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Scientific Reports on Research Projects undertaken in the Kruger National Park during 2006

South African
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FELINE LENTIVIRUS: MOLECULAR ANALYSIS AND EPIDEMIOLOGY IN SOUTHERN AFRICAN LIONS

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Feline immunodeficiency virus (FIV) is a retrovirus belonging to the genus *Lentivirus* in the family *Retroviridae.* Infection of domestic cats leads to progressive immune dysfunction. Infected animals succumb to a variety of infections and diseases secondary to immunosuppression. Serological testing has indicated that free-ranging lions in South Africa are infected with a lentivirus that is related to feline immunodeficiency virus (FIV) of domestic cats. Little information exists about the genetics and epidemiology of the virus in southern African lions, as the virus has not been successfully isolated from these populations.

We investigated the lentiviruses of southern African lions through a combination of direct genetic amplification from biological samples of 128 lions using PCR, as well as an ELISA assay for antibody detection on 93 of the 128 lions tested with PCR. Fifty-three lions tested positive by PCR, and 59 lions tested positive by ELISA for antibody. The [RT-pol] region of 40 samples from these lions were successfully amplified. All amplification products were sequenced and analyzed with genetic characterization to determine regions of conservation and heterogeneity, and compared with lentiviruses from other felids. Correlates of all resultant data with parameters such as health status, age, gender, geographic locale, and group size were performed, and will aid investigation into the epidemiology in free-ranging populations. This information may be exploited to develop improved methods for virus and virus-specific antibody detection.

WILDLIFE CONSERVATION THROUGH PEOPLE CENTRED APPROACHES TO NATURAL RESOURCE MANAGEMENT AND THE CONTROL OF WILDLIFE EXPLOITATION

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The aim of this project is to expose enforcement strategies that not only fit into the ideology to ensure development and restitution but also effectively reduce the root causes of wildlife exploitation. The project uses a criminological structural model to understand the different root causes of different categories of wildlife exploiters.
Field research was conducted between September 2005 and July 2006. During this period the researcher met up with and interviewed the people at the KNP and outside KNP. An initial analysis of the enforcement of conservation laws in the area demonstrates that formal enforcement through the police and provincial conservation agencies plays an insignificant part in enforcing the law, due to capacity constraints and a misdirected focus of capacity.
Informal and private enforcement units are well resourced and empowered to enforce on privately owned land. Municipalities also put efforts into assisting these organisations to enforce on private land. Traditional structures for enforcing on communal land are almost non-existing. Alternative models of community forums and community development forums are not capacitated to deal with adequate enforcement. There are some good examples of community structures (individuals) that enforces through community policing forums. There were previously some vigilante groups enforcing both conventional and wildlife crime.
There are very few formal CBNRM projects in the area. However there are those projects that have incorporated some of the good concepts of community participation. There has been no evaluation of the impact of these programmes on the conservation of biodiversity. There is a new community management programme starting for the enforcement of the new community reserve at Manyeleti (newly approved land claim). Informal compliance structures such as hunting associations are not empowered (or given the legal mandate) to efficiently enforce the law.

A REGIONAL SCALE PASSIVE MONITORING STUDY OF SULPHUR DIOXIDE (SO_2), NITROGEN OXIDES (NO_X) AND OZONE (O_3)

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This research aims at monitoring, measuring and validating emissions of sulphur dioxide (SO_2), nitrogen oxides (NOx) and ozone (O_3) centred on the industrial Highveld emanating from various sources. Mapping of critical concentration levels and temporal variations of these pollutants will be then possible and seasonal and annual averages and trends will be identified. The project will establish for the first time a regional scale quantitative deposition pattern of important acid precursor gases and ozone, with which to validate regional scale air pollution dispersion models. The information derived will constrain the range of impacts on natural systems (critical loads estimates), such as the KNP, arising from industrial atmospheric emissions from the Highveld.
Currently the project is still in its phase of concentration data collection and no major analysis is undertaken [one year data collection for two of the gaseous species (O_3 and NO_x) is due at the end of August and September respectively]. Inter-seasonal and inter-gaseous species comparisons will be calculated after this data is available. The first interim analyses should be completed by September 2006. It is planned that the first detailed analyses would be performed after one year of the data for all three gaseous species is collated.

METAL ANALYSIS AND PHYSICO-CHEMICAL CHARACTERISTICS OF FOUR MAJOR RIVER SYSTEMS THAT TRANSECT THE KRUGER NATIONAL PARK (SOUTH AFRICA)

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The Kruger National Park by virtue of its position along the eastern border of South Africa is dependent upon seven major rivers for its water supply all of which arise outside the Western borders, draining eastwards through the park and into Mozambique. A survey of four of the seven rivers (Luvuvhu, Shingwedzi, Letaba and Sabie) was undertaken between January 2005 and July 2006. This time period allowed for both high and low flow samples to be obtained. The main objectives were, to determine physical and chemical water quality within and outside the Kruger National Park, to collect information on Shingwedzi River which has little historic data, to determine spatial and temporal variation in selected metal concentrations of sediment, water and fish at selected sites, to identify the presence of metal pollutants in selected tissues of freshwater fish from the four rivers and to identify impacted areas that will possibly require further investigation.

Two sites were selected in each river system, except the Letaba which had three sites. One site was situated within the borders of the Kruger National Park and the other upstream of the border. Each site was of sufficient distance from the border so as to obtain accurate and reliable data. Water, sediment and biota in the form of fish were obtained from each site. Metal concentrations (Al, As, Cd, Cr, Cu, Fe, Pb, Zn, Mn, Ni) were investigated in water, sediment and biota whilst physico-chemical parameters were determined for water and sediment. Nutrient levels were also determined. Sediment and water samples were processed using a three step extraction procedure (BCR) and filtration methods respectively whilst fish were analyzed by means of microwave digestion.

A general trend of lower organic content within the sediments at sites outside the Kruger National Park was observed. An exception to this was the Sabie River; in addition the Sabie River also showed the lowest organic content in general. Data for the Shingwedzi River within the KNP showed the highest organic content over all with values of 6.0815 % during high flow and 6.2619 % during low flow. It was also noted that the Letaba River varied the most over the entire river system with values ranging from 0.7745 to 4.9069 %. The results obtained for *in situ* oxygen analysis showed a general trend of slightly higher oxygen readings during high flow than low flow, the Luvuvhu river outside the park, being the only exception. Variation in dissolved oxygen concentration in the Shingwedzi River was the highest. The Klein Letaba River and Sabie River with values differing by at least 4.5 mg/l and 60 respectively. Temperature and pH values were generally consistent; however temperature extremes of 28.1 and 26.3 ° C were recorded in the Letaba and Shingwedzi Rivers during high flow. The Shingwedzi River on a whole showed a more alkaline pH when compared to the other rivers. Data for nutrient concentrations is being analyzed. This information will be available in the next report.

TOWARDS A SOCIO-ECOLOGICAL SYSTEMS VIEW OF THE SAND RIVER CATCHMENT, SOUTH AFRICA: A RESILIENCE ANALYSIS OF THE SOCIO-ECOLOGICAL SYSTEM IN THE SAND RIVER CATCHMENT, SOUTH AFRICA

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In South Africa, the Sand River Catchment is an example of the increasing conflict that is developing around natural resource use and their sustainability. On the human side, the imperative of generating and sharing wealth through development, land reform and black empowerment are widely stressed. The natural capital of the region, contained in game-rich tourism areas, is situated in and around poor rural communities. Water resources, in particular, are stressed and likely to come under further pressure to meet the demand for increased development.

In response, several initiatives are currently underway in Southern Africa to establish integrated approaches to water/natural resources, their sustainability, equitable use and management. Such approaches include Integrated Water Resources Management in the case of water. Almost all of these more holistic approaches make direct reference to balancing human and natural systems in an equitable way. A key catalyst for this re-orientation in thinking arose as a critique to the sectoral view and management of natural resources. This narrow view – often referred to as the 'silo' mentality – is considered to be ill equipped to meet the challenges of a complex and rapidly changing world. In contrast support has grown linking systems into a socio-ecological system (or SES) where interlinkages are explicitly recognised. The SES project comprises three phases: (I) A descriptive phase which outlines socio-economic characteristics and trends of the catchment; (II) An analytical phase where the resilience of this system is described using the tools of the Resilliance Alliance and (III) A participatory phase in which stakeholders are invited to examine the preceding analysis and to develop future scenarios for the catchment.

All three phases are nearly complete. In summary, by adopting a systems view of catchment and its biophysical and socio-economic components, progress has been made. Clear linkages have been demonstrated between livelihoods, catchment health and landuse practices. It has provided a framework that explicitly incorporates local knowledge and that of researchers and practitioners into a meaningful systems view. The SES framework has been instrumental in informing the soon-to-be established Holistic Rivers Programme**.**

We suggest that the incorporation of systems thinking into policy and project development is essential because we live in a complex world of linkages that play out in outcomes like livelihood vulnerabilities and ecosystem threats, which are most often the focus of development interventions.

SYSTEMIC LINKS BETWEEN SOCIETY, WETLANDS AND WOODLANDS - THE BUSHBUCKRIDGE CASE

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This study undertaken in the Bushbuckridge area seeks to establish systemic links between social, economic and biophysical subsystems. The Sand subcatchment of the Sabie has the advantage of receiving considerable study and project management action, because it is a highly stressed catchment with high levels of poverty and hence is a priority for rehabilitation. The focus in the study has been on linking ecosystem services derived from freshwater, with human livelihoods, and this includes important influences feeding through from the land-cover (woodland) subsystem. Wetlands play an important role in contributing to local livelihoods in the region. The techniques used in this study, which try to establish an overall picture of system function, include qualitative systems dynamics (interlinked cause-effect networks, particularly to pick up feedbacks) and vulnerability analysis determination using resilience theory. The idea was to test out these methods of generating a holistic picture of system behaviour and resilience, to test its usefulness as a general framework, especially since a common understanding by different stakeholder groups and sectors would help unify or at least facilitate future study, and future resource-related decision making (such as in a proposed bioregional programme). This particular paper will highlight the systemic woodland-wetland links, also as influencing and as mediated through human actions, in an overall socio-ecological system formulation.

INFLUENCE OF BOVINE TUBERCULOSIS *(MYCOBACTERIUM BOVIS)* ON CONDITION AND REPRODUCTIVE SUCCESS OF FEMALE AFRICAN BUFFALO *(SYNCERUS CAFFER)* IN KRUGER NATIONAL PARK

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The impact of the current bovine tuberculosis (BTb) epidemic in African buffalo (*Syncerus caffer*), in the central region of Kruger National Park, South Africa, was investigated in relation to reproductive success of females. Over a four-year period, 72 marked adult females of known BTb status were compared by age, reproductive status, calf survival and body condition (an indicator of health and nutrition) during the wet and dry seasons. Age did not correlate with the likelihood of infection. Similarly, reproductive status, and calf survival, were not found to be correlated with age for female buffalo. BTb positive cows had significantly smaller gain in condition during the wet season than BTb negative cows suggesting that gestation may be the critical stage of reproduction for infected animals. Barren BTb positive cows started the dry season in poorer condition suggesting that these cows could have been inhibited from reproducing by the disease.
BTb positive cows that reproduced probably suffered from subclinical symptoms, and were therefore able to maintain condition, although pregnant cows may have appeared healthier than they were due to the presence of the foetus. Calved cows ended the dry season in significantly lower condition than barren cows, but tuberculosis infection did not appear to reduce the ability of infected cows to reproduce and did not reduce calf survival. There was an indication of long-term reduction in reproductive output for infected cows, but this needs to be investigated further. A condition threshold may exist for reproductive ability, below which reproduction is inhibited. In the absence of sudden environmental change, which could otherwise breach the condition threshold, we suggest that BTb is unlikely to have a great impact on population dynamics of buffalo. African buffalo are therefore excellent maintenance hosts for this chronic disease, which may be of major concern for management and conservation of more susceptible species.

INTRA-SPECIFIC COMPETITION WITHIN BUFFALO MIXED SEX HERDS: ASSESSING THE DEMOGRAPHIC DIFFERENCES IN FORAGE SELECTION IN BUFFALO HERDS

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No data analysis has been done to date

BIOCOMPLEXITY IN AFRICAN SAVANNAS: PATTERN AND PROCESS OF WOODY COMMUNITY STRUCTURE IN THE KRUGER NATIONAL PARK

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This project was approved in February 2006 as part of the *Biocomplexity in African Savannas* program registered with KNP Scientific Services and funded by the US National Science Foundation program. The project is articulated in two parts: the creation of a tree-cover map for Kruger National Park based on remotely sensed data and the development of an ecological model for the understanding of tree distribution as a response to environmental and disturbance factors in the park.

The work has so far focused on the collection of data for the map. Some changes from initial plans have been applied consequent to data availability and technical issues. We opted for aerial photos taken during the SAFARI 2000 campaign to create a fine-resolution base of training and validation sites where tree cover will be assessed by means of object-oriented analysis. The analyses run so far have shown that common classification methods that use spectral properties of images are not adequate to discriminate trees within the savanna matrix. Software like e-cognition provides instead a new approach to extract this information from images and has shown to be a new and interesting alternative to explore. The tree-cover map for the whole park will be created through the scaling-up of a site-based relationship between tree-cover estimates and spectral information derived from MODIS satellite.

There are three statistical procedures among which we need to choose to proceed: development of a multiple non-linear regression model and the extrapolation to all the points of the Park, building of a regression tree and then extrapolation to all the points of the Park and finally development of a model for the park applying cokriging techniques. Cokriging appears to offer the most appropriate approach, but we will need to evaluate availability of resources for it. The validation of the map grounds on a subset of the classified photos that will be left a part from the mapping and on data collected in the fields during March and April 2006. The field data were collected at 11 sites distributed across the Park comprising the experimental burnt plots (EBPs). Tree cover was estimated using a densiometer.

The modeling part of the project will be based on the tree-cover estimates derived from the aerial photos. Our aim is to explore patterns and processes of woody cover emergent from interactions between climate, soil types, topography, and coupled variations in herbivory and fire frequency within the Park. For this work, we will use the data provided by the KNP GIS laboratory. Possible ways of accomplishing this task include non-linear regression models and regression trees.

IMPROVING CARDIO-PULMONARY FUNCTION FOR A SAFER FIELD ANESTHESIA OF WHITE RHINOCEROS

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Current field anesthesia protocols for white rhinoceros (*Ceratotherium simum)* using a potent mu opioid agonist [etorphine] and a tranquilizer [azaperone] causes respiratory depression and drug-induced muscle rigidity and tremors that further impair respiration, leading to a cascade of marked cardio-pulmonary alterations including hypoxia, hypercapnia, hypertension, tachycardia and acidosis. This hypoxia was corrected in a field situation by nasal intratracheal intubation with oxygen supplementation (15 to 30 l/min), but the acidosis and elevated CO_2 were not corrected; probably due to impaired ventilation and ventilation/perfusion mismatching in the lungs of recumbent rhinoceros.
A study is underway to develop safer field anesthesia protocols with improved muscle relaxation and less cardio-pulmonary alterations using the following dosage in adult animals of 40 to 90 mg of butorphanol (a mixed mu opioid antagonist and kappa agonist) and 25 to 50 mg of midazolam in combination with 2 to 3.5 mg of etorphine. In preliminary studies, the mu antagonist effect of the butorphanol greatly lessens the respiratory depression and muscle rigidity and tremors caused by etorphine. Animals were less hypoxic with an increased respiration rate and slower heart rate plus a lower end-tidal CO_2. The majority of the rhinoceros became standing immobile within 10 min, which facilitated minor manipulative procedures and allowed crating without partial opioid reversal. Once in the crate either naltrexone and/or diprenorphine were given. Naltrexone reversed the effects of both the butorphanol and etorphine. Diprenorphine appeared to only reverse the etorphine, leaving the sedative effects of butorphanol intact. Respiration improved in these animals and excessive head-pressing in the crate was not seen, with its potential to impair respiration.

MONITORING A WATER HYACINTH INFESTATION ON ENGELHARDT DAM AS PART OF AN INTEGRATED MANAGEMENT PLAN FOR WATER HYACINTH CONTROL IN SOUTH AFRICA

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Project aims to develop an integrated management plan for water hyacinth control, combining biological control, herbicidal control and nutrient control, tailored to the climatic regions of South Africa.
The main product of this research will be a set of guidelines for regional water managers for the integrated management of water hyacinth, combining biological control with, where necessary, herbicidal control and nutrient control, each tailored to the climate of the locality. Ideally, herbicidal applications will be minimal, of low environmental impact, *ad hoc* and eventually unnecessary as the biocontrol agents take hold.
We are monitoring 15 water hyacinth sites around the country to assess their status in terms of nutrient levels, local climate, plant health and biocontrol agent numbers. The study area for this part of the project which includes the KNP, is on the Mkhadzi Spruit (23º50'21"S 31º38'14"E), 50m upstream from where it enters Engelhardt Dam on the Letaba River. Five water hyacinth biocontrol agents have been released at the site, the weevils *Neochetina eichhorniae* and *Neochetina bruchi*, the mirid *Eccritotarsus catarinensis*, the moth *Niphograpta albiguttalis* and the mite *Orthogalumna terebrantis*.
To date, 23 months of sampling have shown Mkadhzi spruit to be a medium nutrient, warm site, where the biocontrol agents are prevalent and damaging. The site was separated from Engelhardt Dam using a floating cable in August 2005 enabling us to monitor the progress of the infestation in the spruit. By preventing movement of the weed in and out of the dam we were able to monitor exactly what was happening in the agent/weed interaction. Preliminary analysis however indicates that biocontrol alone is not sufficient to maintain the plants at an acceptably low level. Control will only be maintained when augmented with periodic sub-lethal herbicide applications. Biocontrol will therefore serve to slow the population build up of water hyacinth reducing the frequency of herbicide intervention. Flooding will further limit the need for herbicide applications as plants are washed out of the system.

