

The Hobatere Concession Area was visited for two days in November 2016 to assess the practicality of studying the mountain zebra there and, if possible, to check for any overlap between the Hobatere and Otjovasandu populations. It proved easy to photograph mountain zebra at Hobatere, partly because there are only two main water holes that the animals can access in order to drink. The total number of individuals photographed, coded and identified was 108. At this early stage it is not known what proportion these are of the total population but at one point while at the Tree House waterhole I counted 77 zebra waiting to drink and eventually set up IDs for 58 animals from photographs taken at this waterhole. All 108 animals were checked against the 749 animals in the Etosha ID library and there are no animals in common. This will need to be checked further when more data are in hand but at present there is no evidence for the hypothesis about overlap between Hobatere and Etosha.
Out of the 108 animals in Hobatere, there were none under 1 year old and I did not notice any other animals in this age group. There were only 3 animals of 1-2 years. This is the worst reproductive performance of any of the sites studied (including ones with lower rainfall in the South) and suggests a declining population. It would be worth exploring the role of the recent drought and of lion predation in these events and, subject to approval, I hope to improve our understanding of this important population.

Naukluft National Park and Buellsport Guest Farm

One aim of current research is to obtain an individual-based estimate of numbers and investigate key population processes of mountain zebra in the 1,148 km2 area of the Naukluft extension of the Namib-Naukluft NP. A previous air survey (Kolberg, 2013) estimated a population of 2,643+/-452 but the author commented “The results of this survey should be seen as an absolute minimum….in some places the ruggedness of the terrain made it impossible to fly low and hence many animals will have been missed….secondly, zebras, when standing still, especially in the shade of a cliff or in a deep ravine, are extremely difficult to spot and some animals may have been missed…” Problems also arise in ground counts because of the escape behaviour of mountain zebra in broken terrain and while such counts provide a useful index, the problems can only be fully overcome by an individual-based census technique. Unfortunately this is a slow process because the recognition of individuals (using variation in stripe patterns) is time-consuming in a large population. It also takes a while to build up a network of camera traps and show whether or not they are sampling the entire population. Progress to date can be seen in the following map with the network of cameras in operation in 2016.

Figure 1. Camera trap locations in 2016 in the Naukluft extension of the Namib-Naukluft National Park, Namibia. The two orange symbols in the north-east show the two camera traps in Büllsport Guest farm that are mentioned in the text. © L.M.Gosling.

Large numbers of camera trap images are collected and the numbers of known individuals accumulate steadily as camera trap record are analysed. For example, at the time of writing (January 2017), 1,122 animals have been identified in 2016. An idea of progress can be obtained from the proportion of animals seen in the previous year that have identified in the next and, of the 1,723 animals identified in 2015, 41% have been seen so far in 2016. And 22% of the 1,122 animals seen so far in 2016 are new, some of them adults that have previously escaped detection and some new foals. There is a retrospective element in information about numbers because, when a new adult is identified, its presence can be back-projected for two years so there will be additions for two subsequent years before a total is complete. The total known alive in 2013, the most recent 'complete' year is 2,426. The proportion that this number is of the total population will finally be estimated using mark-recapture technique but this must await further analysis to determine what proportion of the whole population is being sampled by the camera traps deployed.

While the overall picture is still emerging some long-term results are available from individual waterholes where cameras have been in place since the project started in 2011. For example, at a waterhole called Panorama, which has been intensively sampled using camera trapping (plus some normal photography of wild groups), 627 individual mountain zebra have been recognised to date. Some of these must now be dead and the latest complete number for a year is 526 in 2013. The numbers known alive in 2011 and 2012 were 457 and 528 zebra which suggests that the numbers visiting this waterhole were relatively stable over these three years. These numbers were not of course

present at any one time. Mountain zebra are sometimes quite mobile and these numbers are the *'source population'*, the numbers that visit the water-hole over a defined period.

Individual-based techniques also allow the estimation of processes such as birth and death rates. Thus of the 457 animals known alive in 2011 at Panorama, 400 (87.5%) were still alive in 2013 which gives an annual mortality rate of 6.3% over these two years. This sample includes all ages and if the analysis is restricted to adults (over two years old) the annual mortality rate declines slightly to 5.9%. These rates are quite low considering that mountain zebra sometimes leave the Park and visit neighbouring livestock farms where some are shot. One reason for low mortality is that the key predators, lions and wild dogs are absent in this area. Leopards and spotted hyena are present in the Park in reasonable numbers and probably kill a number of foals and perhaps a few adults. Hyenas are potentially major predators of zebra but they are most effective as group-hunting, coursing predators on level ground and they do not form large groups in the mountainous Naukluft. Some mountain zebra are shot when they visit neighbouring farms and a small amount of trophy hunting is allowed in the Park. However, given known rates of increase, it is probable that none of these sources of mortality are sufficient to limit the population and it is more likely to be food-limited, particularly during severe droughts.

