



Mountain Zebra Project

Population ecology of Hartmann's mountain zebra in southern Namibia

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Figure 1. Mountain zebra group at Scorpion waterhole in the central region of Gondwana Canyon Park. Photo © Morris Gosling.

Introduction

This is the sixth progress report on a study of the population ecology and conservation of Hartmann's mountain zebra that has been underway since 2005. The project aims to help support the conservation of this sub-species in Namibia and to study population biology using an individual-based approach. Hartmann's mountain zebra (*Equus zebra hartmannae*) is a protected species in

Namibia and of global conservation importance (Novellie et al, 2002 & 2008; IUCN Red List Category: Vulnerable) and, while numbers have increased in some areas, they remain vulnerable under drought conditions, particularly where seasonal movement is restricted by enclosure 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).

My initial 2006 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 1874/2015. The longest data series is available from the first study site in Gondwana Canyon Park, a 1,253 km² private park that was established in 1997, and the adjacent Ai-Ais/Fish River Canyon NP but the study has been progressively expanded to additional areas. Further data have been collected from the northern part of NamibRand Nature Reserve, a 1,722 km² private park which is open to the Namib-Naukluft NP to the west and has been studied since early 2010. A large scale study is currently underway in the Naukluft mountain extension (1,148 km²) of the Namib-Naukluft NP in collaboration with the MET. Studies at Büllsport Guest Farm, a privately owned farm which promotes mountain zebra conservation and is adjacent to the Naukluft NP, and Geluk Farm which adjoins the NamibRand NR have provided valuable information about movements between state protected land and private farms. The Naukluft and NamibRand study areas, plus adjoining farms, fall within the NAM-PLACE Greater Sossusvlei-Namib Landscape scheme and the Gondwana CP study area falls within the Greater Fish River Landscape scheme. If successful, these ambitious, landscape-scale schemes may have enormous 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.

There has been further discussion about the problem of hybridization between mountain and plains zebra (best known in Etosha NP) and a senior MET scientist now plans to study this problem for a PhD at Witwatersrand University, RSA. In the meantime, this problem remains a major threat to the genetic integrity of Hartmann's mountain zebra.

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 have provided the main sources of external funding.

Methods

As before, I have adopted an individual-based approach (e.g. De Angelis & Gross, 1992). 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 type of bar-code which I developed for this study. The individual-based approach allows the 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. Results summarised here show, for the first time, how source populations can be predicted for any current year using historical data and such calculations are provided here for Gondwana CP and NamibRand NR for 2015. 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 reports.

Gondwana Canyon Park (GCP) and Ai-Ais/Fish River Canyon NP

The long term monitoring in Gondwana Canyon Park (GCP) has employed a cluster of camera traps in the north of the Park and these have provided the data on which the most important insights about population processes are based (including the analyses of age-specific survival presented in the last progress report). However, in recent years there have been conspicuous increases in mountain zebra numbers in the south of the Park and so in 2014 and 2015, in collaboration with Park staff, the camera trap network in GCP was extended to the south of the Park to investigate these changes. This was partly to investigate movements into and within the Park, and partly in preparation for area-wide monitoring of the large areas to the west that, together with GCP, form the Greater Fish River Landscape scheme. The following map shows the new cameras in the south and the proximity of Fish River Canyon to the west.