STRUCTURE AND FUNCTION OF RIPARIAN UPLAND BOUNDARIES

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The project goal was to determine whether the structure of riparian vegetation influences the role of the riparian zone as a modulator of flows moving between the upland savanna and the river. Animal movement and nutrient distributions across the riparian zone may be differentially affected by vegetation structure. Additional contrasts in the system such as soil parent material and location on the hydrologic network may influence the interaction among vegetation structure, animal movement, and nutrient dynamics. To investigate these links, we selected 45 sites along the Shingwedzi and its tributaries. These sites represent 5 replicates of the following 9 treatments: 1-6) continuous, discontinuous, and sparse canopy on granite and basalt derived soils, 7-8) savanna uplands on granite and basalt soils, and 9) granite block tributaries. In March 2005, all sites were sampled which included high resolution mapping of the woody vegetation, sampling ground vegetation cover of grasses and forbs, quantifying number and length of animal trails through the sites, soil physical and chemical characteristics, and woody vegetation tissue chemistry. Leaf litter from the dominant species was collected and analyzed for tissue chemistry. The chemical analyses of the soil and plant tissues have been completed.

Across the 45 sites, species richness ranged from 1 to 17. On average, riparian sites contained 11 species of woody plants and the upland sites averaged 3 species. Riparian communities on basalt soils had higher vegetation cover than riparian communities on granite soils. On basalt soils, vegetation occupied an average of 61% of the site compared to 55% of the site covered on granite soils. The variation in plant cover was higher among communities on granite derived soils than on basalt derived soils. Total vegetation cover was also greater for riparian communities on basalt soils (66%) than granite soils (62%). The differences in percent of site covered by vegetation and % canopy cover suggest that there may be more layering of the canopy in riparian communities on granite derived soils relative to those on basalt soils. Basalt soils have higher concentrations of calcium, magnesium, potassium, and sodium. They also have higher pH compared to granite derived soils.

Riparian zone have significantly greater nitrogen (N) and carbon (C) content than upland soils regardless of parent material. In addition, the pH of soils in the riparian zone is significantly higher than upland soils and the bulk density is significantly lower. Sodium is the only macronutrient found to differ significantly between riparian and upland sites. Sodium concentrations are higher in riparian sites. Within the riparian zone, C and N concentrations were significantly higher in sites.

COLLECTION OF INSECTS FOR EVOLUTIONARY STUDIES OF THEIR RELATIONSHIPS

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The object of our work was to recover South African representatives of the target insect orders Mantodea (praying mantises), Isoptera (termites), Odonata (dragonflies) and Coleoptera (beetles) as part of global collecting efforts to sample the diversity of these important insect groups and understand their evolutionary history. Collecting was very successful. Co-worker Svenson was able to spend time comparing specimens collected from Kruger with types in the Paris Museum of Natural History in October 2005 which resulted in alterations to several of the tentative identifications provided previously which were based on publications rather than direct comparisons between specimens.
Additionally a large number of beetles were recovered which are currently being identified by colleagues at the University of Georgia. We will forward you a list of the species recovered when they are identified. The second phase of this research, sequencing genes from the specimens and constructing evolutionary trees is currently underway.

HABITAT SUITABILITY ASSESSMENT FOR SABLE ANTELOPE

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The objectives of the project are; to identify environmental features associated with the historical sable distribution in the Kruger National Park; to identify environmental features associated with the recent distribution of sable; to identify those environmental features associated with variation in occurrence of sable within their recent distribution range; from this basis, to develop a habitat suitability model for sable from the Kruger data; and to test the model by applying it to data for sable distribution and habitat features in Hwange National Park, Zimbabwe.
Sable have historically occurred mainly on the western granite substrates of the Kruger National park. Within their ranges concentrations on core areas are evident. While abundance has declined the distribution range has contracted only slightly around the periphery. Most sable herds were recorded within 0 – 1 km of permanent water sources. Kruger National Park has abundant surface water, thus water may not explain sable distribution and habitat selection in Kruger National park.
Positive associations between the occurrence of sable and buffalo ($P < 0.001$) or zebra ($P = 0.016$) were evident over 1981-1986 before the sable decline and 1991-1996 after the sable population had dropped. The three species were using the same ranges however, their correlations were weakly positive. The correlation coefficient of sable to buffalo numbers was $r = 0.373$. The correlation coefficient for zebra to sable during the same period was $r = 0.159$. Even though sable, buffalo and zebra favoured the same areas, sable herds were recorded less frequently in blocks with high numbers of zebra ($P < 0.001$) or Buffalo ($P = 0.013$). A point pattern analysis (Wiegand-Moloney 2004) showed evidence of sable herds occurring separately from either buffalo herds or zebra herds only at small scales (< 3km).

FIRE MONITORING IN SAVANNA ECOSYSTEMS USING MODIS-NDVI AND SPOT-NDVI: A CASE STUDY OF KRUGER NATIONAL PARK

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The heterogeneity of savanna ecosystems is guaranteed by disturbance events like fire, droughts, floods, browsing and grazing by herbivores. For conservation areas with limited space to preserve biodiversity, fire monitoring is crucial. Long periods of satellite remotely sensed data provide an alternative solution to estimate the distribution of different vegetation types and fire-affected patches through time. This study focuses on application of MODIS data to detect, identify and delineate fire-affected areas in KNP (Kruger National Park) for 2001-2003 period. Fire scars on KNP's savanna were identified using threshold and supervised classification methods on MODIS (Moderate Resolution Imaging Spectroradiometer) 500 m, 32-day global composites using a combination of band 1 (red), 2 (NIR, near infrared), 4 (green) and 6 (SWIR, short wave infrared). On identified fires scars the spectral index of albedo, NDII (Normalized Difference Infrared Index) and NDVI (Normalized Difference Vegetation Index) were extracted. The following four broad habitat types were used for this analysis: Riparian woodland, dense woodland, mixed woodland and open tree savanna.

The values of albedo, NDII and NDVI during June – October period for different years are lower on fire-affected patches. Mixed woodland is the largest habitat burned with 21%, 43% and 2% of KNP area affected by fire in 2001, 2002 and 2003 respectively. Riparian woodland is the least affected by fire. Supervised classification method has more accuracy for fire scars detection in KNP savannas during June-October period. MODIS data can be used successfully for fire monitoring in savanna ecosystems.

Based on interpretation of fire scars extracted by supervised classification, it can be said that in general, fire is more extensive in mixed woodland and open tree savanna than on riparian woodland and dense woodland.

The index patterns (albedo, NDII and NDVI) are the same as in the threshold method: Burned areas have lower values than unburned. However, in this method the difference between the indexes of burned area and unburned is greater and consistent in all three years. No fire scar was detected in June 2002 and September 2003.

SEASONALITY AND 20TH CENTURY CHANGE IN THE FEEDING ECOLOGY OF HERBIVORE COMMUNITIES IN THE NORTHERN BASALT PLAINS OF THE KRUGER NATIONAL PARK, SOUTH AFRICA

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This study tested the hypothesis that ecological differentiation between browsers and grazers underlies evolutionary diversification of ungulate herbivores in African savannas. Stable isotope tools were used to document feeding styles (%C_4 or grass intake), and to provide control for variations at annual, seasonal, monthly, and regional variations in diet in model testing. The primary focus area was the Northern Basalt Plains to improve understanding of the complexity of plant-mammal interactions within this key landscape.
Results suggest that feeding style is more continuous than can be explained by simple browser/grazer dichotomy. Feeding style varies across taxa even within these two 'guilds' so that universal diet classification schemes are misleading. For example, some schemes argue that grazers can be separated into 'variable' and 'obligate' grazers, browser into 'folivores' and 'frugivores', and mixed-feeders into 'mixed browser/grazers', 'generalist browser/grazer/frugivores', 'mixed-feeders preferring browse', and 'mixed-feeders preferring grass'. Carbon isotope data for variations in diet show that the species compositions of any one of these guilds varies substantially across space, so that such schemes are potentially misleading. Stable carbon isotope studies allow expression of these variations in statistical models.
Results of plant crude protein and fibre content are in accord with several recent studies that suggest browse (and fruit) have a lower potential cell wall digestibility than grass due to higher lignification. This, coupled with digestion-inhibiting effects of secondary compounds in browse, demonstrates that reference to browse as "concentrate" foods is misleading. Thus, if browser/grazer differentiation does underlie ungulate evolution, the higher fibre digestion efficiency expected for grazers is only an adaptation to ensure complete digestion of fibre, rather than improved tolerance for poor quality diets as previously predicted.
Impala are demonstrated to show maximum browse intake in riparian systems, minimum at artificial waterholes, and maximum grass intake in the dense woodlands around Punda Maria. Linear regression models suggest that impala increase their grass intake in regions/periods in which %N of this resource is higher, but their diets are not regulated by changes in other factors such as rainfall.

THE SAMPLING METHOD OF ELEPHANT (LOXODONTA AFRICANA) TUSKS

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This project uses stable isotope proxies for diet changes in elephants to document past, and predict future responses of elephant-plant interactions to climatic and anthropogenic changes in the Kruger National Park (Kruger). Stable isotope data archived in different materials allow for upscaling from short- to long-term ecological processes. Faeces afford insight over a few days, hair several months, and serial profiles from ivory cover several decades because elephant tusks grow continually throughout the animal's life in ordered annual and sub-annual layers.

Plants and faeces were collected. The extensive survey of plant isotope compositions in Kruger revealed that variations are smaller than expected given the range of climate regimes and habitats in the Park. These findings for plants indicate that reconstructions of diet based on animal isotope signatures are reliable within any one savanna environment, animal data unlikely to be affected by environmentally-induced variations in plants (e.g. rainfall).

Carbon isotope analyses of elephant faeces have revealed dietary differences between northern (north of the Olifants River) and southern populations in Kruger This is because while elephants in the southern regions of Kruger show massive diet switches from the dry (~10% C_4 grass in diet) to the wet season (~50% grass), northern elephants maintain a relatively high grass intake year-round (~40-50%). At monthly scale, the timing of diet shifts increased from browse-dominated to more grass-rich diets in southern elephants generally occurring in the late dry/early wet season (September and October). These data also show more subtle variations in diet at higher spatial resolution than was previously available (central regions of Kruger included) that allow testing for distinctness in elephant feeding ecology amongst different populations. Results of a Principle Components Analysis (PCA) based on month-to-month changes in diet across eight regions identified four components which represent the diet composition (in terms of browse:grass intake), and monthly differences therein, of elephants in different Kruger landscapes. There appears to be a trend on increasing total grass intake, and decreasing seasonal heterogeneity, in diet from south to north, whereas granite/basalt distinctions do not persist. Note that south central granites form a distinct component, but this may be due only to "anomalous" values for one month (June) and overall elephants in this region may behave similarly to those on southern granites and basalts. Nonetheless, there are at least three distinct elephant ecologies identified for Kruger based on these data, and animals from these zones should hence be treated as such.

ECOSYSTEM MODELING TO UNDERSTAND SAVANNA BIOCOMPLEXITY AND INTERACTIONS BETWEEN VEGETATION, ELEPHANTS, AND HUMANS IN KRUGER NATIONAL PARK

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The purposes of this project are two-fold. First, it represents a site-specific adaptation of the SAVANNA ecosystem model to Kruger as part of the larger project to examine the biocomplexity of African savannas. The main questions of this component of the project are concerned with explaining variations in woody cover as outcomes of multiple interacting factors. These factors include, climate, soil fertility, herbivory, and fire. We are interested in system level, or emergent outcomes of basic processes taking place in the system. One example is a causal pathway between soil fertility, its effects on forage quality, the effects of forage quality on herbivory, and the effects of herbivory on fuel load and fire. This gives rise to fundamentally different ecosystem structures in nutrient rich and nutrient poor savannas. Once the model is working well for Kruger, comparative studies with the Serengeti Ecosystem in Tanzania will be carried out. The application of the model to Serengeti and Kruger will form the basis for larger scale simulations of East and South African savannas.

BELOW GROUND PROCESSES EXPERIMENTS

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The project seeks to determine the relative importance of nitrogen and phosphorus limitation in belowground processes and plant production. In each plot, we harvest aboveground biomass and separate the biomass between grasses and other herbaceous dicots. Harvests occur in January and March. In the fertilization experiment, preliminary results show a significant increase in biomass with N and P addition and even greater production with fertilization with N and P. Future years' harvests will determine the long-term, interannual relative limitation of productivity by N and P. Differences among plots in microbial populations are being determined as is the relative importance of N and P for decomposition of shoots.

MECHANISMS OF ADAPTATION: ANALYSIS OF GEOGRAPHIC VARIATION IN A POLYPHENIC BUTTERFLY (*BICYCLUS ANYNANA*)

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The project aims to increase our knowledge on the extent and mechanisms of adaptation of ectothermic insects (exemplified by the East African butterfly *Bicyclus anynana*) to the temperature increase associated with global climate change. It focuses on the genetic mechanisms involved in adaptation. This will help to predict the speed of adaptation in relation to the global climate change scenarios, as is especially relevant for organisms with limited migratory abilities. The aim is to study populations from distinct geographical regions along a latitudinal gradient. Initially we planned to collect live specimens from two populations of *Bicyclus anynana* in each of the following countries: Ethiopia, Malawi, Uganda and South Africa. After transporting the butterflies to our lab in Leiden, the Netherlands, laboratory stocks are established. At the moment we have two healthy South African stocks in the lab, one from the Greater St. Lucia Wetland Park in KwaZulu Natal and one from Mpaphuli Cycad Reserve, Limpopo Province. We also have two healthy stocks from Malawi. Next month we will start a large-scale life-history experiment comparing these four lab stocks of *Bicyclus anynana*. In addition, we will analyse the stocks for genetic differentiation using microsatellite markers. Depending on the outcomes of these experiments, we will adjust further field work plans.

THE ECOLOGY OF ANTHRAX IN THE KRUGER NATIONAL PARK

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The anthrax cycle in its natural habitat, such as the KNP, is fully integrated and in symbiosis with the other elements of the ecosystem. It suggests a symbiotic relationship with the natural environment and is therefore indigenous to the region. This (indigenous) hypothesis is strongly supported by further studies on the genotype grouping (taxon-area cladograms) of anthrax isolates which prove that the geographic origin of *Bacillus anthracis* is the sub-Saharan African continent with the Kruger National Park playing a central role. *Bacillus anthracis* organisms can survive abiotically as dormant spores over very long periods (hundreds of years). In the KNP an endemic pattern of anthrax, punctuated by sporadic epidemics, has been identified. The endemic situation in Pafuri is maintained by an abiotic (persistent spores in concentrator areas = Hape drainage) / biotic (availability of hosts) cycle. The scouring effect and silt deposition of floods interrupt the endemic situation in Pafuri. The outbreak of anthrax epidemics in the KNP have a medium term (10 – 30 years) cyclical, temporal pattern, with rainfall periodicity and its effect on the ecosystem, a driving force. The course of anthrax epidemics were also found to be determined by rainfall, being limited to the drier months of the year, resulting in a seasonal trend. Epidemic outbreaks are initiated and propagated by a combination of availability of susceptible hosts, stress and successful dissemination/transmission of anthrax spores.
Scavengers, especially vultures, open up carcasses and spore development take place.
Vultures infect drinking troughs. Buffalo are most vulnerable to this mode of transmission.
Seasonal rivers with stagnant pools in winter are favourable to spread of anthrax. Active flowing rivers form barrier or deterrent to the spread of anthrax. Blowflies disseminate anthrax from an opened carcass to the vegetation, where mainly kudus pick up infection. Kudus are the principal or maintenance host of anthrax in the KNP. Outbreak dependent on high kudu density. All other animals are incidental victims to anthrax in the KNP. Onset of rain interrupts anthrax epidemics in the KNP.
The actions of man, such as the building of water troughs and excessive pressure on rivers causing stagnancy, affect the course of outbreaks.

VARROA MITE INFESTATIONS AND THE POPULATION GENETICS OF HONEYBEES IN THE KRUGER NATIONAL PARK

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The main aim of the study is to investigate the population genetics of honeybees (*Apis mellifera*) within the KNP. Other aspects concern the determination of the honeybee population structure within KNP, the investigation of the gene flow between any subpopulations and the estimation of the degree of migration between any subpopulations. In addition, the progress of *Varroa* mite infestations and any other bee disease in the park can be monitored.
We have found that the *Varroa* mite has now spread throughout the park, but an independent study suggests that African bees are resistant to the effects of this parasite. Preliminary analysis of the population genetics show the occurrence of 5-6 colonies per square kilometer in the park. More detailed analysis of population structure, gene flow and honeybee reproduction will be undertaken once samples remaining from older batches as well as samples from the last batch collected in July this year have been genotyped. We have now genotyped 60% of the 1312 samples we need for this analysis.

SURVEY OF ARACHNIDA OF THE KRUGER NATIONAL PARK WITH EMPHASIS ON SPIDERS (EXCLUDING MITES AND TICKS)

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As part of the South African National Survey of Arachnida (SANSA) an inventory of the Arachnida of the Kruger National Park are underway. The arachnids (spiders, scorpions, solifugids, amblypygids and pseudoscorpions) constitute an abundant and highly successful group of invertebrate animals. In the past invertebrates were largely ignored in conservation endeavours. Meaningful conservation cannot take place if species involved are not known. Therefore, surveys of invertebrate fauna become more important, especially in reserved areas where conservation strategies are already in place.