The most remarkable result during 2016 was unprecedented (in this study) movement from the Park onto adjacent farmland. Individual-based research has been underway at one such farm, Büllsport Guest Farm, since 2009 and over most of this period only small numbers of animals have moved between the Park and the Farm. This changed dramatically in the last months of 2015 and the first months of 2016 when there was large scale movement from the Park to the farm with the zebra somehow finding their way through livestock fences. The movement was probably a response to local showers which produced a green flush in the area to the north-east of the Park, including Büllsport, when there were drought conditions elsewhere. Distances travelled were over 45 km from Swartberg in the South-West and over 29 kms from Panorama in the North-East. 258 new animals were identified on the farm in 2016 and, of these, 84 (33%) were individually known animals from the Park. Such animals inevitably come into conflict with livestock farming interests and 10 out of the 84 known animals were shot. Most of the survivors moved back into the Park over the year, probably to feed on dry season food reserves at higher altitudes. However, due to the drought conditions, such reserves were in limited supply and there may have been significant natural mortality in 2016 which could continue up to the time when significant rain falls.

The Naukluft Park forms part one of Namibia's ambitious area-wide landscape conservation schemes: the Greater Sussusvlei-Namib Landscape. These schemes emphasise non-consumptive ecotourism as the land-use practice of choice in such arid areas; and the need for freedom of movement so that wild herbivores can respond to patchy rainfall. A number of properties have removed their fences in recent years and the movements seen in 2016 demonstrates how important the principles of free movement are for the long-term survival of mountain zebras in these emerging landscapes.

NamibRand Nature Reserve

Individual-based monitoring of the mountain zebra population in the northern part of NamibRand has been continuous since 2010 and it is now generally possible to estimate the approximate size of the population in any current year using an enumeration-based technique (see previous report for details). The population under discussion is the 'source population', the animals that use a defined area at some point in the year, not the numbers present at any one time (which are best estimated using mark-recapture). The source population is important because its size determines genetic viability (rather than the numbers present in one part of its range). And, in addition, these are the group of animals which may range far beyond the Reserve boundaries that need to be considered as a unit for conservation management.

Figure 2. Mountain zebra at the Moringa valley waterhole in NamibRand GR. The left hand animal is NR463f who was first seen as an adult in 2012; she has been seen every year since and has also been photographed at the Porcupine waterhole. *© L.M.Gosling.*

The enumeration-based procedure for calculating the size of the source population gave an estimate of 767 mountain zebra in the northern part of the NamibRand GR for 2015 and I aimed to repeat this procedure for 2016. However, this technique includes a predictive element based on the re-sighting rate of identified individuals from year to year: in practice, at this site, 73.5% of the individuals seen in one year will be seen in the following year. Unfortunately, sampling was erratic in 2015 and led to a prediction of only 231 of those identified in 2015 being seen again in 2016. If an average of 44% new animals were seen in addition to this then a total of 350 would identified in 2016. But, with relatively high quality sampling in 2016 and more photographs still to be analysed, the total actually identified in 2016 is already up to 380 and so, in spite of being incomplete, this latter value is preferred. The total source population also includes an 'uncatchable' element (animals that are temporarily outside the study area or too young to be identified) and on average these comprise 34.7% of the population. Including this element brings the total to 582 mountain zebra at an average density of about 1.94 zebra/km^2 (assuming the area occupied is about 300 km^2) in 2016. This is probably an underestimate because more photographs remain to be analysed from 2016 records and, until these are included, it is not possible ascribe any significance to the fact that the 2016 value is lower than the predicted estimate of 767 in 2015.

As mentioned in previous reports, the northern population of NamibRand is divided into two sub-populations, one in the north-west (and extending out onto the farm Geluk adjacent to the Reserve) and one in the north-west, the animals that spend most of their time in the Nubib Mountains. The sub-populations are separated by an expanse of flat open habitat (see Figure 3) and while groups of mountain zebra occasionally use these habitats they generally appear to return to their core areas. A further animal was discovered to have moved between the two sub-populations in 2016, bringing the total to two individuals out of 885 identified during the course of the study.