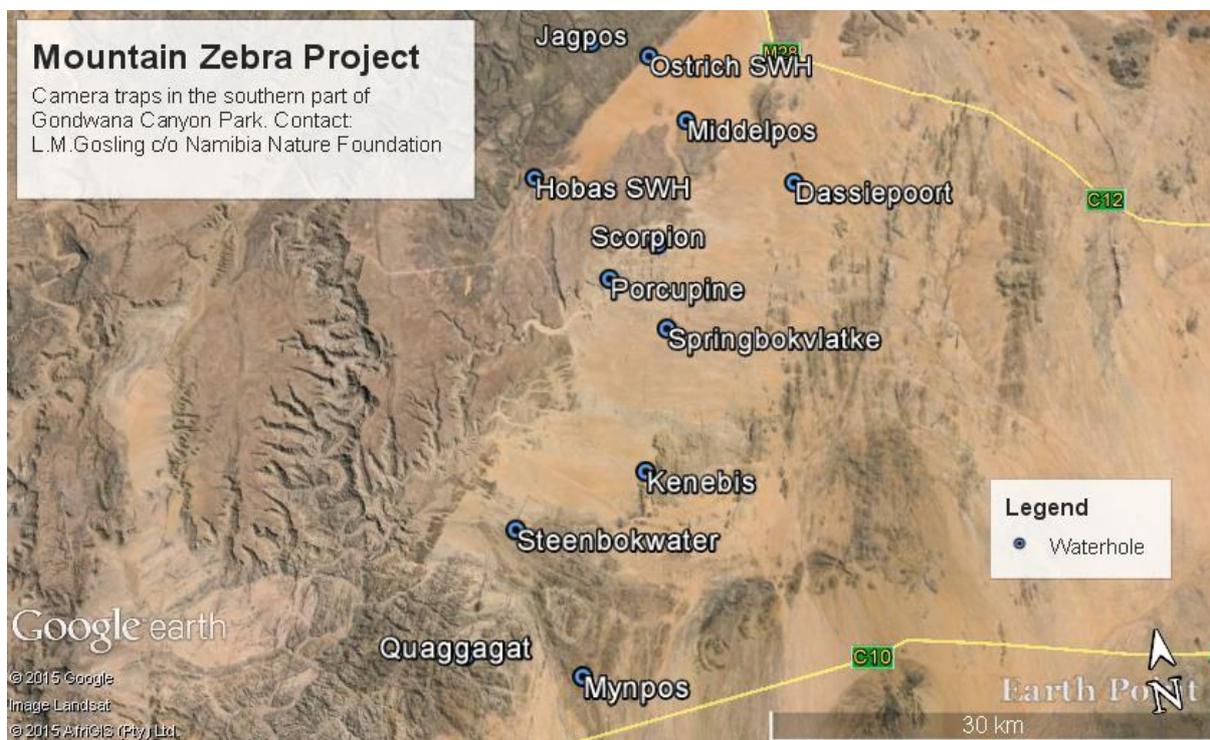


Figure 2. Camera trap network in the southern half of Gondwana Canyon Park.

Thus, a network of cameras now extends throughout the entire 1,253 km² of GCP. The Park has an elongated shape along a north-south axis and the camera network allows study of movements along this 70 km long axis. Up until the extremely dry conditions of 2015 (following the very low rainfall of the 2014-15 rains) these movements were very few. Less than 2% of the new animals detected in the south were shared with the north and most of these were males, suggesting movements dictated by searching and competing for mates rather than movements in relation to food and water. However, the large scale changes in numbers in the Park in recent years are believed to be the result of seasonal migration along an east-west axis in response to variation in food and water. The latest drought in 2015 appears to have caused additional movements with some animals moving north as grazing was locally depleted and, with most of the population now individually known, it has been possible to track these movements.

I have now worked in GCP since 2005 and have accumulated a useful database of known individual zebra and population changes. Over the last year I have used this historical information together with rainfall data collected by Park staff to predict mountain zebra numbers in any current year and the proportion of the 'source population' (see below) that is in the Park at any one time. The analysis is based on the numbers of individuals identified in past years (mainly from camera trapping), prediction based on responses to variation in seasonal rainfall and comparison with GCP ground counts (also carried out by Park staff and volunteers).

Briefly, once the number of individual animals identified in a year has been established, we can use regression analysis to predict 3 components in the annual total of the following year: (1) the proportion of the animals identified in a year that will be identified in the following year; (2) the proportion of the animals identified in a year that are new; and (3) the proportion of animals which are not identified in a year but which are known to have been present either from earlier or later observations (these can be called 'uncatchables': animals that are temporarily outside the study area or too young to be identified). This development comes partly from the finding, using annual values from 2005 to 2012 (the period when these numbers are complete in my database), that once the first variable is in hand, the others (1-3 above) can be predicted with a high degree of reliability from their historical relationship with seasonal rainfall. The Pearson r^2 values for the relationships between seasonal rainfall and the last three of these variables are respectively 0.50, 0.52 and 0.56 which shows what a massive influence this single independent variable has on mountain zebra dynamics in this arid system.