The overall aims of this project, as part of the South African National Survey of Arachnida (SANSA) are, to collect, describe and make an inventory of the Arachnida species of the Kruger National Park, to published results in the form of checklists and taxonomic papers, and to include data in the SANSA electronic database on arachnid fauna in conserved areas.

A collecting trip was undertaken in October 2005 , the aim of this trip was to determine the distribution range of the baboon spider *Ceratogyrus paulseni*, a species newly described from the KNP, and to try and collect males. Results of this survey show that *C. paulseni* are endemic to the park and it has a very small distribution range, as it has so far only been found from an area around the Letaba Camp. Preliminary data indicate that most of the other baboon spider species recorded from the park namely *Augacephalus junodi* (Simon, 1904), *A. breyeri* (Hewitt, 1919), *Idiothele nigrofulva* (Pocock, 1898), *Ceratogyrus bechuanicus* Purcell, 1902, *Harpactira gigas* Pocock, 1898 and *Idiothele nigrofulva* (Pocock, 1898) are fairly common in the park with a wider distribution pattern. However, further surveys are needed to determine their conservation status especially that of *C. paulseni*.

BREONADIA SALICINA RESPONSE TO THE 2000 FLOOD, SABIE RIVER, KRUGER NATIONAL PARK: IMPLICATIONS FOR RULE BASED MODELLING AND MONITORING

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Project objectives were to directly test the predictive capabilities of the *Breonadia* model, to determine the population structure and response of the Sabie River *Breonadia salicina* population subsequent to the 2000 Sabie River flood event, and to utilise this new information to update the *Breonadia* model.

The *Breonadia* Model does not withstand testing with regard to its ability to predict *B. salicina* recovery in pool-rapid channels subsequent to a catastrophic flood. Recruitment was absent in the monitoring sites at the time of the field survey but occurred on bedrock substrate in bedrock anastomosing and mixed anastomosing channels. Thus the model predicts overly optimistic recruitment levels subsequent to a catastrophic flood. Sprouting was found to be an important disturbance response in *B. salicina.* Sprouting was also found to increase with decreasing size class.

Recruitment occurs in response to the underlying physical template while sprouting and flowering is related to individual size-class and damage severity. The data suggest that sprouting continues to limit flowering in adult size classes five years subsequent to the 2000 flood. The likelihood of flowering is expected to increase gradually with time after the flood, as adult trees recover lost biomass. Sprouting influences flowering and therefore seed production within the population and is a likely limit on recruitment. Thus the Breonadia Model must be updated to take the influence of sprouting on fecundity into account.

The *Breonadia* Model does not take sprouting into account and thus makes optimistic predictions about the recruitment of new individuals subsequent to catastrophic floods. A penalty to fecundity calculated by the model was determined from field data and extrapolated to include all years from immediately after, until 10 years after any catastrophic flood. The model code was adjusted to take these penalty values into account.

The original monitoring sites are located in pool-rapid channels as this channel was considered the most sensitive to sedimentation. The low population densities occurring in the pool-rapid channel type are not representative of the population as a whole. Recruitment subsequent to the 2000 flood was found to occur in the anastomosing channels, and most strongly in the mixed anastomosing channel type. It is suggested that monitoring sites be moved to bedrock sections of the mixed anastomosing sections of the river in order to track the recruitment response of *B. salicina*. As part of the monitoring program, it is recommended that data on flowering and sprouting be collected to improve the penalty values utilised in the *Breonadia* Model. A long term fecundity study would provide more insight into limits to seed production.

WATER USE IN RELATION TO BIOMASS OF INDIGENOUS TREE SPECIES IN WOODLAND, FOREST AND PLANTATION CONDITIONS

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There is widespread belief that indigenous trees use less water than exotic trees. However, there is insufficient information on indigenous species to prove or disprove this hypothesis. Furthermore, growth rates of most indigenous tree species are slow when compared to exotic plantation species, rendering them economically unviable from a timber production perspective. However, the quality and value of the ecosystem goods and services that indigenous trees provide may be very high, possibly providing an economically and ecologically attractive alternative land-use option.

The overall aim of the project is to investigate rates of growth and water use of a selection of indigenous tree production systems, and to make economic and hydrological comparisons to current commercial forestry systems. Comparisons are being conducted for sites spanning a wide rainfall gradient.

Field study sites include *Podocarpus falcatus* plantations at Woodbush State Forest near Magoebaskloof (MAP=1200mm), mixed evergreen indigenous forest near George in the southern Cape (MAP=850mm), and Combretum-dominated savanna in the Kruger National Park, which was selected to represent the low rainfall (570mm) end of the rainfall spectrum. This phase of research is taking place in woodlands south of Skukuza, where the Heat Pulse Velocity (HPV) technique is being used to measure sap flow velocities (and ultimately water use) of some commonly occurring tree species (i.e. the proportion of total evaporation that originates from the tree component of the vegetation). Additional research from this project (scintillometer technique) is providing measurements of spatially averaged total evaporation rates over a 4.25 km path above savanna vegetation (i.e. combined tree / grass evaporation rates).

Tree species selected for water use measurements using the HPV technique were the Red Bushwillow (*Combretum apiculatum),* Marula (*Sclerocarya birrea)* and False Marula (*Lannea schweinfurthii)*. Results so far suggest that water use by these indigenous trees is closely correlated to season (soil moisture availability), tree leaf area, and vapour pressure deficits. Transpiration in the *Sclerocarya birrea* and *Lannea schweinfurthii* trees ceases during the dry winter months when they lose their leaves. The *Combretum apiculatum* trees show a similar trend in transpiration rates, however the transition between dry and wet seasons is less pronounced as these trees typically retain a proportion of their leaves throughout the winter months. Additional project objectives still to be investigated include: estimates of aboveground biomass production and the value of utilisable products; suitable modelling frameworks to permit spatial and temporal extrapolation; and potential economic returns from water used by the trees.

DEVELOPMENT OF A CLEARING PROTOCOL BASED ON ECOLOGICAL CRITERIA FOR MESIC SAVANNAS AND SWEET GRASSVELD FOR THE WORKING FOR WATER PROGRAMME

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The project aims to provide an overview of the effectiveness of existing clearing methods for major invasive species in South African mesic savanna and sweet grassveld ecosystems. The degree to which ecosystems are able to recover after clearing will be assessed, taking into account the dominant alien species, duration and density of invasion, features of the ecosystem and indigenous vegetation that affect recovery (such as soil stability and indigenous seed pools).
This project includes two separate field-sampling studies. The first was the establishment of permanently marked sites in areas where *Chromolaena odorata* and/or *Lantana camara* was being cleared in seven regions between Soutpansberg in the north to Hluhluwe in the south. The second was the establishment of experimental plots where different clearing treatments were applied and the response of the indigenous and exotic vegetation was measured. Final analyses and report will be done in 2007.
Some preliminary results from the experimental plots at Tzaneen have indicated that the cut and treat method to be the most effective in terms of follow up effort required and also in the recovery of grass diversity and cover. However, this method took significantly longer than the foliar spray or hand pulling treatments. At the Hilltop site the percent cover of Triffid weed in 2005 was significantly different between the control (un-cleared) plots and the cut and treat stump method for both the stacking and no stacking treatments (t-value=2.22, p=0.04; t-value=2.4, p=0.003 respectively). This verifies that this is an effective clearing method.
At Hilltop the stacking treatment took three times longer than not stacking. The follow up treatments were consistently quicker to do than the initial treatments, taking on average one eighth of the time to do the initial clearing treatments. The foliar spray method was the quickest method while the cut and treat method takes about two times longer (Kruskal-Wallis ANOVA by ranks, p=0.01). At Hilltop grass diversity and cover in 2005 were significantly higher in the cleared plots compared with the control. This suggests that indigenous vegetation recovery is significant using this clearing method. At Teens Botha there were no significant trends with regards to indigenous vegetation recovery and clearing treatment.

MECHANISMS OF GRASS/TREE INTERACTIONS IN SAVANNAS

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The primary objective of the TGP is to develop a predictive understanding of tree/grass interactions in savanna ecosystems. The project is focussing on addressing a number of main questions which are addressed in separate individual projects.

DEVELOPING A FRAMEWORK FOR ASSESSING THE RISK OF INVASION IN THE CATCHMENTS SURROUNDING THE KRUGER NATIONAL PARK

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Protected areas are becoming increasingly isolated with river corridors forming one of the most important links to the surrounding landscape. Unfortunately these corridors are also conduits for invasion of alien species into protected areas. Although qualitative risk assessment protocols are useful for preventing introductions of unwanted species, problems associated with managing a suite of species already present in a particular area remain. Objective assessments of the risk of spread from different watersheds would assist managers by identifying areas where proactive intervention would be most effective and where monitoring for new incursions is most important.

The need to define management options based on the spatial arrangement of species of primary concern as well as foci of propagules, calls for a combination of species- and landscape-level approaches. The species-level section of the framework should identify species of primary concern and their distribution. As certain species are considered more serious invaders, the presence of one or a few of these requires specific and targeted management action. The landscape-level component needs to assess sources of propagule pressure outside the protected area.

We formulate such a risk-assessment framework and apply it with reference to South Africa's Kruger National Park (KNP). The framework guides the interrogation of species distribution and abundance, providing the means for the assessment of areas of concern. The case study shows that the KNP is clearly facing increasing pressure from alien species in the upper areas of neighboring watersheds. This assists the KNP mangers in identifying areas for proactive intervention, monitoring and wise resource allocation. Even for a very large protected area like the KNP, sustainable management of biodiversity will depend heavily on the response of land managers upstream. We suggest that this framework is applicable to plants and other passively dispersed species into protected areas, situated at the receiving end of a wider drainage basin.

BEYOND FILLING THE GAPS: ADVANCING THE SCIENCE OF INVASION ECOLOGY USING A NEW CONCEPTUAL FRAMEWORK

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The ecological and economic impacts of biological invasions are increasing. The ability to predict and manage invasions however is lagging. Although advances have been made in understanding the mechanisms underlying invasions, these are mostly case specific, with little generality. The understanding of and research on invasions is also becoming increasingly fragmented and frequently disassociated from the rest of ecology. Conceptual frameworks and models have been successfully used in developing new understanding of ecological phenomena such as ecological boundaries and heterogeneity. We describe a framework and model template that contextualises the key components and linkages in the invasion process. This new framework is inclusive in order to generalise across invasive species, systems and scales and to provide a structure to synthesize research in invasion ecology. We use an example from the Kruger National Park, South Africa, to further suggest how this framework can guide management response to invasions.

THE IMPACT OF AGE AND CLIMATE ON REPRODUCTIVE RATES OF AFRICAN ELEPHANTS (LOXODONTA AFRICANA) IN KRUGER NATIONAL PARK

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Over one third of captive African and one tenth of Asian elephants that are hormonally accessed exhibit irregular estrous cycles or no ovarian activity at all even though they are of reproductive age. Females that do not cycle do not ovulate and, therefore, cannot conceive. What causes ovarian acyclicity and if it is exclusively a captivity-mediated phenomenon is not known. It has been suggested that acyclicity does not occur *in situ*, but that may be because hormonal characterizations of ovarian cycles have only been conducted on captive animals. Wild elephant populations have not been statistically analyzed in the context of individual ovarian activity and it is quite possible that not all females cycle all the time. Demographic studies that show reproductive rates decline with age in free-ranging African elephants and as they reach matriarchal status. Environmental factors also impact reproductive success. In some areas of Africa, wild elephant conception and birth rates have been reported to be higher in the rainy season than the dry season when resources are limited. The mechanisms that control changes in reproductive success with age, social rank and precipitation are not know because no one has evaluated the physiology associated with altered reproductive function. If luteal inactivity (i.e., reduced progestin concentrations) occurs in free-ranging females, whether it is due to rainfall, age or the attainment of matriarchal status, it could be functionally similar to the ovarian acyclicity observed in *ex situ* elephants.

The objective of the current study was to analyze the database of elephants culled within Kruger National Park (1976-1995) for evidence that age and precipitation impact reproductive success of African elephants in the Park. We are using Smut (1975) as a model for our analyses and subdivided the park into four regions. To date, we have analyzed the culled data with respect to age and location within the park. Some preliminary results indicate that the sex ratio of subadults (age 0-14) was 1:1.08 (771♂♂:770♀♀) and for all culled elephants was 1:2.07. There was a seasonal distribution of mating activity with 73.3% of conceptions taking place during September and January.

The youngest age of conception was 8 years (n=6). By age 12, all females had either corpora lutea or albicantia present. The majority of elephants >8 years were lactating (63.0%) or pregnant (47.5%). One-fifth (20.8%) of females >8yr were neither lactating nor pregnant, mostly in the youngest and oldest age classes. The percent of reproductively active females (pregnant and/or lactating) dramatically declined while those inactive increased for females in the older age classes (>50).

We plan to complete our analyses using the precipitation data within the next month and then prepare the results for publication.

TREEHOUSE RESEARCH PROGRAM FOR PEOPLE AND CONSERVATION

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The Treehouse Research Program for People and Conservation (TRPPC) endeavors to develop and test an integrated learning framework that incorporates clear and measurable social objectives into adaptive management systems for protected areas. This effort is motivated by the recognition that the lack of well-defined social objectives in Protected Area Management (PAM) perpetuates a system of partially informed decisions. Through engaging and evaluating the implementation of social objectives, the role of protected areas in local and national society will be better defined and the on-going cultural/social relevance of protected areas can be enhanced and secured.

To understand the contextual relevance of protected areas, the TRPPC is assessing the relationship between parks and people in settings throughout southern Africa and the United States. Cross-cultural comparisons of the degree to which learning is featured in Protected Area Management organizations will facilitate a deeper understanding of their unique circumstances and challenges. Examination of how problems are framed and addressed within differing systems will provide opportunities to expose the effectiveness of how differing paradigms for developing and managing the social values of protected areas.

One of the primary purposes of the research described above is to facilitate the development of training materials for protected area managers. These training materials will be designed to amplify protected area managers' capacity to proactively confront the social and political challenges that protected areas are faced with. While much of these training materials will be presented after the relevant research is completed, the Senior Researchers explored many of the relevant issues with senior wardens and administrators of Etosha National Park, Namibia during the latter part of July 2006.

ASSESSMENT OF LION POPULATION DEMOGRAPHY AND ABUNDANCE IN THE KRUGER NATIONAL PARK

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This project aims to develop a technique that can be used by managers and researchers of lion populations to determine population estimates and population processes.
Before any census work could be done it was necessary to conduct a calibration exercise to calculate various probabilities of response and the effective radius of call-up stations. This was accomplished during June 2005 in the central district of the KNP around Satara. Here each night a team of two vehicles headed out to areas of recent lion sightings increasing our chances of finding lions. One vehicle was used to monitor the response of the lions to the call-ups. The other vehicle played the call-up from a pre-determined distance measured by GPS. Over 4 week we encountered 34 groups of lions (169 individuals) that we tested. From this we determined that the maximum effective sampling distance was 4.2 km, with about 60% of all lions responding to the calling stations. However, as there was a large difference in the response rate of lion groups either with or without young cubs (<12 months) in attendance we calculated a correction factor to be applied differentially to responding lions groups of each type. Thus groups not containing cubs are corrected by a factor of 1.44 for non-response, and groups with cubs are corrected by a factor of 4.35.
After completing the calibration phase, the census commenced in the Far North region of the park. The area from Pafuri down to the Olifants River was covered (n = 104 calling stations), with 142 individual lions being attracted. At each pre-determined call-up site the equipment was set up and the calls played continuously for one hour. The call used throughout has been the distress calls of a buffalo calf. Data recorded included the species, time of arrival, group size, and for lions we also record each individual's sex, condition, stomach size, estimated age, if the females were lactating, and any other detail relevant to the project, such as, brand marks, radio collars, vocalization and behaviour. The largest pride encountered was on the Shangoni section comprising of 21 lions.
The second phase of the census was conducted from Malelane up to Satara. In this area 118 calling stations were conducted resulting in 286 lions being recorded. Although preliminary, our data and population estimates for the whole park can be summarised as follows, in the northern granites (323), northern basalts (276), southern granites (540) and southern granites (442). These results present the first ever estimate of lion density throughout the park.

FIRE HISTORY AND LONG TERM VEGETATION DYNAMICS IN SOUTHEASTERN KRUGER NATIONAL PARK

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This project aims to study in detail the relationships between fire, climate and vegetation dynamics for chosen localities in the KNP by reconstructing long-term fire histories. Past vegetation change and fire history are reconstructed from analysis of fossil pollen and charcoal abundance in sediments. This information on long-term variability in tree cover and will help ecosystem managers decide when management intervention is necessary.
The initial Mapimbi data shows no clear correlation between charcoal counts and changes in pollen types. Contrary to normal expectations increases in grass pollen do not correlate with increases in the total amount of microfossil charcoal. Similarly, no clear correlation between changes in vegetation structure and charcoal were found when comparing riverine gallery vegetation and open bushveld savanna-type vegetation. However, increases in what could be domesticated grasses (i.e. Maize) does correlate with a peak in charcoal at 98-86cm dated to the 16th century.
Preliminary analysis of planktonic and benthic/epiphytic diatom assemblages from Mapimbi shows that a general decrease of benthic/epiphytic species is expected during phases of high lake levels. In turn, planktonic species are more common during periods with lower water levels. Generally a good correlation between the diatom assemblages and the grass pollen data exists, notably in relation to planktonic species. It is likely that the grass assemblage is dominated by *Phragmites*, growing on the lake margins. High grass pollen counts associate with favourable conditions for the growth of *Phragmites,* when rising lake levels inundated riverine gallery forest, causing a decline of associated species.
Preliminary analysis of samples from the Chiluetse lake shows a high dominance of grasses throughout the sequence. In terms of trees and shrubs, savanna vegetation is represented by *Mopane*, presently dominant in the area, and *Acacia*. Riparian vegetation is also present e.g. *Moraceae* (ie *Morus mesozygia*) type pollen, *Spirostachy*s, *Diospyros, Meliaceae, Myrica* and *Syzygium*. The vegetation around the lake is likely to have been relatively open, dominated by Mopane broadleaved savanna, throughout the time represented by the core. Variations in Cyperaceae and *Typha* pollen suggest lake levels have fluctuated.

