Progress Report I

Population ecology of Hartmann's mountain zebra

2018

Waiting to drink at the Moringa waterhole in NamibRand Nature Reserve. The animals are members of a breeding group and the small waterhole is occupied by a dominant female (right). The two animals waiting to drink are offspring in the group, the youngest born in the 2016-17 summer and, on the far left, a male born in 2015. Photo © L. M. Gosling

Introduction

This is the eighth progress report on a long-term study of the population ecology and conservation of Hartmann's mountain zebra (*Equus zebra hartmannae*), through wet and dry cycles, that has been underway since 2005 in partnership with the Ministry of Environment and Tourism, Gondwana Canyon Park and NamibRand Nature Reserve. It deals mainly with 2017, the most recent year of almost complete sampling. An additional notable event was the completion of the IUCN Red List re-assessment for the sub-species. The assessment was prepared by a working group comprising Kenneth /Uiseb, Holger Kolberg, Jeff Muntifering, Sarah King and myself and will be published during 2018 (Gosling, L.M., Muntifering, J., Kolberg, H., Uiseb, K. & King, S.R.B. 2018. *Equus zebra* ssp. *hartmannae.* The IUCN Red List of Threatened Species 2018. In press.).

The Mountain Zebra Project aims to help support the conservation of the sub-species 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; Gosling et al, 2018; IUCN Red List Category: Vulnerable, A3bcd (IUCN version 3.1) 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 (Barnes, et al, 2009). 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 2259/2018. The longest data series is available from Gondwana Canyon Park, a 1,253 km^2 private park established in 1997, and the adjacent Ai-Ais/Fish River Canyon NP and the study has since been expanded to additional areas for comparative purposes. Work started in 2010 in the NamibRand Nature Reserve, a 2,150 km^2 private protected area which is open to the Namib-Naukluft NP to the west. A large scale study is underway since 2011 in the Naukluft mountain extension (1,148 km^2) of the Namib-Naukluft NP and at Büllsport Guest Farm and Gondwana Namib Park, both of which adjoin 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 will have great value for mountain zebra conservation because they are large enough to support genetically-viable 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, the adjacent Hobatere Concession area since 2016.

Feedback has been provided about the results of the study to all landowners and other stakeholders involved and to the Rufford Foundation, Montpellier Zoo and the Gaia Nature Fund 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 have developed for this study. Water hole sampling takes advantage of the fact that mountain zebra are water dependent and must drink on most days, particularly in dry weather. The design of camera trap networks to achieve representative sampling of zebra populations depends on local knowledge about the use of water resources and calculation of connectivity between pairs of waterholes in the network. 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 study area in western Etosha NP (Otjovasandu) was visited twice during 2017, and sampling carried out as before using normal photography from a car. Large numbers of photographs of right sides of the body of zebra were taken at all of the main waterholes (Dolomietpunt, Klippan, Rateldraf, Jakkalswater and Renostervlei) and individuals identified from their stripe patterns. The total number of individuals identified in 2017 was 507, and some more identifications in 2018 bring the total known alive in 2017 (from this technique) to 520. The total number in the Etosha ID library is now 1,046 although some of these animals will have died since being identified (the study started in 2012). Work in the Park, as before, was designed to allow mark-recapture estimates. The May 2017 estimate, based on 3 days 'marking', an interval of one day, and 3 days 'recapture' was 857+/- 168 (mean +/- SE) mountain zebra. The November-December estimate based on 2 days 'marking', an interval of one day and 2 days 'recapture' was 1,136+/-220 mountain zebra.

As reported previously, a 'citizen science' project is being undertaken to try to take advantage of the large number of photographs taken by visitors to the Park. Posters have been put up at the Galton Gate and at Dolomite Lodge and a Facebook page started to encourage such assistance (see https://www.facebook.com/EtoshaHMZ). A number of people have sent in their photographs but while these have been extremely valuable, more work is needed to promote the scheme before it becomes useful at a population level.