The numbers obtained by summing the results of the analyses outlined above give the *source population* in a year, that is, the animals that visit GCP at some time during the year (but are not all present at any one time). This can be compared with instantaneous estimates to give the proportion of the source population present at particular times. The best estimate of the numbers present at one time in the year comes from the annual ground counts carried out by Park staff and volunteers. However, the background time series analysis uses data from the Northern part of GCP where we have been collecting individual based data since 2005. And so the comparable ground count data are from those sectors of the annual ground count that fall in the Northern part of the Park. When both source population and ground count data are in hand we can then calculate the proportion in the Park at the time of the annual ground count and relate these to rainfall (Figure 3). Once again, this variable is significantly predicted by seasonal rainfall ($r^2 = 0.50$):-

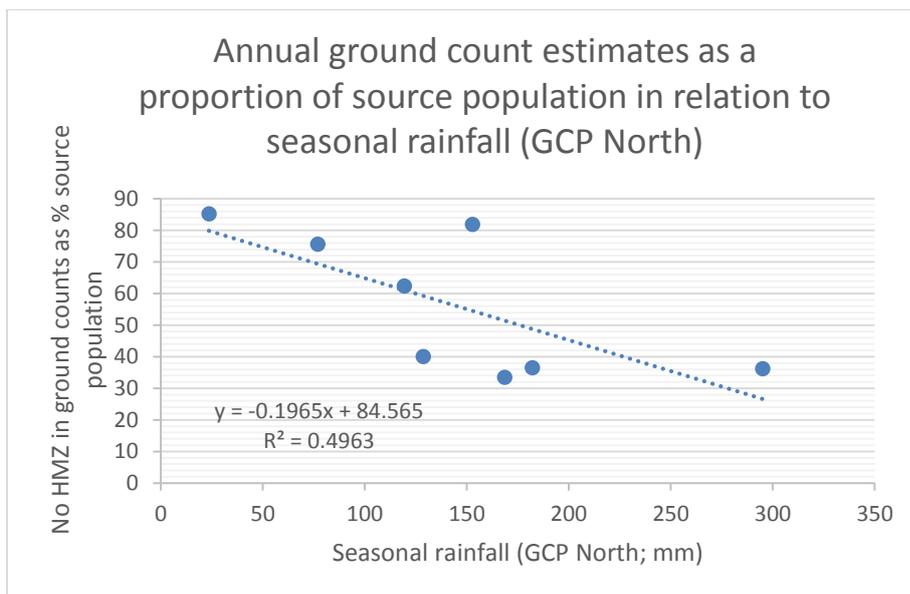


Figure 3. The annual total of mountain zebra estimated from ground counts in Gondwana Canyon Park (carried out by staff and volunteers) as a proportion of the source population (determined by individual-based monitoring) in relation to annual rainfall.

This means that once the number of known individuals in the previous year has been determined and the seasonal rainfall measured (when the season is over in April or May), the relationships mentioned above can be used to estimate numbers in any current year. Thus, in 2015, the proportion of the source population that was in the Park during the latest ground count can be estimated, following a season when rainfall was below average. The starting point is the number of individuals identified from camera trapping (and some normal photography) in 2014. This currently stands at 697 individuals (in the North of the Park). From relationship (1) mentioned in Para 3 above and the knowledge that the 2014-15 rainfall season was drier than average we can predict that about 86% or 599 of these will be seen in 2015. From relationship (2) above we can predict that 'new' animals will be about 31% of the animals identified in the year and so the total that will be identified will be about 874. Next we need to add animals in the south of the Park. We only started camera trapping in the South in 2014 but sampling was quite intensive and 394 were identified in that year. If the same relationships apply in the South of GCP as in the North we can calculate that the number identified in the South in 2015 (re-sightings plus new animals) will be about 494. The total for the animals that will be identified in the whole Park is thus about 1,368. But this does not include animals that will not be identified in the year, the 'uncatchables'. The average for these in previous years following below average rainfall is 30% of the source population and when these are included this suggests that the total source population of GCP in 2015 is about 1,965 animals.

With a source population of about 1,965 mountain zebra during 2015, and given the ground count estimate of 1,083, then about 55% of the source population was in the Park at the time of the count. This value falls below the regression line (although within the error; see Figure 3) for the relationship between rainfall and the proportion of the source population in the Park (probably due to heavier rainfall to the west of GCP, in the Ai-Ais National Park, which led part of the population to depart in that direction). The 2015 ground count estimate gives an average density of 0.86 mountain zebra per km² within the 1,253 km² Park. If this density applied across the range of the source population then it can be calculated that this population uses an area of about 2,274 km². While this calculation clearly operates on a number of simplifying assumptions (uniform density etc.), it suggests a scale for the point that the mountain zebra seen in any limited area are generally part of a larger population that needs a larger areas in which to survive.