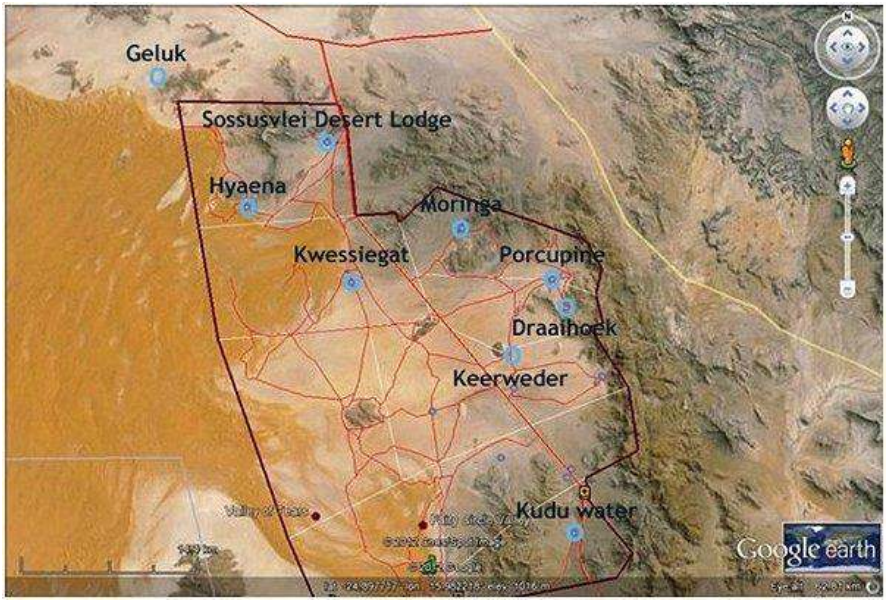


Figure 3. Map of NamibRand water holes mentioned in text and/or in previous reports. Adapted from a map prepared by Ann Scott.

The situation between the north and the more southerly group around Losberg changed dramatically during 2016. Previously only one animal was known to have moved between these two groups but, as in the Naukluft, movement in response to localised rainfall in otherwise dry conditions had a major effect.

In this study most animals are individually known and movement events (immigration) are signaled when a large proportion of the animals identified have never been seen before. This was the case in 2016 when of the 380 individuals identified so far, 32% were new. Many of the new animals appeared in January and February when they came to drink at the waterhole at the eastern end of the Moringa valley. By May the influx had ended and the new animals had mainly disappeared, presumably returning to the Nubib mountains in the east.

While mountain zebra are known to move large distances in response to variation in rainfall the movements seen early in 2016 were relatively unusual. The evidence for this comes from detailed records of individual zebra obtained from camera trapping over the past six years. The individual-based approach allows us to separate animals that are new because they have been born recently from those that are more likely to be immigrants because they were first identified as adults. So, for example, of the 314 individuals identified during 2015, only 30 (10%) were new and, of these, 16 (52%) were less than two years old. Many of the new individuals in 2015 were thus probably born in breeding groups

that are either resident in or regular visitors to NamibRand. In contrast, of the 120 new animals identified so far in 2016, 89% were over two years old and are thus likely to contain many immigrants. Camera trap photographs show that the immigrants were members of both breeding and bachelor groups.

The rainfall of the 2015-16 season was well below average and this may be partly responsible for the observed movements. As in most droughts there is patchy, localized rainfall and, within a few days, localized sprouting vegetation appears whose biomass is directly related to the amount of rain and soil conditions. On lowland plains the amount of green vegetation is greater for the same amount of rain than in rocky areas and so, at the start of the rains, mountain zebras typically move down towards such green flushes when they are available. When the vegetation is exhausted they move back to higher altitudes where vegetation has meanwhile often recovered (again depending on local rainfall) and where springs persist often into the dry season. Responses of this kind were probably responsible for the observed movements in NamibRand. One part of a more detailed analysis is to consider the condition of the animals when they arrive and when they leave. An example of this is shown in the following figure with a photograph of the adult female NR776f on the 23rd January 2016 when she was first detected and another of her just over three months later, on the 1st of May. The improvement in body condition is dramatic and supports the idea that the movement of which this female was a part is part of a seasonal feeding strategy to take advantage of localized grassland productivity.