The Hobatere Concession Area was visited on single days in May and December 2017 and the mountain zebra sampled using normal photography and individual recognition. 87 individuals were identified in 2017 compared to 108 individuals in 2016. Hobatere is notable because the population has exceptionally few young animals. There were 3 animals (2.8%) between 1 and 2 years old and none below 1 year old in 2016; and none below 2 years old in the 87 animals identified in 2017. Observation of animals seen in the field (including those that could not be photographed for IDs) gave the same result. Thus, there appeared to be extremely low or zero recruitment to the adult population in these two years. This is in contrast to the nearby population in Etosha NP, where of the 178 individuals identified in Etosha in 2016, 10.7% were under 2 years old when first seen; and of 242 identified in 2017, 9.1% were under 2 years old. In the absence of any obvious recruitment in the Hobatere population, it must thus be declining at some unknown rate. If it is being replenished by immigration this raises the

question of the impact on the source population. The most likely factors responsible for reproductive failure at Hobatere are the food supply and/or predation by lions. The food supply was poor in 2016 but the rains of 2016-17 were good and produced excellent growth of grass and other herbs. This grass from 2016-17 still persisted as extensive and abundant standing hay in late 2017, and the mountain zebra were in good condition. Thus, it seems unlikely that the food supply was limiting reproduction. In contrast, there is evidence that lion predation may have a significant impact at this site. Both of the main two main waterholes used by zebras at Hobatere are close to rocks and scrub that provide good cover for lions, a predator that is a specialist ambush hunter. Mountain zebra are water-dependent and usually drink at least once every day. Given the absence of alternatives (except for brief periods following showers when there are temporary pools) they thus approach the two water holes in a highly predictable fashion and, inevitably, hunting attempts by lions, both unsuccessful and successful occur very frequently. There have been several zebra corpses fresh and old in the vicinity of the waterhole when I have visited. Where conditions for predation are thus weighted towards the lions, the most vulnerable animals will be taken first and it seems possible that young zebra may have been completely removed in this process. There are precedents for this from other areas, for example in the Serengeti NP in Tanzania where the zebra population is believed to be limited by predation and where the main impact is via predation on animals of under a year.

The situation at Hobatere could be modified by providing more waterholes of a design that reduces the chance of predation to normal levels by providing improved visibility; the waterhole design used in Etosha NP seems a good model. Reasons for doing this are first that the mountain zebra population in Hobatere is valuable as part of the relatively small proportion of the national population that occurs in protected areas; and second, the future of the important lion population in Hobatere ultimately depends on a healthy zebra population as a key food resource and at present this appears to be under threat.

Naukluft National Park, Büllsport Guest Farm and Gondwana Namib Park

Two visits were made to the central Namib study areas during 2017, in May and November and camera trapping continued throughout. The network of camera traps in the Naukluft extension of the Namib-Naukluft NP functioned quite well with breakdowns mainly due to damage by spotted hyenas and baboons. Analysis of 2017 photographs is well advanced but not yet complete. At the time of writing in July 2018, the mountain zebra ID library for the Naukluft NP contains 3,556 individual zebra, although some of these will have died since being identified. The largest annual total known alive was 2,933 in 2015 (this is larger than more recent values because there is a retrospective element in the enumeration: for example animals seen in 2014 and 2016 must have been alive in 2015 even if they were not identified). The number known alive in 2017, the year under report is 1,824 but this will increase with further sampling. These 2017 numbers include a small number of animals (29) identified from the camera traps in Gondwana Namib Park (the landholding containing Namib Desert Lodge to the west of the National Park). Numbers on Büllsport Guest Farm are assessed separately and 84 were known alive there in 2017. In addition, 45 animal that had previously been seen in Büllsport were seen at various locations in the National Park. Numbers in Büllsport depend on differences in rainfall and herb layer quality between the farm and the National Park. Thus in 2016, there were relatively good rains in Büllsport and 436 individual zebra occurred there (not all at the same time) mainly due to easterly movement from the Park. The far lower value of 84 in 2017 is because of relatively good rains in the National Park which held the zebra in the Park.