ARTIFICIAL WATERPOINTS: HOW THEIR DISTRIBUTION AFFECTS THE HERBACEOUS, WOODY STRUCTURE AND COMPOSITION?

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It is hypothesized that the wide distribution of artificial waterholes in the KNP led to an increase in bulk grazers. This would have changed the grass composition towards herbaceous species that are more resilient to herbivory. Plant surveys comparing the vegetation inside enclosures with only selective grazers with vegetation outside will provide information to test this hypothesis. Furthermore herbaceous surveys done before and after the closure of about 200 water points across the KNP in 1998 would provide further information towards testing this hypothesis.

Analysis done so far has concentrated on the vegetation changes that have occurred in the N'washitsumbe enclosure since it was fenced off from the rest of the Park. Results have showed that there is a significant difference between the vegetation within the enclosure and the vegetation outside the enclosure. However, these differences are only significantly different along the northern and southern fence lines; whereas there is no significant difference along the western and eastern fence lines. Reasons for these results are still being researched.

The grass biomass within the enclosure is also significantly lower than that outside and this can be attributed to the diminishing quality of the vegetation due to the selective grazing. In order to determine this, the data was tested for homogeneity of variances and Shapiro-Wilks test was used to test the data for normality. The data for the grass biomass was then transformed, using a log transformation in order to obtain homogeneity of the variances; and t-tests were then run on the data.

VELD BURNING IN THE KRUGER NATIONAL PARK

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The role of fires in the history and shaping of the landscape of the Kruger National Park (KNP) can be traced as far back as 1912. By the 1950's it had became clear that knowledge pertaining to where, when and how often the veld (rangeland) in the KNP should be burnt was severely lacking. In 1954 a fire research programme was initiated in the KNP in the form of the experimental burn plots (EBP's). The initial objective of this project was to investigate the effect of season and frequency of burning on vegetation in the four major vegetation communities in the park.

The plots were located in the vegetation landscapes described by Gertenbach 1983, viz. the Lowveld Sour Bushveld of Pretoriuskop (sandy granitic soils); the *Combretum spp* / *Terminalia sericea* Woodland (sandy granitic soils) near Skukuza, the *Sclerocarya birrea* / *Acacia nigrescens* Savanna (clay basaltic soils) in the vicinity of Satara and the *Colophospermum mopane* Shrub on Basalt (clay basaltic soils) north of Letaba.

There are a total of 208 rectangular plots each measuring approximately 380m X 180m (± 7 ha). The trial was laid out ostensibly as a randomised block design with four replicates comprising different season and frequency treatments. The plots are protected from wildfires by means of a double firebreak.

The seasonal treatments comprise burning in October after rain (spring); December (early summer); February (mid-summer); April (autumn) and August (winter). The frequency treatments comprise burning annually (B1), biennially (B2) and triennially (B3). In 1979, two additional treatments were added on the basalt replicates at Satara and Mopani viz. quadrennial (B4) and sexennial (B6) burns. One plot in each replicate receives no burning and serves as a control treatment (C).

THE INFLUENCE OF ADDITIONAL PERMANENT WATER ON THE RESILIENCE OF A COMPLEX ADAPTIVE ECOSYSTEM

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Purpose of the programme is to understand the relationship between permanent water sources (including sub-surface water) and local and regional biodiversity and ecosystem function with specific emphasis on the rare antelope in the KNP. A framework summarizing the hypotheses of the effect of artificial waterpoints on the ecosystem has been developed. The following discussion addresses the different hypotheses and the evidence we have gathered thus far to support these hypotheses.

Zebra increased with increasing water and showed an initial decline as waterpoints were closed, tsessebe, sable and roan showed the same increase with water. There has also not been an increase in the rare antelope since water was closed, but rather a decline which is concerning specifically is sable that are not a marginal species in the KNP. The change in zebra population from 1977 when the water development programme ended to 1998 when almost two thirds of the waterpoints were closed illustrated the increase in zebra, while the period of 1998 shows fluctuating zebra numbers with no clear response to the closure of waterpoints, in spite of the initial decline. Wildebeest that utilize the areas around waterpoints extensively increased between 1998 and 2002, but declined and stabilized at about the same number as before closure. There was also an in increase in the percentage decreaser species with increasing distance from water on the northern plains.

Elephant damage decreased with an increase in distance from water, the proportion of trees that had fire damage increased with an increase in grass biomass. The proportion of trees damaged by fire increased to more than the proportion damaged by elephants within the first 150 - 350m from water on basalt, but only within 650 - 1000m from water on granite.

There was an decrease in protein concentration in *Urochloa mocambiscensis* with increasing distance from water indicating a concentration of nitrogen near waterpoints. This is probably due to defaecation and urination by herbivores utilizing these waterpoints. The higher protein concentration in forage close to waterpoints is evidence of the creation of a lawngrass type situation where animals concentrate and enrich the areas where they forage. The change associated with these waterpoints allows population numbers of animals dependent on these resources to build up, while such areas are less suitable to selective grazers.

THE PRESENT STATUS AND FUTURE SUSTAINABILITY OF THE POLLINATION SYSTEM OF *FICUS SYCOMORUS* IN THE KRUGER NATIONAL PARK

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There are several factors that may threaten the long-term sustainability of this fig-fig wasp obligate mutualism. First, competition between the pollinating wasp species and other wasp species that seem to utilize the same niche could result in the systematic loss of the pollinator. Second, since wasps only live in the fig fruits, irregular and clumped fruiting patterns can lead to periods where there may be no habitat for the wasps. This may become a crucial problem if phenology is closely linked to precipitation, which is expected to change in the future.
Apart from quantifying the phenology, we are testing four possible explanations for a stable coexistence between competing species. 1) Niches are actually different, 2) Competition is prevented by temporal division of habitat, 3) Facultative sex ratio adjustment by wasps may be a density dependent population growth regulator, and 4) the wasp population may consist of a metapoulation that will allow a 'chaotic' coexistence.

POPULATION DYNAMICS AND ELEPHANT MOVEMENTS WITHIN THE ASSOCIATED PRIVATE NATURE RESERVES ADJOINING THE KRUGER NATIONAL PARK

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A total of 1801 sightings of bulls have been made since May 2003 until July 2006. A total of 431 sightings of breeding herds were made since May 2003 until Aug 2006. This figure includes multiple sightings of the same herd within a month as well as sightings of herds were no identification records could be collected either due to poor visibility or rapid movement amongst the members of the herd. A total of 247 identikits of cows within family units have been collected.

Eleven collars are currently deployed; seven on bulls and four on cows. Seven study animals have been monitored for more than a year (Mac, Classic, Diney, Alex, Joan, Barry and Mandy).

Two collars currently deployed are still due for replacement, i.e. that of Alex and Joan. We are hoping to do this within the next couple of months, as both collars have exceeded their expected lifespan. In studying elephant movements and range use it is critically important to collect data over a number of years to determine patterns that are the consistent over time and how they relate to environmental conditions that change within and between years. For this reason we feel it is important that the GPS-satellite collars currently fitted to Alex and Joan be replaced with GPS-GSM collars and this be done while these collars are still functioning.

Another study site will be established on the Joubertshoop (Portion 13) property and monitoring will commence before and after this property is incorporated into the APNR.

The research relating to this project will be conducted in two phases as in addition to the wire netting technique used at the Hancock and Ntsiri study sites, the use of chilli extracts will also be tested. The reports relating to the Hancock and Ntsiri sites have been provided in previous reports.

Five natural mortalities have been reported during the period under review (August 2005 – Aug 2006).

TREE PATTERNING AS A RESULT OF FIRE FREQUENCY

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The purpose of this project was to understand the role of fire in the spatial clustering of trees in savannah ecosystems. The main goal was to increase knowledge about savannah burning regimes since it can create insight in the long-term fire resistance of woody species that form clusters. These clusters potentially exclude fire and thus remain unaffected by fire regimes.
The data was collected in the winter of 2005 at the experimental burning plots. Data collected included nearest neighbour distances for randomly selected trees in the experimental burning plots, and clay content of the soil. Further data was obtained on fire frequencies, fire intensities and distances to water points.
The study has shown that clustering of savanna trees is a function of competition and fire. Fire however, plays a less important role than was hypothesized on the basis of models. Competition for water seemed a more important factor determining whether trees occur in clustered patterns. Also, we showed that clustering is probably an active process that occurs through the recruitment of seedlings or the clonal fashion of growing of tree species like *C. Mopane*. Finally, the results showed that trees can protect each other from the negative effect of fire.

ASSESSING AND MONITORING LOCAL SCALE IMPACTS OF *OPUNTIA STRICTA* ON ARTHROPOD ASSEMBLAGES IN THE KRUGER NATIONAL PARK, SOUTH AFRICA

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This project aims to investigate the degree of change in invertebrate assemblages as a result of alien plant species invasions in KNP. More specifically, habitat specificity of dung beetles and spiders and variation in these assemblages, within a habitat system characterized by different levels of *O. stricta* invasions, will be examined. Second, groups of species characteristic of each plant invasion level (indicators), as well as species that may be used to monitor changes in invasion levels (detectors) will be identified. Detector species will be used to predict change in the intensity of plant invasions. Third, should these detector species successfully predict any change, the option of using these species to rapidly predict the biological impact on invertebrate assemblages at feasible "maintenance" levels will be further explored. Feasible "maintenance" levels or theoretical low invasive levels are levels identified by the KNP management services at which the follow-up control of invasive plants is most efficient from an economic point of view. However, the biological impacts at these theoretical low levels are currently unknown.
The research questions asked will form part of the park's long-term strategy to manage invasive alien species. Consequently, this study will take the form of simultaneously addressing pure scientific questions as well as basic conservation management needs. Four different habitat areas characterized by four different levels of *O. stricta* invasion (high; intermediate; no infestation and pristine) have been identified. In each of these, five replicated sampling sites will be selected from which the volume and ground cover of *O. stricta* patches will be determined. Within each sampling site, spiders and beetles will be collected bimonthly over a period of 12 months (i.e. six temporal replicates) using un-baited pitfall traps. In the case of spiders, additional sampling will be conducted using leaf litter sifting and active searching. To date, six temporal replicates have been completed. 2166 Coleopteran individuals have been collected representing 80 species in 11 families.

SYNBIOSYS KRUGER - AN INFORMATION SYSTEM FOR THE EVALUATION AND SUPPORTING THE MANAGEMENT OF BIODIVERSITY AMONG PLANT SPECIES, VEGETATION TYPES AND LANDSCAPES IN THE KRUGER NATIONAL PARK

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SynBioSys Kruger is a collaborative project between Alterra Wageningen University Research, University of Pretoria and South African National Parks, aiming at the development of a biological information system, which will operate as a tool for supporting the evaluation and management of biodiversity in Kruger National Park. By bringing together the wealth of existing data at the levels of – plant and animal – species, ecosystems and landscapes, the system will strongly contribute to understanding the ecology of the biological levels involved. The power of the computer software package *SynBioSys Kruger* is threefold: (1) the entire system is data driven, (2) it is an open-ended system, and (3) large datasets can be analyzed and displayed visually using a GIS platform. Due to the availability of scientifically sound vegetation data, the first version of *SynBioSys Kruger* is focused on vegetation and plant species data, together with available environmental data influencing the vegetation of the KNP. Data from fields such as zoology, entomology, tourism and management programs will be incorporated as data become available. Any data containing spatial or temporal information can therefore be incorporated into this open-ended multi-disciplinary information system. Until recently, data such as species distribution, population demography, migrations, ecosystem composition and dynamics, plant-herbivore interactions, predator-prey relationships, landscape changes were stored, managed and analyzed as separate entities. *SynBioSys Kruger* will safeguard and integrate the existing data and will enhance data compilation. This synthesis of data and information into a single system will be of great importance to managers of different disciplines, acting as an electronic encyclopedia, from which data may be extracted for further analysis. The software package will be of great help in training programs and education, including tourism.

THE ECOLOGICAL DETERMINANTS OF GROUP SIZE AND COMPOSITION IN TERRESTRIAL PRIMATES

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This study is aimed at determining how ecological factors shape the social systems of terrestrial primates and to provide a quantitative test of the theoretical models we have developed to examine the trade-off between predation and feeding competition in primates. The primary objective of the research project is to survey the size, composition and density of baboon and vervet groups throughout the Kruger National Park.

To date, two trips to KNP have been made. These visits have focussed on surveying the entire park from the tourist roads to generate a map of baboon and vervet densities. Wherever possible the size and composition of the encountered groups was also recorded. Both surveys have indicated that the highest primate densities are in the area of the Sabie and Sands rivers between Skukuza and Lower Sabie and also along the Luvuvhu River around Pafuri.

Based on 9689km of driven surveys (without differentiating between habitat types but with fairly even coverage of the reserve) the estimated population size for the KNP baboons is 1556 groups (confidence limits 1163-2080). The mean group size of the groups sampled is 40.52 giving a population estimate of 62240 (confidence limits 47124-84281). The figure for vervet monkeys is similarly high. Based on an estimate of 2742 vervet groups (confidence limits 1983-3789) and a mean group size of 13.4 individuals, the estimated population size is 36626 (confidence limits 26487-50611). Current analyses are therefore breaking the survey routes into different habitat types. In particular separating out the riverine and non-riverine routes is essential. However it is entirely possible that primate densities are actually higher along roads and other travel routes as the animals use these for moving longer distances. While this is particularly true of baboons, both species will use will use road bridges to cross rivers.

BIOLOGICAL CONTROL OF *OPUNTIA STRICTA* IN THE KRUGER NATIONAL PARK AND SURROUNDS

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Two herbivorous insects, a phycitid moth (*Cactoblastis cactorum*), and a cochineal insect (*Dactylopius opuntiae*) have been introduced into KNP for biological control of one of the park's most troublesome invasive species, *Opuntia stricta.* The primary objective of the programme is to reduce and maintain *O. stricta* at levels where no other control measures are needed. The immediate objective is to reduce the invasiveness of the weed by decreasing its biomass and preventing seed production, so that the problem is curtailed and unaffected regions of the park are protected.

Both insect species are now well established in the park, particularly the cochineal, and are causing widespread damage and mortality of the weed. Earlier studies showed that while *C. cactorum* was suppressing the growth and fruiting of the weed, more needed to be done to improve the biological control programme. This resulted in the release of *D. opuntiae* in 1997 with spectacular results. After an initial set back due to exceptional rainfalls soon after the release of the insects, the cochineal began to thrive during a dry spell at the end of the decade and within a two year period the biomass of *O. stricta* had declined by over 85% in the research plots. The crash in the plant populations was mirrored by a decline in the insect populations. The challenge now is to determine where the system will stabilise.

Fruit production by the weed has been severely curtailed by the insects and almost no fruit was produced in the research plots during the last two years. This curbing of seedling must have caused a substantial decline in the rates of long-range dispersal of the weed and is helping to keep the problem in check.

A long term monitoring programme is under way to quantify the eventual levels of control that are achieved and to determine how sustainable these are.

THE SPATIAL DEMOGRAPHY OF SELECTED TREE SPECIES IN THE KRUGER NATIONAL PARK, IN RELATION TO ELEPHANT IMPACTS

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Currently the focus is on finalizing the data sets and drafting chapter outlines, which will be provided in due course. Only two areas in the southern section of KNP need additional transects for marula and false marula.

ENNOBLING THE WILD AFRICAN MARULA (*SCLEROCARYA BIRREA* SUBSP. *CAFFRA* SOND)

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Out of several thousand of wild Marulas 9 were registered with the Department of Agriculture: Division Genetic Resources as superior cultivars. Four of these are in the KNP and a fifth very promising one was also found near Phabeni gate. Final certificates were received from the Division of Genetic Resources for three of the cultivars as full bearing daughter trees were already established and the genetic stability could be verified.

To comply with the Plant Protection Law, two trees of each of the 9 ennobled cultivars were planted at Nelspruit, Pretoria, Origstad and Phalaborwa. At Skukuza only replicates of the selections found in and very near KNP (Phalaborwa and Kruger Gate) were planted in 2006. All 14 trees at Skukuza are growing although ants were a severe problem and had to be treated. These plantings will regularly be visited to assure only the grafts are growing and not the wild rootstock. Regular irrigation, fertilisation and pest control will also be applied.

Within three to four years these trees should be bearing fruit after which the genetic stability could be proved and the cultivars officially registered.