Figure 4. Body condition of the adult female NR776f on the 23rd January 2016 (left photo) when first detected in the north-east of the Reserve and on the 1st of May (right photo). ©L.M.Gosling.

During 2016, camera trapping was resumed near Losberg in the central part of NamibRand and early results add further information about unusual movements in the reserve. Before 2016 earlier camera trapping in the south had revealed only one movement to the north. This was by a young female and was probably an example of the normal dispersal by young animals, often on their own, when they leave their birth groups. However, the new data from near Losberg (at the Verweg waterhole – not marked but near Kudu water in the map in Figure 3) showed a remarkable increase in the degree of overlap with the north. Of the 41 individuals identified so far at Verweg, 13 (32%) had previously been seen in the north. This is further evidence for major movement in 2016 probably in response to localized grazing conditions. Future research will investigate the extent to which animals return to their original locations after such movements. The numbers of mountain zebra in NamibRand are greater than previously known, but the population is still small in relation to the numbers needed to ensure long term genetic viability. Because of this, genetic exchange between sub-populations is essential and our study will aim to get an improved understanding of patterns of connectivity across the Reserve.

Gondwana Canyon Park and Ai-Ais National Park

Mountain zebra (HMZ) research started in Gondwana Canyon Park (GCP) in 2005 and intensive sampling using 16 camera traps at waterholes continued throughout 2016. The database that has been collected is now the longest series for any free ranging mountain zebra population and over 90% of the population is now individually known. Long term known-age data are necessary for most predictive modelling of animal populations and the individual records being collected are now becoming extremely valuable for unravelling key population processes. The main advance to date is in quantifying age-dependent mortality over the first 6-7 years of life and showing that a key factor is the risk of mortality during dispersal from birth groups during dry years. The main gap remaining is mortality when animals become senile and it is normal for this to be the last piece of the jigsaw when studying a long-lived species. Some sub-adult animals could be assigned a birth year back to 2003 at the start of the study and so some known-age individuals are now 13 years old. Overall over 60% of the population is now of known-age because most members have been born since the study started.

One particularly valuable older age group, even though their age is known only approximately, is the group of animals first identified in 2005 and 2006 who were already over two years old (and thus impossible to age in the field). This group must have contained animals from about two years of age up to the ecological maximum in the area. This latter is unknown but may be between 15 and 25 years, although, due to low rainfall (average 114mm per annum) it is likely to be lower than in more northerly parts of the species range. Information on this group can be used to estimate mean adult mortality. Of the 59 adults first identified in 2005, 25% had disappeared (presumed dead) by 2013 (the most recent complete year in which no further animals will be added by back-projecting animals that were seen subsequently), which gives annual mortality of about 3.2%. A similar calculation for the 47 adults first identified in 2006 gives annual mortality of 4.3% per annum.

It is helpful to divide the GCP area into two main sections for the purposes of this study since the South (consisting of the area around the Kanebis, Steenbokwater, Quaggagatt and Mynpos waterholes) has only been intensively studied since 2014. The remaining 12 waterholes have been monitored more-or-less continuously although the number of cameras has increased gradually over the years. In 2015 a camera was added at Rosentjiebos, in the Ai-Ais National Park and about 8 km to the west of the Gondwana Canyon Lodge and results from this camera are included.

In the North, the number of individuals identified in 2016 is 1,072. A few more will be added by further sampling but the great majority of individuals being identified at the time of writing have already been detected in 2016. This includes a small number known to have died during the year but most deaths go undetected (or cannot be identified) and a larger, unknown proportion will also have died since being identified due to the drought. Out of the 1,072 individuals, 20% were new to the study, some young animals identified for the first time and some new immigrants. An idea of progress in monitoring the population can be obtained by calculating the proportion of the animals identified in the previous year that have been seen in 2016. Thus of 1,054 seen in 2015, 72% have been seen so far in 2016. This proportion is close to what we would expect from regression analysis (reported previously) of these proportions on annual rainfall. The value is believed to be high in 2016 because animals are attracted in to permanent water and not because the population is high (in fact it has probably declined over the last two years).

In the South, 450 animals have been identified so far in 2016 and of these 22% are new. Using a similar calculation to that for the North, of 454 identified in 2015, 70% have been identified so far in 2016. The similarity of the re-sighting rates between North and South (72% and 70%) confirms that the whole population is being sampled at comparable levels.