Representative sampling requires a well-placed network of cameras and the process of establishing the network is still continuing in the Naukluft. There are currently 14 cameras in the National Park, 3 in the adjacent Gondwana Namib Park and 2 in the adjacent Büllsport GF. Individuals and their social groups range across the entire Park, from Namib Desert Lodge outside the Park in the west, across the Naukluftberge to Büllsport in the west. But such movements do not occur every year and most animals are relatively sedentary, being detected by single or small groups of cameras in the network and so it is not possible to wait for such movements in order to sample the entire population. To fill possible gaps, two new cameras were installed in 2017 and when results from these additions are analysed they will help test whether or not the network is sampling the entire population and thus whether it is valid to estimate population size.

The data series from the Naukluft can now be used to explore population trends, particularly from cameras at waterholes that have been continuously sampled. For example, the waterhole at Panorama has been sampled each year since 2011. The annual source population of mountain zebra for this waterhole (the number of individuals that visit it during a calendar year) between 2011 and 2015 have varied between 459 and 540 with no clear upward or downward trend. The average proportion of new individuals at Panorama over the 3 years 2015-17 is 9% and so most (over 90%) of the source population for this waterhole is now known. Individuals from the Panorama source population have been found throughout the Park but most (79% of the 689 animals in the Panorama ID library) have been seen only at Panorama; some that range more widely will clearly have been missed but this does emphasise that movements in response to forage variation does not usually involve entire populations.

Individual-based techniques allow accurate estimation of mortality rates. Thus, of the 1,273 animals known alive in 2011 in the Park, 898 (70.5%) were still alive in 2015 which gives an annual mortality rate of 7.4% over these four 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 7.1%. 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 reasonable numbers and probably kill a number of foals and perhaps a few adults. However, given known rates of increase, it is probable that none of these sources of mortality are sufficient to limit the population. It is more likely to be food-limited and future work will aim to test this possibility.

NamibRand Nature Reserve

Work on mountain zebra started in the NamibRand Nature Reserve (NRNR) in 2010 and, as at other field sites, the central technique employed is individual-based monitoring using camera traps placed at waterholes and field visits to photograph social groups.

There will be further analysis of camera trap results from 2017 but the current analysis is well-advanced. 401 individual mountain zebra have been identified and, of the 387 animals identified in the previous year, 63% have been re-sighted so far in 2017. This percentage will increase a little but in ongoing analysis, the great majority of identifications from 2017 photos are now of animals that have been seen previously during the year. 75 of the 401 animals identified in 2017 have never been seen before. Such new animals generally occur because of reproduction or because they have moved as adults into the area. A third possibility, that animals were present but missed is unlikely since HMZ are water-dependent and thus likely to appear on some of the many thousands of photos taken by camera traps placed at waterholes. In 2017, 85% of the new animals were over 2 years old, so while there have been

a few new foals, the majority are adults and the numbers indicate a moderate level of movement in and out of the area in a year with below average rainfall.

Analysis of long term changes in HMZ numbers is limited by unplanned variation in the performance of cameras and consequent sampling bias. However, the camera in the Moringa valley has been consistently in place and trends can potentially be detected using the 'source population' for this camera. This term refers to the population of animals that visit an area or camera but are not always in that area. There is a high level of connectivity between Moringa and other waterholes in the north-east: 29% in the case of the Porcupine waterhole which is 9 km away; and even 5% with Verweg 23 km to the South near Losberg. The Moringa camera thus samples a wide ranging population probably extending throughout the Nubib mountains. Excluding the value for 2010 and those for the last two years which are still incomplete, the mean size of this source population is 428+/-17 (+/- SE; n = 5) with remarkably little change throughout the period. The total number known alive from all NRNR cameras (5 in 2017) over the same period was 618+/-14, and so, with the reservation mentioned previously about sampling, the Moringa source population is probably about 69% of the northern Reserve population (from the northern border down to and including Losberg).

The number actually in the Reserve at any one time can be estimated using mark-recapture technique. Previous estimates for the northern part of the Reserve were 178+/-9 and 235+/-14 in 2010 and 2011 respectively and these estimates were 37% and 41% of the source populations for those years. Most of the remaining animals were probably ranging outside the Reserve to the east, in the Nubib mountains and beyond. Similar proportions may apply to the Moringa source populations and this will be checked in future analysis. However, most attention is given to the source population in this study because (1) this population gives a more accurate indication of genetic viability, and (2) because it's full range, encompassing other landholdings, must be considered for conservation management of the animals that visit NamibRand.