GCP lies at the eastern edge of a larger mixed-use conservation area, the Greater Fish River Landscape (GFRL) scheme which includes the Ai-Ais National Park and extends over an area of 7,621 km². In the south this area adjoins the Richtersveld Park across the Orange River in South Africa and thus forms the vast Ai-Ais/Richtersveld Transfrontier Park. Mountain zebras exist throughout the Namibian sector of this huge area (they were eliminated in the Richtersveld and may need to be re-introduced) and their populations are slowly recovering following years of persecution by farming interests. Potentially, mountain zebra in this area will form one of the largest and most spatially unconstrained populations in Namibia but we know little about numbers or movements or the critical population processes that will allow us to assess its long term viability. Fortunately an aerial survey carried out under the aegis of the GFRL and the MET has been completed this year and the results are currently being analysed. It is intended that camera trapping will be extended westwards so its results can be integrated with the information yielded by the air survey.

NamibRand Nature Reserve (NRNR)

Monitoring continued on the mountain zebra population in NamibRand, in collaboration with Reserve staff, with camera traps at three water holes in the north (Hyena, Moringa and Porcupine – see map below). Recently the Reserve has purchased new cameras and it is hoped to resume sampling in the farm Geluk outside the north-west of the reserve (this has lapsed recently) and also waterholes in the south of the Reserve.

Sampling has been less systematic than in Gondwana CP but sufficient data are in hand (since monitoring started in 2010) to estimate the approximate size of the source population in the north of the Reserve. As in the case of the Gondwana CP estimate, the calculation starts with the proportion of animals identified in one year (yr) that will be identified in the following year (yr+1). Because of the smaller data base it is not possible to analyse the effect of variation in annual rainfall but the average proportion identified in yr+1 over all years is 73.5%. The number identified in 2014 was 449 and so we would predict that 330 of these will eventually be seen in 2015. Historical data show these are about 66% of the total that will be identified (the rest will be new) so we can expect to identify about 501 animals in 2015. Historical analysis also shows that these are about 65.3% of the total source population, the rest being 'uncatchables' (animals that are temporarily outside the study area or too young to be identified). The estimate, including uncatchables' for the total population for 2015 is thus about 767. It is difficult to give a realistic estimate of density for the population because the largest sector of the population spends most of its time in the Nubib Mountains which form the eastern fringe of the reserve and the population concerned is thus being monitored at its perimeter. Two of the GSNL satellite-tagged animals were collared in NamibRand and these have been photographed at the Moringa waterhole over the period of this report. Their range (see Mendelsohn 2014 a & b) provides the best indication to date of the population range to the east of NamibRand.

As mentioned in previous reports, the northern population 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 4) and while groups of mountain zebra occasionally use these habitats they generally appear to return to their core areas. Only one individual (out of 766 identified during the course of the study) has moved between the two sub-populations. It was first photographed on farm Geluk outside the north-western boundary of the Reserve (see Figure 4) and was then photographed at Moringa, 22 km to the south-east. This animal seems to have dispersed alone when 2-3 years old.