However the values for North and South cannot be simply added together because some animals move between these two areas and this movement has increased in the last two years of drought. Thus of the 1,072 individuals seen in the North in 2016, 22% have also been seen at one or more of the four Southern water holes. Thus about 143 individuals are common to both North and South and the total identified in the Park in 2016 is thus about 1,379 zebra. And, as shown previously the number identified in a year is only a proportion of the true source population since some animals do not visit GCP during any one year. For example, in 2013, the most recent year when the individual census is complete, 1,259 animals were known to be alive but only 59% of these were identified during the year; the presence of the remainder were inferred by back projecting from records in subsequent years. If a similar proportion were identified in 2016, then the total source population in 2016 would be about 2,337 zebra. Of course this is not the number present at any one time which will be far fewer. In fact results to date suggest that the number of animals counted by Park staff during annual ground counts which take place on one day is about 56+/-8% (mean +/- SE) of the source population.

A key long-term aim at this site is to test the current working hypothesis that the GCP mountain zebra source population has reached mean carrying capacity and that in future it will tend to decline in dry years and recover in wet years. The size of these fluctuations may be large depending on the severity of drought conditions both in the Park and in ecologically connected areas to the west. It is however unlikely that the current situation has reached a form of dynamic equilibrium because the population does not yet have a stable age distribution. When this is achieved by a larger proportion of the population reaching senility the population should respond more sensitively to drought through a combination of density dependence and a larger part of the population being at risk. The most useful addition to this state of affairs (from a management perspective) would be an increased level of natural predation, perhaps though the natural (or assisted) arrival of a viable hyena population. These predators would tend to dampen the population fluctuations due to rainfall variation and, equally important, would maintain natural selection in the population.

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L. M. Gosling, Newcastle upon Tyne, UK.
7 February 2017.

Appendix A: Research proposal to MET (11 April 2006).

Population ecology of Hartmann's mountain zebra

PI: Prof. L.M. Gosling

Description of the proposed research

Objectives

We aim to carry out a long-term study of the population ecology of a newly protected population of Hartmann's mountain zebra (*E. z. hartmannae*: IUCN Red List Category EN Endangered A1b) and the interaction with their karoo habitat. The initial study area will be Gondwana Cañon Park, a recently established 112,000 ha reserve in southern Namibia. When the study of the Gondwana population is well-established, the study area will be extended to a wider area of southern Namibia since the Gondwana animals are part of the population that ranges widely across private and government-owned land in the south.

Specific aims are to estimate the mountain zebra population size within Gondwana Cañon Park and its seasonal and year-to-year variation, to estimate the factors limiting population size and the carrying capacity of the park under different rainfall patterns. These objectives are complicated by the movements of zebra within and outside the park and these movements, in relation to water and sward characteristics, will be a key focus of the study.

The limiting factors may be most easily detected by comparison with an area of high rainfall and we aim to collaborate with Okatumba Wildlife Research in Okomitundu Farm to carry out such studies of mountain zebra population ecology.

Motivation

Mountain zebra, *Equus zebra*, are an endangered species (IUCN Red List Category EN Endangered A1a) and Hartmann's mountain zebra are a 'Specially protected Species' in Namibia. However, locally in Namibia, they reach densities that may cause conflict with livestock farmers (Novellie et al 2002) and in low rainfall areas they may potentially damage the fragile plant communities on which they depend. Annual road transects in Gondwana Cañon Park show that the population is increasing (from estimates of 40 to over 400 in the past five years) and the park managers need to know what numbers the park can support without long-term damage to the vegetation of the park. In the absence of large predators (except small numbers of leopards), the population is probably limited by water and food, but the interaction of these two factors is poorly understood. Spatially explicit approaches are needed to measure the importance of various water sources and the local impact on plant communities within range of these sources.

The conservation of animals living in the arid south depends critically on movement in relation to unpredictable and patchy patterns of rainfall and plant productivity. The agencies responsible for conservation in the south of Namibia need to understand plant-herbivores interactions across large and heterogeneous areas of semi-desert. These areas may also change as some fences are removed to give greater freedom of movement; for example in Gondwana and between Gondwana and Fish River Canyon NP. The need for management intervention is generally reduced with greater freedom to move in relation to habitat variation. However, the changes that occur as such plans are implemented will require parallel understanding of ecological processes so that it is possible to modify management plans. The motivation of the project is to provide the underpinning ecological understanding that will allow rational conservation planning.