GLOBAL SOIL MACROFAUNA DIVERSITY AND ECOSYSTEM FUNCTION: BASELINE DATA FROM SOUTH AFRICA

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We were collecting termites for DNA sequencing, to include them in a worldwide study of termite relationships. This larger project is what I have been spending my time on, and I now have a very good (and large!) termite phylogeny, which I am presently preparing for publication. The termite species that we collected at Kruger were checked through for species of importance for DNA sequencing, but are otherwise waiting their turn to be identified and included in the global-level comparison of termite assemblages, which will ultimately be published when we have some of the more pressing work completed. My comments on the higher termite species richness around Punda Maria is therefore mostly observational at the moment - I remember that this was the only area in the park where we found one of the species of the 'Cubitermes group', a clade of species which are most diverse in tropical rainforests, and which are not found in arid environments. (Bear in mind that the great majority of termites exhibit similar diversity patterns).
The data from the soil transect that we conducted near Pafuri is also part of a global-level study, and one that is gradually being added to, so this will be a little while yet before it will be fully analysed and written up for publication. I have spoken with Dr Paul Eggleton, who will be taking the lead in the analysis of this data, and he tells me that although he cannot say much specifically at the moment, the order level data from the leaf litter and soil scrapes at Pafuri fits the general model of being a typical sub-tropical assemblage on a large continental land-mass. Also as expected for a dry forest sample, as Pafuri was, the proportion of ants and termites there is less than would be expected from an equatorial moist forest site. As I mentioned, termite diversity declines as the habitat becomes drier. There is also a tendency towards fewer soil-feeding species and increased diversity of the fungus-gardening species (the Macrotermitinae that we found in the many large mounds). By living in mounds, they are able to regulate their conditions in a manner optimal for the colony, despite being in relatively dry conditions. This is clearly harder for species living more freely in the soil (which prefer moist forest conditions), hence the loss of species such as the Cubitermes in the drier areas of the park.

IS THE INVASIVE WEED *CHROMOLAENA ODORATA* A THREAT TO THE KRUGER NATIONAL PARK?

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Chromolaena odorata is a problematic terrestrial invasive originating from South America that has established itself as a monoculture in the KwaZulu Natal province of South Africa. It has already spread along the major rivers within the Kruger National Park. The threat that it poses to the KNP was evaluated firstly according to its potential spread, using the climatic modelling programmes CLIMEX and FLORAMAP, secondly by ground truthing the current spread and thirdly, evaluating the potential of the biological control agent, *Pareuchaetes insulata*, to overcome climatic incompatibility and establish in the release sites in the KNP.

CLIMEX revealed that *C. odorata* will potentially spread throughout the KNP although not as severely as it has in KwaZulu Natal, whereas the FLORAMAP results indicate that the spread may be excluded from the northern extremities. The ground truthing revealed that the current populations both inside and outside the KNP pose a potential threat via propagule dispersal and finally the CLIMEX results indicate that *P. insulata* may not establish as a result of low climatic suitability of the release sites.

Therefore, with *C. odorata* posing a threat to the biodiversity of the KNP, an integrated pest management plan must be implemented immediately in order to manage the spread of this devastating weed.

ECOLOGY OF RIFT VALLEY FEVER VIRUS IN THE KRUGER NATIONAL PARK

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Evidence of seroconversion to Rift Valley fever virus (RVFV) in young buffaloes in 1998 and 2005, and proven RVFV infection in buffaloes and other herbivores in 1999, suggest that possible foci of endemicity for this arthropod-borne virus may exist in the KNP. The proposed study aims to provide evidence for or against this hypothesis by investigating buffalo sera for a period of three consecutive years and, simultaneously, monitoring populations of potential or actual vector mosquitoes along a north-south gradient in the KNP.

A batch of 245 buffalo sera and 2 white rhino sera were obtained from the Veterinary Wildlife Service of the KNP and screened by microtitre virus neutralization test (VNT). Thirty eight of the buffalo sera were positive for neutralizing antibodies at dilutions/titres of 1:10 or greater that successfully neutralized virus at a titre of 10^2 $TCID_{50}$/50 µl; neither of the 2 rhino sera was positive. Of the 28 positive buffaloes for which age data was available, only 4 were males. The significance of this finding is not clear. More importantly for our purposes, 6 of these sera were from calves under 12 months of age, although only two of these occurred in calves aged between 6 and 12 months old. Maternal antibodies are generally assumed to have been lost in this age group, although there is no published evidence for the extent of passive immunity in newborn bovines. One other serum from a calf aged 20 months was also positive, although the titre was only 1:10. All of the highest titres occurred in adult animals.

Aliqouts of buffalo sera from the 1998 bovine TB serosurvey in the northern part of the Park, that had been tested by ELISA, and had been subsequently stored at the Special Pathogens Unit (SPU), were retested by VNT. Of 409 sera tested thus far, 16 were positive, of which one calf was 4.5 months and 1 calf was 12 months old. It is suspected but not yet confirmed that these sera correspond to some of those tested by Prof Peter Howell, formerly of the Department of Tropical Veterinary Diseases based at Onderstepoort. Prof Howell has been contacted by Prof Swanepoel and has committed to make available the VNT results from the sera tested by him in 1999, which had first shown seroconversion in weaner buffalo calves from the KNP's northern herds.

Funding has been secured from the Poliomyelitis Research Foundation to assist with funding for the field collection of mosquitoes and for serological and virological testing of specimens from vertebrate hosts and vectors.

PLANT AVAILABLE NITROGEN UNDER DIFFERENT WATER REGIMES IN A SAVANNA, KRUGER NATIONAL PARK

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Data on grass and tree growth in response to varying levels of soil moisture, coupled with data on available nutrients would inform us of the importance of nutrients or water as a driver in savanna systems. Here we report the preliminary results of an experiment where various combinations of trees and grasses are exposed to different rainfall and competition treatments. Measures of available water and nutrients are determined under these different conditions.
The data shows that treatments with additional rainfall have higher mineralization rates than those treatments where rainfall is reduced. Furthermore, the data shows a seasonal pattern in mineralization rates, with the dryer season experiencing lower rates than the wetter season. The rate of mineralization peaks immediately after the spring rains and then shows a steady decline through out the season. Treatments with different combinations of grass and tree also showed differences in mineralization rates. The grass treatments are wetter than the tree treatment due to increased infiltration and water retention. This also explains the high mineralization rates in the grass treatments.
The data on grass biomass and tree radial increments shows that there is competition for water and nutrients, with grasses having a competitive edge in wetter treatments and trees showing a competitive edge in dryer treatments. These results suggest that it is a complex interplay between nutrients and water that are essential for plant growth in savanna systems.

FOREST COLONIZATION OF SAVANNAS: PATTERN AND PROCESS

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Increased density of woody plants, "bush encroachment" have many cascading ecosystem consequences, but little is known about factors that influence and/or limit the process of forest colonization of savannas. In a broad-leaved deciduous woodland ecosystem in Pretoriuskop, southwestern region of the Kruger National Park, we conducted a field experiment to investigate the effects of fire frequency and canopy cover on species composition under the canopies of *Sclerocarya birrea* (*S. birrea*) also known as marula and *Terminalia sericea* (*T. sericea*) also known as silver-cluster leaf, and on the open habitats. An open habitat was defined as an adjacent circular plot without any canopy effect. The entire canopy area was used as the sampling plot under each tree and an adjacent circular plot of similar area was sampled in open sites. All individual woody plant species were identified, measured, counted and recorded. The height and basal diameter of the recorded plants were measured by means of calipers and/or tapes. We collected soil samples for nutrients analysis, soil pH measurements and soil moisture measurements at different soil depth, 5, 15, 25, and 45 cm respectively.

The number of species was found to be highest under *S. birrea*, low under *T. sericea* and lowest on the open habitats. Decreasing fire frequency decreased the number of individual woody plants under *T. sericea* and on the open habitats, whereas decreased fire frequency increased the number of individual plants under marula. Decreased fire frequency increased the number of species under both marula and *T. sericea* and on the open habitats. The soil pH was found to be medium acid under marula and strongly acidic under *T. sericea* and on the open habitats across the fire gradient.

In conclusion, there was a definite effect of trees on their understorey environment because they influenced woody density and soil properties. There was high woody density under tree canopies as compared to the open habitats and soil moisture was high on the topsoil layer, with an increase of exchangeable cations under the canopies than open habitats, as suggested by other researchers (Kellman 1979, 1984; Belsky et al. 1989. Belsky 1994) that savanna trees influence savanna productivity underneath their canopies. Fire exclusion alone did not lead to forest invasion because few new saplings are found on the open sites and under *T. sericea*, but there was a shift to dense trees and shift in species composition with no burn under marula. Forest colonization depends on canopy effects, fire exclusion and resource availability.

SOIL EVOLUTION ON GRANITIC CATENAS

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The most exciting data so far have been the erosion rates, chemical depletion and mineralogy. Kruger has one of the lowest erosion rates recorded by cosmogenic isotopes, this finding gives us confidence that catenas have plenty time to develop in the lowveld due to the high residence time of the soils before they are eroded. The great age of the soils means that chemical weathering is likely the dominant mode of landscape evolution since the lowveld is hardly tectonically active nor has it been subjected to glaciers or landslides. Our calculations of chemical depletion indeed confirm that these soils are highly depleted in most of the rock forming elements such as Silica and Aluminium. Finally, we have found unexpected trends in the clay mineralogy of soils on catenas. The southern African dogma dictates that we should expect smectite on footslopes and kaolinite on crests. Our preliminary finding, however, show that it not smectite on the footslopes but large concentrations of kaolinite; and, both smectite and kaolinite occur on the crests.

A PREDICTIVE MODEL TO IDENTIFY THE LOCATION AND EXTENT OF SODIC SITES IN THE KRUGER NATIONAL PARK USING REMOTE SENSING TECHNIQUES

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The aim of the project is to produce a digital map of the sodic sites found in the entire Kruger National Park from digital images obtained using remote sensing, and digital image classification techniques. A literature survey has shown that a sodic site is a function of its position in the landscape (footslope near a river), and the soil chemical and physical properties resulting from that position. This gives rise to unique, high quality forage and vegetation cover attracting herbivores which utilise the nutrients in the plant material to the extent that bare patches are created.

The geographic positions of known sodic sites in the Kruger National Park will be collected and plotted in a GIS in the coming months. If there is not enough known data to use as training sites for the classification, a field trip will be organised for October to collect sufficient data. Different images will be used at different scales to determine the effectiveness of the classification methods and these will each be evaluated using a confusion matrix and Kappa statistics. This is seen as an iterative process and both accuracy and cost of images will be borne in mind with regards to the usefulness of the resultant digital map.

Kruger National Park GIS Laboratories have provided the Landsat images together with the map of sodic sites for the northern section of the Kruger National Park produced in 2001. This map shows the 'salt and pepper' effect of pixel based classification systems and the use of an object-based image classification method is now being investigated.

Higher resolution images will be provided by KNP GIS as the project progresses for limited areas of the park.

Erdas Imagine will be used for image analysis and eCognition will be used for the object-based image classification. All pre-processing of images required will be done by experts to be sure of a robust image used for classification. These software tools will be used to classify sodic sites from digital images and provide a predictive map (still to be verified) by December 2006.

THE ROLE OF MEGAHERBIVORE BEHAVIOUR IN DRIVING FIRE-GRAZING INTERACTIONS AND GRASSLAND COMMUNITY STRUCTURE: COMPARING PROCESSES ACROSS CONTINENTS

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The aim of the project is to assess how ecosystem and community structure and function respond to key ecological drivers (fire and grazing) in savanna grasslands. Identical research programs have been established in the Kruger National Park, and in North American grasslands (Konza Prairie, Kansas, USA) to assess convergence and contingencies in grassland responses to these drivers. During Oct/Nov 2005, a total of 105 grazing exclosures (37.5 m^2) in replicated unburned, 1- and 3-year burn treatments (capitalizing on the long-running EBP experiment in the Satara region), and in two burn treatments within a large Cape buffalo enclosure near Satara were erected. Inside each grazing exclosure and in paired plots that were open to grazing, a 2x2 m permanent subplot was established and sampled plant species composition in the early (Jan) and late (Mar/Apr) growing season (N=210 subplots). In addition, in each of these paired grazed and ungrazed plots annual aboveground net primary production (ANPP) was measured and soils collected for measuring total C and N content. Herbivore habitat preference and foraging behavior in response to these fire treatments, were surveyed twice-weekly throughout the 2005-06 growing season (Oct-Mar).

Plant species composition analyses revealed that in general, richness and diversity of both grasses and forbs increased with decreasing burn frequencies. The highest richness and diversity was found in the unburned plots, with annually burned plots typically lowest. In addition, grass cover decreased with increasing burn frequency, whereas bare ground cover increased substantially with increasing fire frequency. The distribution of large mammalian herbivores, was not correlated with metrics of plant community structure, grass nutrient content, or the distance of the plots from water. However, herbivore abundance (selectivity) was negatively correlated with grass cover and positively correlated with bare ground cover and forb biomass production, for both the early and late season plant communities. Consequently, herbivores preferred frequently burned plots to infrequently or unburned plots. This counterintuitive result that herbivores which forage primarily on grasses prefer areas with comparatively low grass cover suggests that the risk of predation may largely govern herbivore habitat selection and foraging activity. Further, these behavioral responses (herbivore habitat selection and foraging intensity) likely to have strong top-down impacts on the plant community (e.g. reducing grass cover in overly-grazed 'safe' habitat, thereby indirectly enhancing forb productivity).

VEGETATION RESOURCE DISTRIBUTION AND DYNAMICS ASSESSED USING HYPERSPECTRAL (AND BROADBAND) REMOTE SENSING AND THE RESPONSE OF WILDLIFE IN THE SOUTH AFRICAN SAVANNA

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The research project aims to map the distribution of di□erent grass leaf biochemicals considered to act as attractants and deterrents of wildlife, the mapping will be done using remote sensing. The distribution of the biochemicals is to be mapped over the Kruger National Park (KNP) and this will then be related to wildlife distribution.
In order to achieve this goal of mapping the biochemicals it is first necessary to determine how the biochemical concentrations can be identified within remotely sensed imagery. This is done in a controlled laboratory/greenhouse environment before it is taken up to the field level. Wild seeds of the grass *Urochloa mosambiscensis* were collected from the Gene Bank of the Agricultural Research Council in South Africa. This species is not grown on a commercial basis and the germination procedure has not been studied extensively. The success rate of germination was unknown and was first tested before the plants could be used in the greenhouse experiment. Trials using two di□erent germination techniques showed that the seeds had a very low viability (less than 5%). Seeds of grass *Digitaria eriantha* were obtained. This species is grown commercially and the methods for germination are well known and the seeds are highly viable. Using these seeds the greenhouse experiment was then initiated.
The greenhouse study was a multifactorial study that was designed to study the e□ects of soil nutrient concentration (Nitrogen and Phosphorous) on di□erent plant ages and the resulting e□ect on plant biochemical production. Reflectance measurements of the plant canopy, leaf and dried ground material were collected for the seedling, adult, flowering and dormant stages of the grass. The few seedlings of *U. mosambiscensis* that germinated in the above trial were grown under the di□erent soil nutrient treatments and measured at the adult phase of growth. The data preparation and processing on the reflectance measurements has begun. By the end of May 2006 the greenhouse experiment was in its final stage. The dried ground material has yet to be chemically analysed. All of the plant material from each stage in the experiment will be analysed together after the greenhouse experiment is terminated. It is expected that the chemical analysis will be done in July and August 2006.
The main outcomes from this first year are therefore the production of the proposal, the literature review and the reflectance data obtained from the greenhouse experiment. As of yet been no publications have been produced.

HABITAT AND FORAGE DEPENDENCY OF SABLE ANTELOPE (*HIPPOTRAGUS NIGER*) IN THE PRETORIUS KOP REGION OF THE KRUGER NATIONAL PARK

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This study is aimed at contributing towards establishing the causes of the decline of low density antelope species in the Kruger National Park (KNP). The goal is to gain a better understanding of habitat and forage dependency by sable antelope at different spatial scales in a region where the largest sub-population persists.
The objectives of the study were stated to be; establishing foraging area features selected by sable seasonally; identifying the grass species and/or grass characteristics that sable depend on seasonally; determining the use of burnt grassland by sable antelope or the conditions governing utilization; and establishing nutritional status of sable over the seasonal cycle so as to determine the nutritional consequences of grazing patterns.
The study focuses on four herds occurring in the Pretoriuskop region i.e. in the vicinity of Numbi gate, Phabeni gate, Shitlave dam and Nhapi boulder. GSM-GPS collars were fitted to four adult females each belonging to a separate herd in the beginning of June 2006. The herd occurring in the vicinity of Numbi gate serves as the main focus herd for the study and contains two collared females of which one female has been collared since 14/11/2005.
Collection of foraging data and data on habitat use commenced in the beginning of June 2006. The study is still in the early stages and thus no data has as yet been analysed.
The readings received from the GSM-GPS collars appear to be very accurate which allows me to collect data on feeding and habitat features at a very fine scale. All herds except the herd in the vicinity of Shitlave dam remain within cell phone reception regularly. It seems as though the sable utilize a relatively small area within their home range intensively, revisiting the same areas on a regular basis. Faecal samples have been collected from all four herds for the purpose of microhistological identification of the grass species consumed. No feeding has yet been found on recently burnt areas despite the availability of burn grassland with green flush.

A SCALED PERSPECTIVE OF THE CONTEXT, STRUCTURE AND DYNAMICS OF RIPARIAN/SAVANNA BOUNDARY VEGETATION PATCH MOSAICS: IMPLICATIONS FOR THE MANAGEMENT OF COMPLEX SYSTEMS

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The central aim of this project is to gain a deeper understanding of the spatial and temporal dynamics of riparian/savanna boundary vegetation patch mosaics, in a manner which contributes to both the theory of landscape ecology and vegetation/landscape management within the Kruger Park.
Standard techniques for extracting tree heights from LiDAR work well in forested systems but do not adequately represent more heterogeneous savanna vegetation. Using ArcGIS and eCognition a tools, I have developed protocols to automatically extract surfaces of tree crown coverage and height from the LiDAR data. I have focused so far on a section of the Phugwane River and am now testing how well these protocols work across the study range. Initial results indicate that LiDAR data, when coupled with object based image analysis, could provide managers with an excellent tool to monitor changes in the three-dimensional structure of woody vegetation in a spatially explicit manner over relatively large areas.