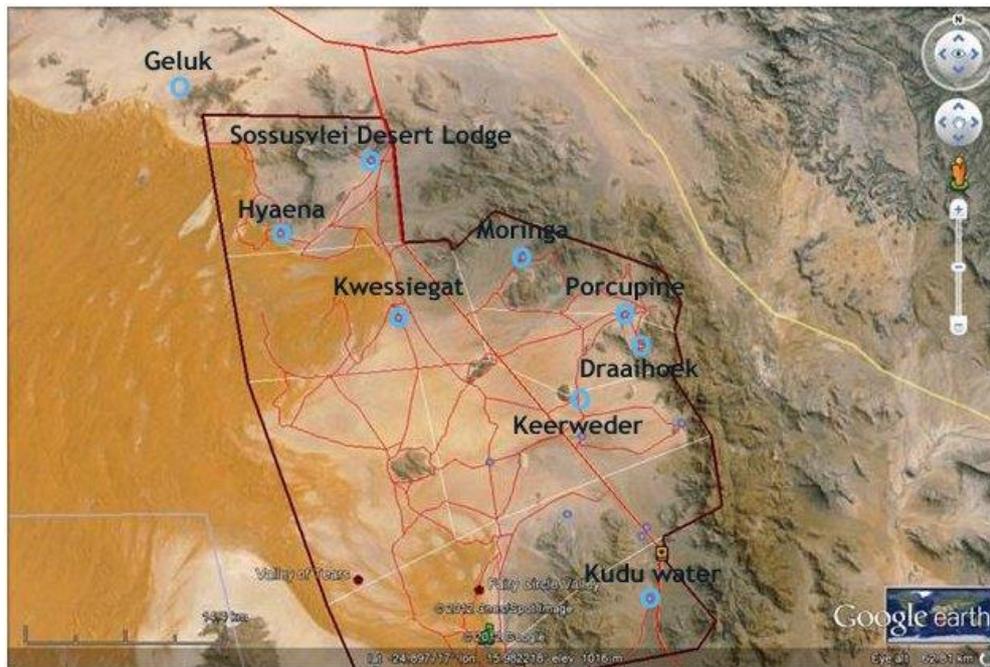


Figure 4. Map of NamibRand water holes mentioned in text and/or in previous reports. Adapted from a map prepared by Ann Scott.

The latest estimate of the source population in the NamibRand GR reveals that larger numbers are present than previously believed, but they are low in relation to the numbers needed to ensure long term genetic viability. Because of this, genetic exchange with other populations is essential and it is reassuring that there is some connection between the two northern sub-populations. A priority for the future is to investigate connectivity with animals in the south of the Reserve. One dispersal movements has been observed between animals in the Losberg area and the north-east but more information is needed.

Naukluft National Park

Monitoring of mountain zebra in the Naukluft extension of the Namib-Naukluft National Park (called the Naukluft NP here) has now been continuous since 2011. This Park probably contains the largest population of mountain zebras in a state protected area and is thus a key area for mountain zebra conservation. It is also a core part of the 5,730 km² Greater Sossusvlei-Namib Landscape (GSNL) scheme. The number of camera traps has been steadily increased and reached 11 in 2015 with the addition of a camera near the Olive Trail. The camera network has been designed to combine accessibility by a 4x4 vehicle and representative sampling across the Park. Camera positions are shown in Figure 5 and these also include cameras in neighbouring properties, especially Büllsport Guest Farm (see separate report below) to the east and Gondwana Namib Park to the west.