The information from Moringa suggests that the HMZ population is relatively stable and research is underway to measure the population processes that are characteristic of this state and that potentially limit its size. One key variable is the mortality rate of adult animals. Mountain zebra may live over 20 years in captivity but ecological longevity is probably less than this and there is a possibility that the NRNR population has a balanced age structure, that is, with a substantial proportion of animals approaching ecological longevity and dying from age-related causes, perhaps mainly in dry years. Considering all of the animals identified in NRNR, there were 413 animals over two years old, known to be alive in 2010 and of this sample 57.4% were still alive 5 years later in 2015. If it is assumed that the missing animals died this gives an annual adult mortality rate of 8.5%. More data are needed to carry out broader analyses of age-dependent mortality, and to establish mortality rates in relation to rainfall variation between years.

Gondwana Canyon Park and Ai-Ais National Park

Research on mountain zebra started in Gondwana Canyon Park (GCP) in 2005 and sampling using 16 camera traps at waterholes continued throughout 2017. The area was also visited twice to photograph social groups and collaborate with Park staff on camera trap maintenance. The data series in hand is now the longest for any free ranging mountain zebra population and one key aim is to establish ecological longevity for this important sub-population. 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 15 years old; overall, over 60% of the population is now of known-age because most members have been born since the study started. Mountain zebra live for over 20 years in captivity but it is expected that ecological longevity in the arid South of Namibia will be less than this.

The next few years will thus be critical in obtaining information about patterns of mortality when animals become senile and the roles of density-independent and density-dependent factors in shaping these processes.

As in previous reports, 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 since 2005 although the number of cameras has increased gradually over the years.

In the North, (in fact the Northern and Central regions of GCP) the number of individuals known to be alive in 2017 (those identified plus some inferred to be present from subsequent sampling) was 1,185. More will be added by further sampling. Out of these 1,185 animals, 11% were new to the study. Most of these were new adults seen in the area for the first time since birth rates have been remarkably low in both 2016 and 2017, at least partly a result of dry condition. Progress in monitoring can be assessed by calculating the proportion of the animals identified in the previous year that have been seen in the next. Thus of 1,220 identified in 2016, 69% have been confirmed as alive so far in 2017. These values all refer to the 'source population', the number that visit an area during the year although they are not all present at any one time.

In the South, 352 animals are known to have been alive in 2017 and, of these, 3% were new. 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 recent drought years. Thus of the 1,185 individuals known alive in the North in 2017, 20% have also been seen at one or more of the four Southern water holes. Thus about 237 individuals are common to both North and South and the total identified in the Park in 2017 is thus about 1,300 mountain 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 2015, the most recent year when the individual census is complete, 2,016 animals are now known to be alive but only 68% 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 2017, then the total source population in 2017 would be about 1,835 mountain zebra. Of course this is not the number present at any one time which will be far fewer. In fact results from past years suggest that the number of animals counted by Park staff during annual ground counts which are carried out on a single day is about 56+/-8% (mean +/- SE) of the source population.

Sufficient data are now in hand from GCP to obtain preliminary estimates of mortality in relation to seasonal rainfall. This new analysis employs the change in the number known alive from one year to the next (i.e. the number of the known individuals that survived) to obtain the number and % that disappear. The presence of an individual in a year is based on long-term records and so is more likely to be due to death than movement. The data are from 10 years between 2005 and 2015 and refer to the source population, not the number present in the Park at any one time. The analysis does not include the last two years because the back projection procedure used to enumerate numbers known alive is not complete yet for 2016 and 2017. In the 2005-15 period, the average 'disappearance rate' (here assumed to reflect the mortality rate) is 4.2+/-0.6% and the r^2 value for the relationship between rainfall and disappearance rate is 89.8%. This suggests that rainfall (including its associated effect on the food supply) is by far the most important variable predicting annual mortality. Population density does not seem to have significant effect on annual mortality rate in these preliminary analyses but this may change as the population assumes a more balanced age-structure with a higher proportion of older

animals. This sector of the population is known to be more sensitive to environmental stress (a higher proportion of old animals disappear in dry than wet years) and density dependence may thus become more important.