THE ANATOMY OF THE BRAIN OF THE AFRICAN ELEPHANT

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Global objective is to provide a description of the elephant brain in enough detail as to increase and complement our understanding of elephant behaviour and to provide new directions in the study of elephant behaviour. There has been no progress on this project thus far, as we were awaiting funding from the National Research Foundation which we have now successfully obtained. We are ready to begin organizing the initiation of the field work portion of the project with KNP.

ISOLATION OF POTENTIAL PROBIOTIC BACTERIA FROM THE INTESTINAL TRACT OF HYENAS

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The purpose of the project is to isolate potential probiotic bacteria from various sources including the intestinal tract of hyenas. The lactic acid bacteria and bifidobacteria population present in the gastro-intestinal tract (GIT) of wildlife species including Hyenas have not been investigated. Since hyenas tend to eat even decomposing carcasses without developing illnesses such as diarrhoea, the hypothesis can be made that there should be some unique gastro-intestinal bacteria present to sustain the balance of the GIT bacteria population. The collection of samples from hyenas will be done for 1 year, depending on the frequency of sample availability. The phases of the project will include, collection of intestinal samples, isolation and identification of potential probiotic bacteria and screening of these bacteria for probiotic properties.
Two batches of samples were received from the KNP. The first batch received included samples that were already stored for approximately 3 months at -20°C. Previous research done on porcine intestinal samples showed that porcine samples could be stored for such a period and potential viable probiotic bacteria could still be isolated. However with the hyena samples no viable bacteria could be isolated, we concluded that we needed samples that were not stored for such long periods. We then arranged for another batch of samples which we received during May this year. We were able to isolate some potential probiotic bacteria from these samples and we are currently in the process of screening these bacteria to determine their probiotic properties. We do now know that “fresh” samples are the best to use, if they can be obtained. Thus far there are at least five isolates that showed some potential, further screening is needed.

STABILITY, RECOVERY AND RESILIENCE IN PIOSPHERE SYSTEMS IN THE KRUGER NATIONAL PARK

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The aim of this study is to resurvey piosphere systems in the Kruger National Park (KNP), last described by Thrash in 1990. The project's objectives are to document temporal change in soil infiltration rate and compaction, soil fertility, herbaceous community composition and structure, herbaceous basal cover and woody plant community composition and structure. Approximately 50 % of the piosphere systems surveyed by Thrash (1993) are now associated with closed waterholes. The study addresses recovery and resilience in closed piosphere systems and stability in open systems (1990 – 2006). We are considering changes in soil and vegetation parameters at open and closed waterholes in related to rainfall and soil gradients. To date, only the basal cover data has been completely analyzed.

Basal cover has increased (by 4 – 60 %) between 1990 and 2006 at all sites and in all piosphere zones delineated by Thrash (1993). The logistic equation does not adequately describe the relation between basal cover and distance from water.

Greater increases in basal cover from 1990 to 2006 were recorded at mesic sites relative to drier sites, and granitic soils compared to basaltic soils. In the Skukuza and Satara land systems, the increase in basal cover between 1990 and 2006 was greater in closed sites relative to active sites. In the Phalaborwa system the opposite pattern emerged, and there was little difference between open and closed sites in the Letaba system. More frequently burnt sites have higher basal cover. Rainfall in the previous season was higher in 2006 compared to 1990. This is currently the best explanation for the change in basal cover.

POLLINATION ECOLOGY OF SOFT-WINGED FLOWER BEETLES (INSECTA: COLEOPTERA: MELYRIDAE) IN KRUGER NATIONAL PARK

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This project will provide basic ecological data on flower visitation and pollination by soft-winged flower beetles (Insecta: Coleoptera: Melyridae) in Kruger National Park and other protected areas in South Africa. Numerous beetle species (perhaps as many as 200,000 worldwide, according to one estimate) are found on flowers but their contributions to the pollination of these flowers are in most cases poorly understood. Soft-winged flower beetles (family Melyridae) have been identified as one group of beetles which are likely to be significant pollinators. Although South Africa is home to some of the world's largest and most colorful melyrid beetles, there have been few studies to date of the pollination ecology of these beetles. This project will investigate pollen transport by species of the genus *Melyris* in Kruger National Park (and other areas). This project will help park managers achieve park goals of better understanding insect biodiversity and the contributions that insects make to key ecosystem processes such as pollination.

In the first phase of this project, museum specimens have been studied to identify potential target taxa for the field investigations, which are scheduled to begin in September, 2006. Species of *Melyris* which are known or likely to occur in the Kruger National Park include *M. rufiventris* Boheman and *M. sulcicollis* Boheman. Interestingly, the area which is presently included in KNP has apparently never been comprehensively surveyed for these beetles, raising the possibility that other species will eventually be found to occur in the Park.

ECOLOGY OF TIGER BEETLES (INSECTA: COLEOPTERA: CICINDELIDAE), WITH FOCUS ON RIPARIAN SPECIES

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This project will provide basic ecological data on tiger beetles found in riparian areas in northern South Africa, with special focus on Kruger National Park. Many species of tiger beetles are in decline worldwide (including several taxa in South Africa) and better ecological data is needed to better manage populations of these insects. For each species encountered, a suite of relevant ecological parameters will be recorded at occupied sites. Visitations at multiple sites, should be able to provide a robust characterization of the habitats occupied by the beetles.

In January, 2006, I performed brief inspections of suitable habitat on both the Letaba and Olifants Rivers within Kruger National Park. Adults of the species *Cicindela (Chaetodera) regalis* Dejean were observed on sandbars and sand islands in these rivers. The portions of the rivers examined could be characterized as “mixed anastomosing” using the river morphology classification developed originally for the Sabie River, which means that these rivers reaches included multiple anastomosing channels both in bedrock and in unconsolidated sand.

IT'S MINE, IT'S YOURS: ARCHAEOLOGY AND CULTURAL HERITAGE IN THE KRUGER NATIONAL PARK

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This five-year project traces the transformation of heritage strategies in Kruger National Park from the inception of democracy. It outlines the benefits of this transition for the both scholarly and indigenous understandings of the park as a landscape, both natural and cultural, with its rich heritage and its connections to various communities and stakeholders. My research in KNP reveals the continual frictions among transnational organizations, funding agencies, state projects, heritage bodies and indigenous communities in and around the place of culture in a nature reserve. Both natural and cultural heritage are imagined in particular local and national ways, and each is influenced and impacted upon by global organizations and mandates. Notions of local, state, global and indigenous are all pieced together from this complex mosaic of sources, resources, inspirations, and agendas. What began as a project of tracking the progress of archaeology after ten years of democracy has necessarily come to embrace the fraught relationship between cultural and natural heritage, and to ask why it is that nature often trumps culture in the wider framings of biodiversity and global conservation movements.

In asking why diverse nature offers a more compelling suite of concerns, as opposed to cultural diversity and preservation, a number of differences are laid bare. Nature is neutral, supra-racial, existing and entreating protection beyond race: it can be embraced by the new, multicultural concept of South Africa as the Rainbow Nation. Nature is immediately apprehensible and legible with real time collective consequences for the planet if we fail to meet our protective agendas, whereas the archaeological and historical past requires decipherment, translation and education. Cultural heritage is identity-specific, factional and, while seemingly important for crafting a new national identity, archaeological remains are currently configured to particular communities in partial, exclusionary and politically divisive ways. Multiple stakeholder sharing of the past is understandably difficult given the repressive histories of colonial and apartheid rule. Species diversity is universally recognized and consumed, irrespective of race, nation, religion, gender, ethnicity and so on. It is also globally supported by an organizational and fiscal infrastructure that further operates an index of modernity, civilization, and alignments to first world priorities. The language and scope of biodiversity is inherently modernist and cosmopolitan, neoliberal in ethos, and positively configured as scientific, sustainable, developmental and experimental.

LAND USE CLASSIFICATION AND WATERSHED MODELING OF THE LUVUVHU AND SHINGWEDZI RIVER WATERSHEDS

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The Luvuvhu River supports a fragile riparian ecosystem of rare plant and animal species in the Pafuri floodplain of northern Kruger National Park. Although a critical stretch of the riparian area itself is protected by KNP, the incoming river that supports it has suffered from increasing degradation over the last 40 years. Alterations in land cover and an increasing number of dams and diversions in the upper watershed are causing river drying during winter months and years of drought. This project investigates the relative roles of land cover change and dams on this drying trend using remote sensing, GIS-based hydrologic modeling, and historical discharge records.

A land cover map was created from current Landsat TM imagery using iterative isoclustering and masking. The GIS-based, physically-driven watershed model called SWAT (Soil and Water Assessment Tool) is being used to assess the relative roles of land cover and dams on dry season flows. Soils, climate, DTM, and precipitation input layers were obtained to run the model and river discharge records were used to calibrate model outputs.

After calibrating a limited number of parameters within the hydrologic model, the accuracy of modeled discharge at the annual time-step was high (Nash-Sutcliffe efficiency coefficient of 0.87) and the relationship between predicted and actual river discharge was close to a 'one-to-one relationship' (0.89). However, at the monthly time-step, predictive power declined to unacceptable levels and therefore more 'tuning' of the model needs to take place before different scenarios can realistically be compared.

An analysis of hydrologic records and scientific literature leaves no doubt that the Luvuvhu River has changed dramatically in the last 40 years. The primary changes that have occurred are increased flood magnitudes and decreased base flows. A visual comparison of Landsat images in 1978 and 2005 primarily shows a decline in shrubland and an increase in bare ground. This wide-spread reduction in vegetative cover has probably reduced infiltration rates, resulting in less groundwater recharge and smaller base flows. Over-abstraction from different users upstream of the KNP has impacted on the health of the riparian vegetation leading to some form of territerization in the original riparian zones. In addition, no-release dams that prevent water from flowing from the wet highlands to the dry lowlands are undoubtedly reducing base flows in dry months.

VEGETATION RESPONSES TO INVASIVE ALIEN PLANT CLEARING ALONG THE SABIE RIVER IN AND ADJACENT TO THE KRUGER NATIONAL PARK

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The *Working for Water* programme is one of the major components of invasive plant management in the Kruger National Park (KNP) and was first launched in 1997. Later, a further project worth R6 million was launched , employing 1000 workers, and since then over R20 million has been spent in the KNP on clearing efforts, focusing mainly on riparian areas of major rivers. However, very little post-clearance monitoring has taken place. Thus the aim of this study is to investigate the responses of both exotic and indigenous plant species to invasive plant clearing along the Sabie River, in and adjacent to the KNP, and to consider the implications of clearing on biodiversity conservation. Additionally the study aims to assess both the long term (comparing data from 1997, 2001 and 2006) and short term (comparing data before and after a single clearing season) efficacy of the *Working for Water* invasive alien plants (IAP) clearing programmes in the KNP in order to improve and optimise clearing practices.
Initial analysis of the primary data suggests that levels of certain woody invasive alien species such as *Lantana camara* are being maintained at an acceptable level. However other invasive alien species have established since 2001, several of which were found in high densities (*Senna obtusifolia* and *Xanthium strumarium* (DW1)). Further data collection and analysis will be carried out in the forthcoming months in order to investigate management and environmental factors influencing the current state of riparian vegetation composition and structure as well as to assess the short term efficacy of *Working for Water*.

EFFECTS OF CERTAIN CHEMICAL SUBSTANCES ON SELECTED FISH SPECIES IN THE LOWER CROCODILE RIVER, MPUMALANGA

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The aim of the study is to provide clear understanding of the relation between abiotic and biotic components in the Crocodile River system. It is also aimed at changing the perspective and attitude of major water users in the catchment. Investigation of the levels of anthropogenically generated pollutants will help to trace the source of pollution and try to mitigate the cause. The industrial, agricultural, mining, and urbanization/ settlement activities such as water abstraction, effluent discharge, etc., pose serious potential deterioration of water quality in the catchment.
The results of this study will benefit quite a number of stakeholders. The Department of Water Affairs and Forestry (DWAF), as the custodian of the water resources in the country, will be on the top of the beneficiary list. The findings will feed into the knowledge base of DWAF with regard to water quality in South Africa. Kruger National Park will have much cleaner water needed to maintain the pristine conditions of its wildlife

VEGETATION RESOURCES QUANTIFICATION: INPUT TO THE RARE ANTELOPE RESEARCH

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To this end, this project focuses on the quantification of herbaceous biomass (especially under trees) using an integrated approach involving remote sensing and spatial statistics. The output model will then be used in combination with the sable collard data as well as other environmental variables to better understand how ecosystem heterogeneity affects herbivore diversity. We investigated the possibility of improving understorey biomass estimates using cokriging. Individual bands and ratios computed from MODIS image were correlated with field measurements of biomass covering the Kruger National Park. The band that yielded the highest correlation with biomass was then used for further analysis using cokriging. Three variogram models were developed, one for the herbaceous biomass, one for the best MODIS band and a cross variogram between all pairs of variables involved in the estimation.

The variogram models were then used in cokriging to estimate biomass distribution over the whole study area. Results indicate that cokriging greatly improved biomass estimates ($r = 0.74$) between the predicted and measured test data set and a RMSE of ($\pm$27 % of mean) as compared to multiple linear regression or ordinary kriging between biomass and the MODIS variables. Results from this study have shown that a combination of remotely sensed data and geostatistics can reduce the errors of interpolation in complex savannas. Using band 2 from MODIS image and field biomass in a cokriging environment yielded a RMSE of 830 kg ha^{-1} between the predicted and measured herbaceous biomass on an independent test data set. The result is better than that obtained by ordinary kriging as well as the result obtained by stepwise linear regression on individual MODIS bands and transformed ratios.

The good result obtained in this study can be attributed to the cross-correlation engrained in cokriging as compared to simple correlation or ordinary kriging. By using spatial statistics with remote sensing, spatial autocorrelation on both the primary variable (herbaceous biomass) and the secondary variable (MODIS band) is taken into account. In this regard, cokriging predicts optimally by referring to the spatial dependency represented by the three variograms. In other words, results in this study show that the variance in herbaceous biomass can be more accurately explained by combining spatial information contained in the herbaceous biomass data (through spatial autocorrelation), remotely sensed data (through multiple scattering reflectance signals and their spatial autocorrelation) and the interaction between the primary and secondary variables (cross - correlation).

THE IMPACTS OF OFF-ROAD DRIVING AND OTHER CONCESSIONAIRE ACTIVITIES ON PHYSICAL SOIL DEGRADATION

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This report is a summary of the work done for the second (controls) and the third (quantification) phases of the research of three phases. A baseline for the research was set in the first phase of the project and, now, I am busy with monitoring some of the controls for off-road driving. As part of the controls the following are included; the Lebombo Eco-trail (June 2006), the low-usage tracks (fire-breaks) in the southern section of Kruger, the adjacent private reserves and just normal unused wilderness areas in the concessions. It is envisaged to monitor certain points on the Lebombo Eco-trail again, before the rainy season starts in October/November. The quantification (third phase) is in progress and is being done while monitoring the controls. The quantification involves the development of a formula for quick and easy monitoring/evaluation of the off-road/other concessionaire situation in the private concessions.

THE DEVELOPMENT OF AN INTEGRATED WILDLIFE DISEASE SURVEILLANCE AND MONITORING SYSTEM FOR DISEASE DETECTION AND MONITORING IN FREE RANGING WILDLIFE IN THE GREATER KRUGER NATIONAL PARK

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The aims of the prject were to evaluate the existing Foot and Mouth, Anthrax, Tuberculosis and Brucellosis surveillance and monitoring effort and techniques, together with general animal disease surveillance, within the Kruger National Park, and the other identified TFCA components. It was to assist in developing an integrated wildlife disease surveillance and monitoring system for the greater TFCA, to improve training of and communication with field staff, in order to sensitize them to identify early warning signs of animal diseases and to report effectively. The project further aims to assist with standardizing and harmonizing methods and techniques for collecting specimens and managing animal disease data.
Different sections and concessions within the Kruger National Park, Private Nature Reserves and Tour operating companies were visited. During each visit a questionnaire related to the specific occupational group (ranger, field ranger, tour guide, field guide, and trails rangers) was presented to them and filled before the start of a 3 hour training session. The questionnaire focused on important matters relating to Wildlife Disease Surveillance. Almost 94% of section rangers and field rangers responded that training (veterinary related) is insufficient and must be an ongoing process which will enable them to do proper surveillance. Although the final statistics are not available as yet, the amount of reports from the different sections concerning sick animals, blood smears or carcasses has increased dramatically over the last 4 months due to the awareness campaign.

ENVIRONMENTAL EDUCATION PROGRAMME FOR CONSERVATION OF KRUGER NATIONAL PARK TRANS-BOUNDARY BUTTERFLY POPULATIONS

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The main aims of the study were, to indicate how the rock formations influence the veld types and vegetation which in turn influence the fauna, including butterflies; to determine where the different butterflies occur, so that a complete picture can be formulated of each butterfly's distribution in the KNP. Butterfly atlassing entails collecting butterflies and capturing the data i.e. species name, GPS location, meteorological conditions (e.g. windy, cloudy, time) and other significant information (e.g. grassy area). The Avian Demographics Unit (ADU) are responsible for the atlassing of birds and it is their updated data that is used for the distribution maps of South African birds. The ADU has graciously compiled a website for the Lepidopterists Society, where gathered data can be captured in order to get a clearer picture of the distribution of South African butterflies.