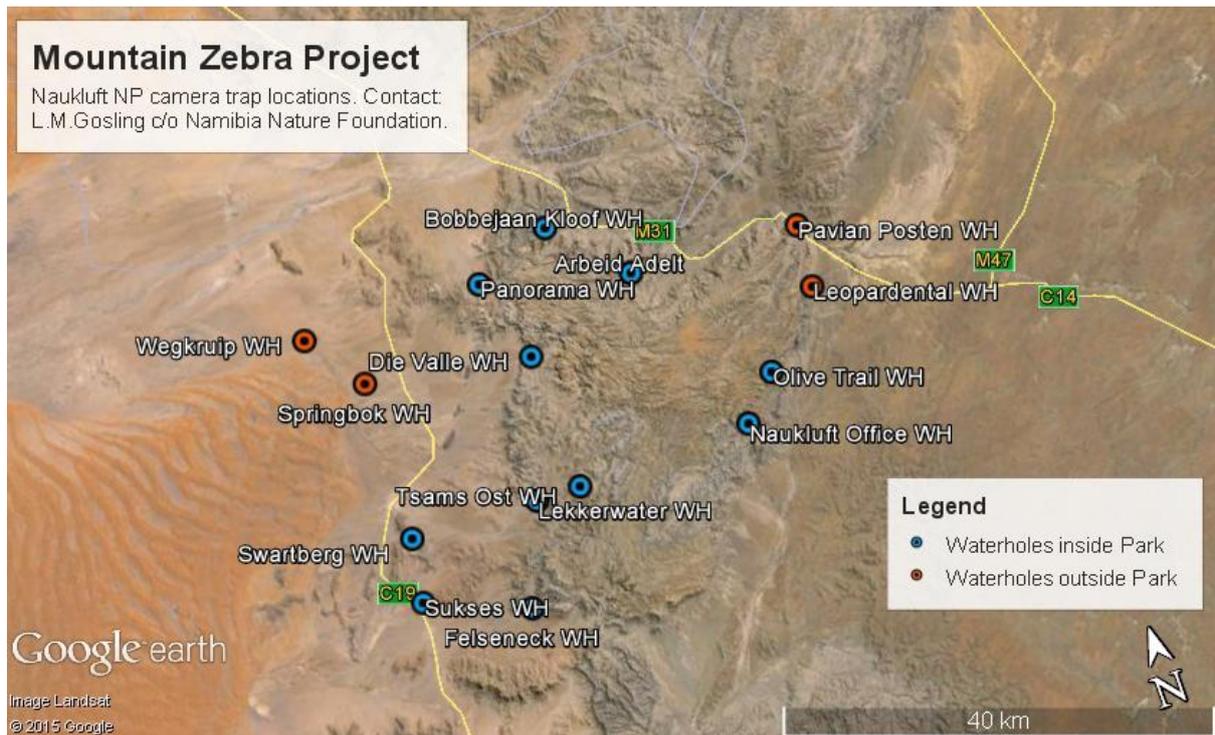


Figure 5. Camera traps in the Naukluft NP and in adjoining land holdings.

It is important to identify connectivity between water holes (the use of more than one waterhole by individual zebra) both to understand this important drivers of movements within the Park and to check how well we are sampling the entire population. Figure 6 shows the proportion of animals shared between pairs of waterholes. There are 11x11 cells in the connectivity matrix and for simplicity the graph includes only values where some overlap has occurred (i.e. it excludes zero values). As expected higher levels of connectivity occur between waterholes that are close together; the fitted curve is an exponential function. Perhaps the most surprising finding is that most values are so low (with two exceptions: Sukses/Swartberg and Sukses/Felseneck), even when water holes are close together. This suggests that many groups are relatively sedentary and also that groups visit many waterholes without cameras, perhaps natural springs in the Naukluft mountains. Presumably the low values are also partly a function of environmental stress and connectivity values may increase when more seasonal data are in hand and when animals are forced to move more extensively during droughts.

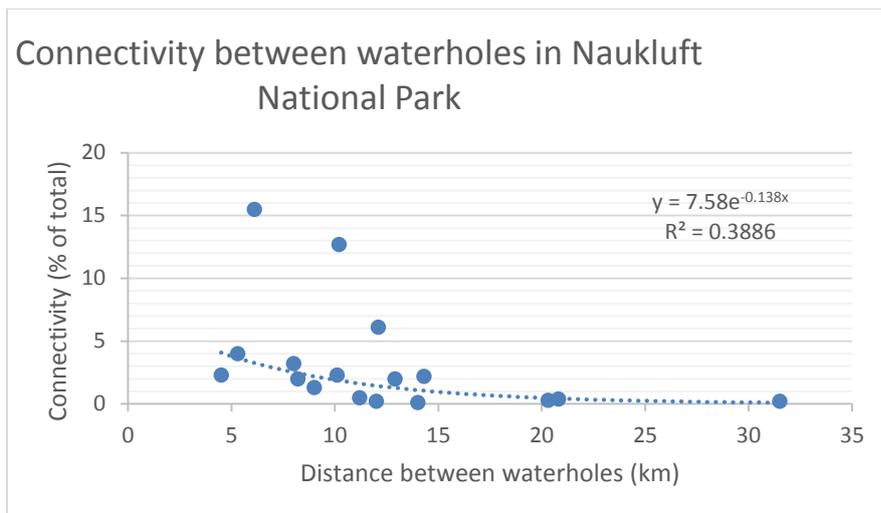


Figure 6. Connectivity between pairs of waterholes in the Naukluft NP. Values are calculated from frequencies of individual mountain zebra that occur at both of a pair of waterholes in relation to the total that use the two waterholes.

The establishment of an ID library, based on spatially-representative sampling, is a slow process because the process of establishing IDs must be done carefully and it is time-consuming. The ID library is now up to 2,289 individuals although some of these will have died. The number identified so far in 2014 and 2015 are 1,036 and 1,080 respectively although both numbers will increase as further data are collected (the total known to have been alive in 2013 is 2,069). It is not yet possible to carry out the same kind of analysis to predict population size as in the case of Gondwana CP and NamibRand NR (above) because the proportion of animals re-sighted is dependent on the period over which different water holes have been sampled. Thus of the 210 animals identified so far in 2015 at Panorama waterhole, 22 (10.5%) are new, a value that is low because this waterhole has been sampled continuously for 4 years (since 2011). By way of contrast, 89 (84.0%) are new out of the 106 identified so far in 2015 at the waterhole next to the old Naukluft MET Office where a camera was first set up in 2014. These numbers can be put in context by an MET air survey estimate in 2013 which led to an estimate of 2,643+/-452 mountain zebra (Kolberg, 2013). The author of the report of this survey believed that this value might be an underestimate and the individual-based data support this possibility.