The SSC Equid Specialist Group's Status and Action Plan for Mountain Zebra (Novellie, 2002) includes the Recommended Action of '*Improving the protected area system*'. The work proposed here will provide the ecological knowledge needed to support this objective. It is also relevant to the Recommended Action of '*Promoting the maintenance of mountain zebras on farmland*' since the zebra population under study moves across private land as well as government-owned protected areas.

Research questions

- What is the population size of mountain zebra in Gondwana Cañon Park and surrounding areas and how does it vary between seasons?
- What is the carrying capacity of mountain zebra in Gondwana Cañon Park, under different rainfall patterns?
- What factors limit the mountain zebra population?
- Does competition with other large herbivores play a role?
- Is there evidence of density-dependent variation in reproduction?
- What are the main patterns of movement of mountain zebra in relation to variation in water, rainfall and plant productivity in space and time?
- How many animals use each of the main watering points in Gondwana Cañon Park and what is responsible for the variation?
- How do spatial constraints imposed by water dependence effect local plant communities?
- What are the main food plants for zebra in Gondwana Cañon Park? How does use vary seasonally and spatially?
- Does body condition vary seasonally and can it be predicted from forage conditions?
- How does group size, reproductive performance and condition differ in an area of high rainfall (Okomitundu)?
- What are the most appropriate long-term monitoring mechanisms available for zebra in the greater Gondwana area?
- What management options are most appropriate for zebra and their habitat in the Nama Karoo biome of the Gondwana / Fish River Canyon Parks.
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Previous relevant research by Principal Investigator

I carried out my PhD on hartebeest (*Alcelaphus buselaphus*) in Kenya (Gosling 1974, 1975) and while currently based in the UK, I have returned to Africa to work on other Alcelaphines such as topi (*Damaliscus lunatus*) and the population biology of hirola (*Beatragus hunteri*) a threatened alcelaphine in north-east Kenya (Gosling, 1987, 1990). Recently I have supervised a PhD study of hartebeest biogeographical variation throughout Africa which included field data collected in the Seeis Conservancy, Namibia under MET research permits 442/2001 and 591/2002; four papers have been prepared from this work and have been submitted for publication. I am currently supervising a PhD study on the ecology and conservation biology of giraffes in Etosha NP under MET research permits 560/2002, 760/2004 and 876/2005; the student, Rachel Horner, has finished field work and has returned to the UK to carry out DNA analysis before writing up; one joint paper has been prepared and will be submitted shortly. Further details of publications on ungulates including reviews of mating strategies (Gosling, 1986) are given in my CV. I am familiar with the work of colleagues who work on equid ecology and am a member of the SSC Equid Specialist Group.

Approach and methodology

The study will be carried out mainly in the field using 4x4 vehicles, telescopes and binoculars. Dependence on existing water sources and karoo habitat will be assessed using field survey (fixed road transects) and camera traps over wet and dry seasons. Fixed camera positions will be used for long-term monitoring of plant growth and vegetation transects will be used to estimate plant biomass and grazing intensity. Data on rainfall and its spatial variation are collected by Gondwana Cañon Park.

Estimates of numbers visiting all main water sources will be obtained using individual recognition and mark-recapture techniques. Movements and group membership will be determined by observations of known individuals during field surveys, by camera traps and, in the future, by GPS tag tracking. Body condition will be estimated using camera trap images. Demographic data including age structure and individual-based, spatially explicit population models (De Angelis & Gross, 1992) will be used for estimates of population viability (cf Novellie et al 1996).

Study species and collections

Vegetation samples will be collected for identification and as reference material for faecal analysis. Fresh faecal samples will be collected for future faecal analysis and, when the identity of the individual zebra is confirmed, for future DNA analysis.

Involvement of MET

No practical assistance will be required from the MET although discussion about the wider context of wildlife conservation in the areas around Gondwana Cañon Park and Fish River Canyon NP would be valuable.

Outputs

Reports will include project reports to the MET and papers submitted to international journals. The data obtained will be made available to the park owners for conservation management.

References

De Angelis, D.L. & Gross, L.J. 1992. Individual-based Models and Approaches in Ecology. Chapman & Hall, New York.

Novellie, P., Lindeque, M., Lindeque, P., Lloyd, P. & Koen, J. 2002. Status and action plan for the mountain zebra (*Equus zebra*). Chapter 3 in: Equids: Zebras, Asses and Horses: Status Survey and Conservation Action Plan (Ed Patricia D. Moehlman) IUCN.

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