During the six month span, three areas were visited. These areas were Skukuza, Berg-en-Dal, and Area 61, near Pretoriuskop. It has been decided to include Marloth Park as a representative area as it falls into the vast distance between Berg-en-Dal (Malelane) and Crocodile Bridge. *Butterflies of the Kruger National Park*, (J Kloppers, 1978, National Parks Board of S.A., Sigma Press, Pretoria) was used as a reference, as to the occurrence of the butterflies. In addition books that record South African butterflies nationwide have been consulted as well, in order to get a clearer, larger picture of each butterfly's distribution.

Surveys of especially Area 61 (Pretoriuskop) and Marloth Park have confirmed that some species do occur in the area, but have not previously been collected here or are considered rare for the area. These species include: *Iolaus pallene, Iolaus caeculus caeculus, Lepidochrysops plebeja plebeja, Mylothris chloris agathina.* On a national map of the area these species have been considered to occur here, due to the continuity of the occurrence of these butterflies in neighbouring areas. By example, only a single female specimen of *Iolaus pallene* was found in Area 61, yet this proves its occurrence in the area, and is confirmed on a national level.

At this early stage it is still difficult to determine the influence of rock formations, veld types and vegetation on the distribution of the butterflies.

THE MEASUREMENT OF HERBACEOUS LAYER DYNAMICS OF THREE LOWVELD SAVANNA TYPES

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The primary objective of this study is to determine which vegetation monitoring technique/s best reflect reality in terms of the herbaceous layer species composition and density. Also, existing and untried monitoring techniques would be replicated within sites of known absolute densities and structure to measure their ability to reflect the true state of savanna herbaceous layers.

SCALES OF BIOPHYSICAL PATCH HETEROGENEITY AND RIPARIAN VEGETATION RESPONSE IN A RIVER LANDSCAPE FOLLOWING AN EXTREME FLOOD DISTURBANCE

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The aims of the project are to 1) examine the pattern of vegetation in the Sabie River, 4 years after the flood and 2) examine the influence of hydrology, riverscape heterogeneity and channel morphology on post-flood vegetation response. Several projects have been undertaken to address these aims and are discussed below.

Understanding the causes and consequences of heterogeneity is a fundamental objective of science in Kruger National Park. Based on the model of heterogeneity from Pickett et al. (2003: The Kruger Experience) we examined the interaction between structural heterogeneity (patches with different disturbance imprints of the 2000 flood) and functional heterogeneity (woody riparian vegetation response) at the zone, channel type and elevation scales in the Sabie River landscape. We used four disturbance patch types (patches that stayed vegetated, patches that were vegetated before the flood but are now a physical state, patches that stayed as a physical state and woody debris patches) because we expect that these will provide different environments for riparian vegetation response.

Overall, there was a significant difference in the area, size and density of all disturbance patch types in the river landscape. Analysis of individual patch types showed congruence of structural and functional heterogeneity only at one scale of river system organization. Multiscaled relationships between structural and functional heterogeneity have implications for spatial and temporal dynamics of the Sabie River landscape. Different patch types contribute unique layers of heterogeneity in the river landscape at the channel type and elevation scales, but vegetation responds to structural heterogeneity at the elevation scale. Given that elevation is a surrogate for flow inundation, the flow regime of droughts and floods of different magnitude, timing and duration will play a major role in shaping the long term responses of vegetation communities in the Sabie River following the 2000 floods.

REGENERATION STRATEGIES OF RIPARIAN PLANTS ACROSS A FLOODING FREQUENCY GRADIENT: DOES THE BELLINGHAM-SPARROW RESPROUTING MODEL APPLY TO A SEMI-ARID RIVER?

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A conceptual model proposed by Bellingham and Sparrow (2000) predicts a unimodal relationship between disturbance frequency and the number of sprouting species in a community. We tested the applicability of this model in riparian vegetation communities recovering from the flood, using elevation above the channel as a surrogate for flooding frequency.

Ordination and cluster analysis were used to divide species into regeneration groups based on the relative contribution of resprouting and seeding to regeneration after the flood. The percentages of species in each group were then plotted across the disturbance frequency gradient. The analysis was performed at two spatial scales: for the whole section on the river within KNP, and for each of the four main channel types.

The proportion of sprouter species in the community decreased with increasing disturbance frequency (towards the macro-channel floor), while the proportion of seeder species increased, at both spatial scales. The proportion of seeder species was greater in the braided and pool-rapid channel types than in the anastomosing channels, where sprouter species were predominant even at the lowest elevations. Overall, sprouter species made up 60-80% of the total species across the entire flooding frequency gradient. Residual vegetation (survived the flood) showed similar trends in sprouter/seeder proportions to new vegetation (established after the flood), suggesting that the flood did not alter the distribution of regeneration strategies in the river landscape.

Our results are consistent with the Bellingham-Sparrow model, for a restricted portion of the disturbance frequency gradient represented in the model. There is strong selection for resprouting in this system compared to other systems affected by fire and windthrow. The composition of the community in terms of regeneration groups appears stable, with little change even after a large flood which created many opportunities for seedling establishment. The extraordinary persistence of sprouter species increases the resilience of riparian vegetation in this system.

CHANGES IN RIPARIAN VEGETATION STRUCTURE AFTER A LARGE FLOOD

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Large floods have the potential to alter vegetation structure, because plants of certain sizes are more susceptible to being removed or damaged than others. Changes in vegetation structure are important because they have the potential to affect many riparian attributes and processes, including habitat availability and heterogeneity, transpiration, nutrient cycling, supply of large woody debris, flow velocity and sedimentation patterns, as well as the general appearance and character of the river.

We used data collected in 1990 and 2004 in the Sabie River to compare vegetation structure before and after the flood of 2000. The distribution of plant heights was altered by the flood, as expected, with more plants in the 1-2 m class and fewer plants in the 3-4 m class in 2004. Mean height decreased from 3.6 m to 3.2 m, and median height from 2.8 m to 2.3 m (an 18% decrease). The proportion of large trees (>10 m), however, remained unchanged at 9-10%. Basal area was less affected by the flood. While median basal area decreased by 7%, from 57.3 cm^2 to 53.2 cm^2, mean basal area actually increased, reflecting the high prevalence of resprouting among damaged plants. Therefore, although tall trees are still present, on average the vegetation is shorter and bushier after the flood than it was before.

To assess the potential of the vegetation to regain its pre-flood structure, we examined the proportions of different life forms (trees vs shrubs) and regeneration groups (sprouters, seeders and intermediate species). The proportions of adult and juvenile shrubs and trees were very similar in 1990 and 2004, with shrubs predominating strongly among juveniles (80%) and less so among adults (50%). The proportion of adult shrubs was actually higher in 1990, possibly because more shrubs than trees were removed during the flood. Analysis of tree/shrub proportions by elevation showed that shrub proportions decreased the most at intermediate elevations, but that many juvenile shrubs were found here, suggesting that shrub proportions here will increase again over time. We can conclude that the shrub:tree ratio has not been substantially altered by the flood, despite the large number of individuals removed during the flood.

Analysis of the proportions of trees and shrubs with different regeneration strategies showed that the proportional abundance of strongly sprouting species of both trees and shrubs increased after the flood, while the abundance of less strongly sprouting species decreased. The rank abundance of species within each regeneration group was largely unchanged. The implications of the increase in proportional abundance of sprouter species for riparian ecosystem functioning have yet to be explored.

RECRUITMENT OF RIPARIAN VEGETATION IN RELATION TO VERTICAL HETEROGENEITY OF A RIVER LANDSCAPE FOLLOWING A LARGE INFREQUENT FLOOD DISTURBANCE

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Riparian vegetation distribution patterns are determined by a complex interaction of biotic and abiotic factors. These are depicted as occurring spatially along longitudinal (e.g., climate), lateral (e.g., substrate) and vertical gradients (e.g., flooding frequency). In many alluvial dominated river systems there is a close association between transverse distance from the channel, height above the channel, flooding frequency and vegetation distribution, where vegetation pattern can be readily described. In geomorphologically complex rivers no generalised relationship exists between transverse distance away from the channel and height above the channel. The arrangement of vertical heterogeneity in these rivers may be associated with unique patterns of hydrogeomorphic factors that influence the distribution of riparian vegetation in a manner that can not be demonstrated easily. Although potentially a strong driver of vegetation distribution in itself we know little about this vertical heterogeneity in an explicit manner, uncoupled from the lateral dimension.

Using accurate data outputs from airborne LiDAR and GPS technology, we quantified the vertical heterogeneity of the geomorphologically complex, mixed bedrock/alluvial Sabie River in the Kruger National Park and examined the distribution of woody vegetation across the vertical dimension of the river landscape, after the large flood of 2000. The large flood allowed us to separate out the immediate vegetation response (i.e., the recruitment of woody individuals post-flood) from past patterns of vegetation response (i.e., the residual or surviving woody vegetation). We applied two tests of the relationship between vertical template heterogeneity and the distribution of woody riparian vegetation. First, we examined randomness in distribution of species recruitment across the vertical dimension. Second, we attempted to expose possible pseudo vertical effects related to past patterns of vegetation distribution, via a direct residual effect.

Results show that the Sabie River has a highly complex vertical dimension that is generally not associated with the lateral gradient, or transverse distance from the channel. This is due to the presence of a vertically heterogeneous macro-channel floor area, in between the two macro-channel banks. The complexity in the vertical component changes down the length of the river dependent on the degree of bedrock influence, coupled with channel width. The immediate response of woody vegetation to this vertical heterogeneity is not random, because various species have elevation niches where recruitment numbers peaked, and this peak differs between species. There are also differential ranges of distribution of various species across the vertical dimension.

COCCIDIA OF BUFFALO IN THE KRUGER NATIONAL PARK

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The objective of this study is the molecular characterization and identification of *Eimeria* species that occur in African buffaloes. For both bovine and buffalo samples, the following will apply, morphological description of sporulated *Eimeria* oocysts recovered from buffaloes, extraction of DNA from *Eimeria* spp recovered from buffaloes, cloning of PCR products and sequencing of the 18S rDNA, and phylogenetic analysis and description of new *Eimeria* species.
Oocyst isolation and microscopy: Four different coccidial oocysts have been isolated from buffalo faeces. Three of these resemble bovine *Eimeria* spp, while one may be an as yet undescribed species.
Molecular techniques: DNA was extracted by using a combination of the method described by Zhao et al. (2001) and the Qiagen Qiamp Stool Extraction Kit (Qiagen Inc, Santa Clarita, CA). The primer set, as described by Zhao et al. (2001), for the amplification of the 18S rRNA gene, was successfully used to amplify a 1 500 bp fragment of the 18S rRNA gene. A more specific set of primers, as well as internal primers will also be designed, by the alignment of all known *Eimeria* species available in the GenBank database at The National Center for Biotechnology Information (NCBI) (http://www.ncbi.nlm.nih.gov/Genbank/index.html).

TEMBO, THE ELEPHANT MOVEMENTS AND BIO-ECONOMIC OPTIMALITY PROGRAM, SOUTH AFRICA

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To predict the distribution of elephants in conservation areas in relation to the nutrient status of the vegetation, in order to carry out a cost-benefit analysis for the optimisation of resource management for commercial purposes and conservation.
The project is divided over 6 different PhD projects.

THE PHABENI GATE PROJECT IN THE KRUGER NATIONAL PARK: A CASE STUDY OF COMMUNITY-BASED CONSERVATION

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The aim of the research study is to investigate the process for the establishment of the Phabeni Gate in the Kruger National Park as an example of a conservation-based community development project. The research strategy used for the study is the *case study*. The focus remained on the specific case, namely the Phabeni Gate project in the Kruger National Park. The type of case study used was the intrinsic case study, focused solely on the aim of gaining a better understanding of the individual case.

Available documentation on the Phabeni Gate was explored and analysed in an attempt to document the process. Where written documents, being either personal or official, were not available, personal unstructured interviews were conducted with participants in the specific project. The story of Phabeni was compiled from official documents and interviews with Ms. Helen Mmethi (2004) and Mr. Solly Themba (2006).

The process for community development as utilised in the field of social work is simple, yet efficient. Development is seen as a social condition and strategies used aim at enhancing the living conditions of a population. The idea that the stimulation of entrepreneurship of individuals will contribute to their own development as well as that of communities is supported.

The most crucial phase in community-based conservation is to have representation from the local community and all role players involved in the project. An action committee has to be formed for the planning process. Sub-committees for the different needs/problems/aspects can then be formed to determine the finer aims and objectives. Implementation only commences after thorough realistic planning where after formal evaluation takes place. Evaluation is part of the process from the start, but the final evaluation will determine whether the aims and objectives have been met. If not, the process starts with the situation analysis again with the necessary modification.

In documenting the story of the Phabeni gate, it is clear that the process that was followed links with the community development model as utilised in Social Work.

INTERFERENCE POTENTIAL OF INVASIVE ALIEN PLANTS WITH INDIGENOUS PLANT SPECIES IN THE KRUGER NATIONAL PARK: *PARTHENIUM HYSTEROPHORUS* AS A CASE STUDY

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Panicum maximum showed high potential for use as an antagonistic species in an integrated programme for control of *P. hysterophorus.* Because we postulate that the phytotoxic allelochemical, parthenin, contributes to the ability of the weed to interfere with other plant species, production and release of the compound by *P. hysterophorus* are of paramount importance with regard to understanding the nature and level of its chemical interference (=allelopathy). Plants were grown in a greenhouse at the University of Hohenheim in Stuttgart, Germany, and the parthenin content in leaves harvested at different growth stages was monitored. Highest parthenin concentrations occurred in the final three growth stages of the plant and it was calculated that a single plant can introduce >267.19 mg parthenin into the environment in a single growing season.

Persistence of pure parthenin in soil was investigated. Four soils with different properties were utilized for the trial, and parthenin DT_{50} values were observed to range from 1.78 to 3.64 days when applied at an initial concentration of 10 µg g^{-1}. Degradation of parthenin was observed to be significantly faster in the loam soil than in the loamy sand or sand. Significant negative correlations were observed between DT_{50} values and the soil characteristics of soil water-holding capacity and soil cation exchange capacity, but not between DT_{50} values and pH and organic carbon percentage.

The sensitivity of the three indigenous grass species used in the field trial to pure parthenin was assessed. Seeds were placed in Petri dishes and exposed to a parthenin concentration range (0-500 µg ml^{-1}). It was observed that *P. maximum* was the most sensitive species regarding germination and early radicle development. *D. eriantha* was the intermediate species, while *E. curvula* was the least sensitive species to pure parthenin.

Based on the findings from these trials it was calculated that a naturally occurring *P. hysterophorus* stand in Skukuza could potentially introduce a concentration of 2350 µg ml^{-1} in the top 2 cm layer of the soil. It therefore seems possible that parthenin alone can inhibit or impede the recruitment of indigenous grass species using allelopathy. It is acknowledged that allelochemicals other than parthenin may also be important in the allelopathy displayed by *P. hysterophorus*, and that competition by the weed is probably another important interference mechanism. Considering the sensitivity of *P. maximum* to parthenin, it may prove challenging to establish the grass from seed in *P. hysterophorus* stands when using the grass as antagonistic species in an integrated control programme.

A STUDY OF FUNGAL PATHOGENS ON NATIVE TREE SPECIES IN KRUGER NATIONAL PARK

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During field surveys investigating elephant wounds, wood rot caused by a species of *Phellinus* was found commonly on *Terminalia prunioides* and on *Acacia nigrescens, A. burkeii* and *A. tortillas*. Fruiting bodies of the wood rotting fungus *Ganoderma* sp. was also found on dead trees in the staff village as well as in the tourist camp. These two fungal genera commonly infect wounds on trees to cause wood rot and in some cases death of trees. Seven surveys of wounds on trees caused by elephants in the Skukuza and Pretoriuskop areas have been conducted in the two-year period of the project. The wounds from which successful isolations were conducted were in general between five to twenty days in age. Samples were collected from *Acacia burkei, A. grandicornuta, A. nigrescens*, *A. tortilis*, *A. welwitschii*, *Albizia petersiana*, *Combretum collinum, C. zeyheri, Commiphora capensis, Dichrostachys cinerea, Lannea schweinfurthii, Philenoptera violacea, Peltophorum Africana, Sclerocarya birrea* and *Terminalia sericea.*
An unknown species of *Ceratocystis* and *Ceratocystis albifundus* were the two most common fungi isolated on the wounds. Signs of other *Ceratocystis* spp. and *Ophiostoma* spp. were also present but attempts to isolate them were unsuccessful. DNA sequence data has confirmed that a previously undescribed *Ceratocystis* sp. is present in KNP. This fungus was commonly found sporulating on the wounds. In artificial inoculation experiments it produced very small lesions on the trees available, indicating that it probably does not cause serious disease outbreaks, but is more an opportunistic pathogen, probably only killing genetically weak trees. It has been characterized morphologically and an article describing it as new will be submitted by October 2006. *Ceratocystis albifundus*, the other commonly isolated fungus is a serious canker and wilt pathogen of non-native *Acacia mearnsii* trees in RSA. It is also common on native tree species around the Pretoria area and pathogenicity tests in the greenhouse have shown that it can result in the death of *Combretum molle* and *A. caffra* trees. To date a total of 26 isolates of this fungus has been successfully collected from KNP. These isolates are currently being analyzed for their population diversity as part of a larger study to determine the possible origin of *C. albifundus*. It is currently hypothesized that *C. albifundus* is most likely native to Africa as it has a broad native host range in Southern Africa, based on survey results of the last two years. Research to date in KNP have, thus, confirmed that *Ceratocystis* spp. infect wounds of a number of native tree species in KNP.