As part of the MET programme supporting the Greater Sossusvlei-Namib Landscape (GSNL) scheme satellite tags were placed on a number of mountain zebra. Three of these occur within the Naukluft NP and their ranges has been mapped in detail elsewhere (Mendelsohn, 2014a & b). Two of these animals have been photographed at water holes and this has allowed information about their social status (which affects their ranging behaviour) to be recorded. The third animal, a male, has not yet been photographed and this, plus the low connectivity values mentioned earlier, raises the concern that a higher density of camera traps might be needed.

Büllsport Guest farm

Büllsport Guest Farm is in the Naukluft Mountains and lies just outside the eastern boundary of the Naukluft NP. The owners encourage a small population of mountain zebra by providing permanent water and the zebra are appreciated by the visitors to the farm who often see them during walks and horse rides. In recent years new fencing has been installed to reduce contact with the Park but some contact may still be possible across the tops of the higher mountains. Three animals have been seen both in Büllsport and in the Park which confirms movement between the two areas but it is not known if such movement is still possible. Small numbers of mountain zebra are culled in

Büllsport to limit competition with livestock and the animals killed are photographed to help with population monitoring. Monitoring of mountain zebra numbers started in 2009 and has continued to date with two cameras which are included in Figure 5 above. 132 animals have been identified so far in 2015 and of these 17 (12.9%) are new). 155 were identified in 2014 and of these 111 (71.6%) have been identified so far in 2015. This is similar to the average re-sighting frequencies calculated for Gondwana CP and NamibRand NR but the source population cannot be easily estimated because of the changes due to fencing.

Etosha National Park

An important population of mountain zebra occurs in the Otjovasandu area of Etosha NP. This area is at the western end of the Park and it is separated from the mountainous areas to the west by the boundary fence. Plains zebra (the Burchell's subspecies) occur throughout the Park and overlap with mountain zebra at Otjovasandu. I visited Otjovasandu briefly again early in May 2014 and added 76 more individuals to the reference library. This brings the number of known individuals in Etosha to 392 (about 49% of the 802+/-116 estimated by mark-recapture in 2012; Gosling 2012). However some of the 392 may have died since the study started in 2012 and an updated estimate would require further systematic sampling.

As mentioned in previous reports, there are reports of animals of intermediate phenotype between mountain and plains zebra and preliminary molecular analysis using faecal DNA shows evidence for hybridization between the two species (Pauline Kamath, pers comm.). It is not known whether such individuals are part of a normal hybrid zone between the two species or if hybridization is an artefact, perhaps due to the effect of the boundary fence which may prevent normal seasonal movements by mountain zebra into the mountains west of the Park. Hybridization potentially represents a major threat to the genetic integrity of mountain zebra and work to investigate this problem remains a conservation priority. Fortunately, a senior MET scientist plans to conduct a PhD on the problem and hopefully this will produce the information needed to plan intervention, should this prove necessary.

Acknowledgements

In Gondwana Cañon Park I am grateful to Sue and Trgyve Cooper, Eddy Shipulwa and the other staff at Holog for much help and support and for looking after the camera traps that were used to monitor mountain zebras; and to Chris Brown and Manni Goldbeck for long term support and encouragement. In NamibRand Nature Reserve I thank Nils Odendaal, Quintin and Vanessa Hartung and their colleagues at Keerweder for ongoing support and collaboration; thanks also to the Directors of NamibRand for permission to work in the Reserve and Dennis Hesemans for hosting a camera trap on the adjacent Geluk farm. I am grateful to Ernst and Johanna Sauber who have provided hospitality and support for the work at Büllsport Guest Farm and to Jonny Kuelbs who has helped look after the camera traps there. Jonny Kuelbs and Clärin Bohn have also helped look after camera traps in the Naukluft Park and this has helped enormously with the expanded study there. Lastly, I am grateful to the Ministry of Environment and Tourism, especially Kenneth /Uiseb, Manie le Roux, Riaan Solomon, Gabriel Liu, and Werner Kilian for support and permission to carry out research in Namibia (most recently under MET research permit 1874/2015). The Rufford Foundation, Montpellier Zoo, the Namibia Nature Foundation and Newcastle University have provided financial and administrative support; the Whitley Fund for Nature made a generous donation to the project.

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11 October 2015.**

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

Population ecology of Hartmann's mountain zebra

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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.

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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