Acknowledgements

In Etosha NP I am grateful to Tashiya Joseph in Otjovasandu, Werner Killian at the EEI and all Park staff for advice and support. In the Hobatere Tourist Concession I thank Marco da Rocha and Albert Simwanza for advice and kind hospitality.
In the Namib-Naukluft NP, I am grateful to Cebens Munanzi, Ephraim Matheus and the Ministry of Environment and Tourism field team for their support; and at Büllsport Guest Farm to Ernst and Johanna Sauber and their staff, with special thanks to Jonny Kuelbs at Büllsport for helping monitor the camera traps down the eastern side of the Naukluftberge. The Gondwana Namib Park adjoins the Namib-Naukluft NP and I am grateful to Quintin Hartung and Persival Sikonga for sending to me photographs from their network of camera traps. Thanks also to Hoger Kolberg and his colleagues for letting me have images from their monitoring of vultures in the Namib-Naukluft NP.
In the NamibRand NR I am grateful for the support and collaboration of Nils Odendaal, Murray and Lee Tindall and their colleagues at Keerweder; and to Denis and Andreia Hesemans at Namib Sky Balloon Safaris on the farm Geluk. Thanks also to the Directors of NamibRand for permission to carry out this work.
In Gondwana Canyon Park I am grateful to Quintin Hartung, Eddie Shipulwa, Mathias Tsameya and the Holoog field team, and to Sue Cooper and the Ai-Ais National Park MET staff, for their help and collaboration; and to Chris Brown, Manni Goldbeck and Philip Brand for support and advice.
I am also grateful to the Ministry of Environment and Tourism, especially Kenneth /Uiseb, Manie le Roux, Riaan Solomon, Tashiya Joseph and Werner Killian, for support, advice and permission to carry out research in Namibia (most recently under MET Permit Number 2259/2018). The Rufford Foundation, the Whitley Fund for Nature, the Parc Zoologique de Montpellier, the Gaia Nature Fund, the Namibia Nature Foundation and Newcastle University, UK have provided financial and administrative support.

References

Barnes, J.I. Nhuleipo, O., Baker, A.C., Muteyauli, P.I. and V Shigwedha, V. 2009. Wildlife resource accounts for Namibia, 2004, DEA Research Discussion Paper, Number 79, June 2009

Barnes, J.I. and de Jager, J.L.V. 1996. Economic and financial incentives for wildlife use on private land in Namibia and the implications for policy. South African Journal of Wildlife Research 26: 37-46.

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

Gosling, L.M. 2012. Mark-recapture estimate of mountain zebras in Etosha National Park. http://www.the-eis.com/data/literature/MZP%20Mark-recapture%20estimate%20Aug-Sep12.pdf

Gosling, L.M., Muntifering, J., Kolberg, H., Uiseb, K. & King, S.R.B. 2018. *Equus zebra* ssp. *hartmannae.* The IUCN Red List of Threatened Species 2018. In press.

Kolberg, H. 2012. Report on an aerial survey of Etosha National park, 6 to 17 August 2012. MET unpublished report.

Kolberg, H. (2013). Report on a mountain zebra aerial survey in the Naukluft and Khomas Hochland, 19 to 24 June 2013. MET unpublished report, pp 1-5.

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.

Novellie, P. 2008. *Equus zebra*. In: IUCN 2013. IUCN Red List of Threatened Species. Version 2013.2. <www.iucnredlist.org>.
Seber, G.A.F. 1982. A review of estimating animal abundance. Biometrics 42, 267-29

L. M. Gosling, Newcastle upon Tyne, UK.
24 July 2018.

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.

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. 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. 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.

Novellie, P.A., Millar, P.S. & Lloyd, P.H. 1996. The use of VORTEX simulation models in a long-term programme of reintroduction of an endangered large mammal the Cape Mountain Zebra (*Equus zebra zebra*). *Acta Oecologia*, 17, 657-671.