THE DEMOGRAPHY OF A CULLED SAMPLE OF AFRICAN BUFFALO, *SYNCERUS CAFFER,* IN THE KRUGER NATIONAL PARK WITH PARTICULAR EMPHASIS ON CORRELATING AGE WITH TOOTH WEAR AND HABITAT

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This project was designed to take advantage of a large cull of buffalo from a number of herds that habitually are found on either basalt or granite soils or less frequently on both. It was a rare opportunity to test a number of hypotheses about the effect of different nutrient resources and environmental factors on tooth wear and the age structure of the population. It was proposed that there would be detectable differences in the cementum thickness compared with the number of growth rings and that there would be correlated differences in tooth wear as reflected in the detailed morphology of the crown surface and differences in crown height. It was expected that animals predominantly feeding on the taller tougher and potentially more abrasive grasses of the granite systems would have higher tooth wear and different tooth profiles compared to animals feeding on the basalt soils. The data to date suggest that there are no detectable difference among the teeth in terms of wear or age of animals from different soil types. This in itself is of interest and other interesting results have emerged. The oldest male in the sample is 12 years and the oldest female is 17 years. For this sample females live longer.

MYCORRHIZAL COLONISATION AND THE ASSOCIATED PHOSPHORUS STATUS IN SELECTED GRASS SPECIES ALONG A CATENA IN THE KRUGER NATIONAL PARK

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The purpose of the project was to develop a better understanding of root mycorrhizal colonisation status of grass species and the soil phosphorus concentrations along a catena. Five landscape positions along the catena were sampled, namely, the crest, seepline, sodic site, ephemeral wetland and the riparian zone. One common and two dominant grass species were sampled at each site. The two main findings of this study were that, mycorrhizal colonisation was found to be highest in the nutrient poor soils of the crest, and that there was little correlation between mycorrhizal colonisation levels and spore densities.

Mycorrhizal colonisation was found to be significantly different between the sites and varied between 7% at the riparian zone and 34% at the seep zone. Colonisation of *Urochloa mosambicensis* was found to be significantly different between sites, with the crest significantly higher in the nutrient poor soils of the crest in comparison to the other sites. Mycorrhizal colonisation was expected to be the highest at the crest due to the nutrient-poor status of the soil found there.

Spores were extracted from the soil and were found to be primarily from the *Glomus* genus. Spore counts were not significantly different between sites. While a positive relationship between mycorrhizal colonisation and spore counts was superficially expected, a non-significant negative relationship was found since not all mycorrhizal fungi release spores into the soil and spores are only one of the three ways in which plant roots can become infected.

Soil analyses for total phosphorus, extractable phosphorus and soil pH were significantly different between landscape positions. Total phosphorus was found to be significantly different between sites. The crest and the seep line were found to be significantly lower than the sodic site and the riparian zone.

Soils from the sodic site were significantly higher than the other landscape positions in terms of extractable phosphorus, ranging between 2.55 μg P g^{-1} dry soil at the riparian zone and 6.13 μg P g^{-1} dry soil at the sodic site. Extractable phosphorus was found to vary between 0.5 to 1% of the total phosphorus across all landscape positions.

Soil pH was found to be significantly different between sites. High concentrations of phosphorus in the soil are known to inhibit mycorrhizal colonisation but in this study mycorrhizal colonisation was found to be non-significantly correlated to extractable phosphorus. At pH 6.5, phosphorus is most available to plants. The pH of the soils from the study catena was therefore optimal for maximum phosphorus availability.

This study has lead to a greater understanding of the vesicular-arbuscular mycorrhizal (VAM) fungal symbiosis associated with grass species in a semi-arid savanna in the Kruger National Park. VAM colonisation is influenced by a number of edaphic, climatic and biological variables including phosphorus availability, soil pH and host plant characteristics. The interactions between these variables results in different patterns and different ecological consequences which are difficult to understand without a long-term understanding of fluctuations within the system.

MONITORING WOODLAND COVER AND BIOMASS FROM SPACE: GMES-FM VALIDATION

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EFFECTS OF BROWSING AND SEASON ON DEFENCE AND GROWTH OF SELECTED WOODY SPECIES AT THE NKUHLU EXCLOSURE

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The main research question of the project is: How are structural, chemical and physiological traits of common woody species in *Acacia nigrescens – Combretum apiculatum* savanna affected by variations in browsing and season? We assume that phenols, tannins and structural polysaccharides in woody plants function as defences by reducing browsing. Broadly, we expect N to decrease during the wet season and chemical defences to increase during the wet season, and increase in less defended species under browsing. During 2005/2006, our focus was on collecting preliminary samples for chemical analysis while testing methods for sampling structural and physiological traits (e.g., browsing impact, biomass allocation, growth rate, specific leaf area, photosynthetic rates) so we could plan more intensive sampling during the 2006/2007 wet season. Leaf samples of six randomly located *Acacia grandicornuta*, *Euclea divinorum*, *Acacia exuvialis*, *Combretum apiculatum*, *Grewia flavescens* and *Dichrostachys cinerea* were collected in the full exclosure, partial exclosure and no exclosure treatments during November, February and April 2005/2006. There was no consistent association between chemistry and species' traits such as leaf retention, leaf size/shape, or habitat preference. There was no clear elevation of defences in less defended species (e.g., *A. grandicornuta*) outside the full exclosure. Neutral detergent fibre (NDF) and N concentrations responded according to the predictions, but total phenolic (TP) concentrations did not. Crest species appeared to support the predictions, but footslope species appeared not to. Species with low condensed tannin (CT) concentrations remained largely unchanged.

SPATIAL AND TEMPORAL VEGETATION CHANGE ALONG A SECTION OF THE SABIE RIVER IN THE KRUGER NATIONAL PARK AFTER THE 2000 FLOOD: A COMPARISON WITH PRE-FLOOD VEGETATION DATA

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The purpose of the study is to assess the dynamics in vegetation response (both temporal and spatial shifts in plant assemblages) along a section of the Sabie River. The results obtained from the study will be used to investigate pathways and possible endpoints of vegetation change along the Sabie River. The study will contribute to the current post-flood research programme and will make valuable, scientific comments to affected parties, including tourists.
The ecological damage caused by the 2000 flood is still difficult to quantify, although, from this study, the effect on the vegetation is definitely noteworthy. A comparison of vegetation data surveyed during 1991 and data surveyed during 2003 showed significant changes in plant communities along the Sabie River in the Kruger National Park after the 2000 flood. Although the 1991 communities were transformed by the flood, the 'new' plant communities are floristically related to the 1991 communities. Most plant community changes are temporal, although spatial shifts could also be observed. Spatial shifts were caused by fluvial geomorphological change, which induced habitat transformation and hence, plant community change. The question remains whether succession is towards the 1991 climax communities or in an alternative direction, and is there a climax state that represents a dynamic environment such as the Sabie River? The differences in plant species composition and abundances indicate successional recovery, although further studies are needed to support the results. The recovery of tree species is still uncertain and the comparison of tree species frequencies is only an attempt to address concerns of the recovery of some tree species. From the reconnaissance survey in July 2005, vegetation survey limitations and shortcomings could be identified and will be addressed during September 2006 field surveys.

DEVELOPING A METHOD FOR MONITORING THE INFLUENCE OF ELEPHANTS ON WOODY VEGETATION

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This pilot study was initiated to develop methods and monitoring techniques to quantify the impacts of mega-herbivores (giraffe and elephant), fire and disease on large trees (>5 m) in the Kruger National Park. This was in response to concern over the increasing elephant population and a paucity of reliable data on the changes in vegetation over time and ultimately the factors driving this. Methods needed to be established which were relatively straightforward, repeatable and provided sufficient data to answer questions on vegetation impacts and change.

Sampling methodology was adjusted and a fixed line of longitude or latitude for subsequent transects was walked. Although this restricted us to heading North, South, West or East, it was easier to maintain a straight line through the bush. The GPS could also be used to establish the width of the line with approximately one increment on the GPS corresponding to approximately one metre. This was confirmed by measuring the width of the line at regular intervals to ensure consistency. Two people, one scribe and a metrician, collected the data. All transects carried out passed through existing VCA plots. Fourteen of these transects were walked. Transects of a shorter length (approx. 1 km) were also carried out, these were used to sample trees in the direction of 10 existing photo points. Ten of these transects were walked. A total of 22 independent transects were walked.

Preliminary results show that 3082 trees from 50 species were sampled within approximately 66 km of transects. The vegetation structure of trees taller than 5 m show a decrease in number of individuals as the height class increases. The number of individuals utilised by any extent by elephants also followed this trend. However, the percentage of trees utilised by elephants through the different 1.5 m height classed remained fairly constant at between 55 and 65%. The greatest proportion of trees pushed over or snapped by elephants occurred in the 6.5 to 8 m and 9.5 to 11 m height classes. The proportion of trees that survived being pushed over or snapped by elephants decreased with an increase in height class. With increasing height class, the proportion of debarking increased, while the proportion of pushing decreased.

SPATIAL DEMOGRAPHY AND DIET OF ELEPHANTS: IMPLICATIONS FOR MANAGEMENT

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As elephants are a major component of the Kruger National Park (KNP) ecosystem, the aim of this project is to understand herd's spatial demography and the feeding behaviour of male and female elephants in various age classes, to provide a spatially explicit predictive model of elephant impact across the study site. Two collars were fitted in December 2005 with the remaining 10 fitted in March and April 2006. Field observations have been underway since mid-March 2006 (4 months). The GPS collars record positions every 30 mins (48 positions/day). Ranging behaviour of female elephants in relation to habitat characteristics and clan relations are being sufficiently recorded. Kernel home ranges were calculated from 6 positions daily (every 4 hours) with core 50% ranges (mean = 85 km^2) and total 95% ranges (mean = 569 km^2). These kernel ranges display clear winter and summer ranges for certain herds. To include excursions outside of core 50% ranges, 100% minimum convex polygon (MCP) home ranges were calculated. MCP's varied in size between 379 km^2 and 2032 km^2 (mean = 1021 km^2). Previous studies on 100% MCP home ranges on 29 radio-collared elephants in KNP yielded MCP's with a mean of 880 km^2.
All the Satara collars except AM90 showed a high degree of association, utilising similar areas. Both the Lower Sabie collars show association as do all the Skukuza collars except AM108. This herd's range extends into Timbavati/Klaserie/Manyeleti complex. None of the other collars exhibit these movements. An important preliminary result is that the ranges of the females extend across the proposed elephant management plan intervention boundaries. Eighty-four feeding bouts have been recorded. Average feeding time was 2:21 mins. The main cause for animals moving from a targeted species was disturbance from vehicles. Most selected species included Forbes (*Convolvulis*), *Acacia nilotica* and *Grewia* sp. Sightings of elephant were most frequent on Ecozone D (57%) i.e. Sabie/Crocodile thorn thickets.

THE IMPACT OF ARTIFICIAL WATERHOLES ON NUTRIENT REDISTRIBUTION AND THE HERBACEOUS SEEDBANK IN THE KRUGER NATIONAL PARK

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The wide-scale provision of artificial surface water has reduced natural fluctuations in surface water availability in the Kruger National Park. It has been argued that this can have negative impacts on natural ecosystem functioning. Various piosphere studies have been conducted in KNP to detect the effects of artificial waterholes, but nutrient and seedbank gradients around waterholes have not been studied previously. Consequently, four waterholes (two on the basalts and two on the granites), with two transects radiating from each waterhole, were studied. The waterholes and transects were selected and laid out to minimize the influence of neighbouring waterholes and the main river courses. Except for Ca^{++} in the *Urocloa mosambicensis* samples and NH_4^+ in the soil samples, all nutrients (N, P, Mg^{++}, K^+, Na^+ for leaf samples and NO_3^-, P, Mg^{++}, Ca^{++}, K^+, Na^+ for soil samples), were found at elevated levels in closer proximity to waterholes compared to further from waterholes when concentrations were transformed into ranks and transects treated as blocks.

However, for nutrient levels in soils, the effect of distance to waterholes was only statistically significant ($p<0.05$) for NO_3^-, Na^+ and K^+. The effect of distance to waterhole on nutrient concentration in *Urocloa mosambicensis* leaves was significant for N and Na^+. Therefore, the same nutrients (N/NO_3^- and Na^+, and to a lesser degree K^+) had elevated levels in the soil and the grass samples collected closer to the waterholes. This suggests that grass reacts to the nutrient status in the soil rather than to grazing pressure (i.e. grazing feedback loops). This suggests that waterholes act as nodes for nutrient accumulation. These changes in nutrient levels can potentially cause a change in the herbaceous layer. Since waterholes are artificial to the KNP system, the redistribution of nutrients attributable to waterholes is considered artificial as well.

For the seedbank study, the results suggest that artificial waterholes cause a redistribution of nutrients in the Kruger landscape and influence the herbaceous seedbank occurring in the topsoil. However, the effect is localized and can only be detected in very close proximity to the waterholes. This agrees with the piosphere effect observed in Kruger for many other variables (e.g. infiltration rate, herbaceous biomass, herbaceous community composition, etc.).

USING ISOTOPIC EVIDENCE OF LARGE MAMMAL NUTRITIONAL ECOLOGY TO TRACK VEGETATION CHANGE THROUGH TIME

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The aim of this project is to study the ecology of large mammals in Kruger National Park, with the ultimate goal of reconstructing its historic environments through stable isotope analysis. We have completed three winter and three summer field seasons, during which we collected plant and fecal samples to broaden our understanding of present large mammal nutritional ecology, and provide a necessary baseline for our historical study. Stable isotope analysis of both feces and hair have shown that during the dry season impala, browse more in Mopane-dominated northern Kruger (~60%), than in southern Kruger (~30% browse). More recent data have shown, however, that there is in fact considerable dietary variability within these broad regions, and that there are dramatic dietary differences between impala on basalt and granite substrates, even when separated by less than 10 kilometers.

Furthermore, analyses of hair from known individuals have demonstrated that male impala graze about 14% more than females. Elephants, in contrast, graze more in northern Kruger (~35% grass) than they do in the south (~20% grass), and indeed had diets comprised predominantly of grass during the rains of 2002. Fecal data demonstrate that the Northern Plains roan eat grass nearly exclusively, and its fecal nitrogen concentration (~0.8%) is lower than that of any other herbivore in KNP, including bulk grazers like zebra and white rhino. Similarly, sable appears to be a near exclusive grazer with fecal nitrogen concentrations (~1.0%).

MODELLING THE CONSEQUENCES OF ELEPHANT DAMAGE FOR THE *SCLEROCARYA BIRREA* (MARULA) POPULATION IN THE KRUGER NATIONAL PARK

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With regard to the modeling component of the work the following has been done, Mr. Mabuduga had in the first instance studied the relevant literature on savannah models and learned some programming skills. Next he went to Prof. Wayne Getz at the University of California, Berkeley to learn GIS skills, modeling skills and general research approaches to environmental management. On the same occasion he also discussed the approach to his project with Prof. Getz. As a result of this visit and an ensuing email discussion between the Getz, Owen-Smith, Grant and Stam it was decided that designing a new model from scratch was too ambitious for a masters project and also unnecessary as there is a useful model available in the form of the Baxter/Getz model. A more realistic approach would be to parameterize the Baxter/Getz model for marula trees and implement it on a GIS platform. This constitutes a considerable diversion from the original proposal, but it is more likely to lead to tangible results.
The fieldwork on this project has been carried out much according to plan, except that the sampling approach was slightly different. Dr. Stam went on a reconnaissance trip in October 2005 on which occasion he checked out the Nkuhlu exclosure near Skukuza and buffalo enclosure near Satara. In December he returned with 3 honours students and marked, measured and photographed ± 90 marula trees, 60 at the Nkuhlu exclosure (10 for each treatment) and 30 at the buffalo enclosure (15 inside and 15 outside). At the buffalo enclosure they also established 4 transects (2 inside and 2 outside) where the numbers of seedlings and saplings were counted.

MONITORING OF GROWTH, RECRUITMENT AND ELEPHANT DAMAGE OF MARULA TREES INSIDE AND OUTSIDE THE NKUHLU EXCLOSURE AND THE BUFFALO ENCLOSURE NEAR SATARA IN THE KRUGER NATIONAL PARK

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This study is conducted in Kruger National Park in the Nkuhlu exclosure near Skukuza and the buffalo enclosure near Satara. The project is meant to acquire longer term data (5 years +) on growth and recruitment of Marula trees and to assess the long term impact of different levels of elephant damage on the trees. The growth and recruitment data are necessary to parameterize a demographic model that is currently being developed. This model is meant to be a tool which can help to determine the population density of elephants that the park can carry.

For the growth experiment we have selected 10 marula trees within each of the six sections of the Nkuhlu exclosure. At the buffalo enclosure we selected 15 trees inside and 15 outside the enclosure. We GPS-ed all trees and measured basal area, stem circumference at breast height, crown width and height, and stem height below the crown. Crown measures were determined on photographs. The average heights were not significantly different between Nkuhlu and the buffalo camp (t-test). At Nkuhlu there were some more trees in the two largest size classes, which can be attributed to the presence of the Sabie River. We have recently also placed 24 dendrobands to determine stem width growth.

Recruitment has been determined by counting, mapping and measuring all individuals ≤ 1m tall in four 20 x 100 m transects, two of which were located inside the buffalo enclosure and two outside. Due to a paucity of seed/saplings at the Nkuhlu site this inventory was limited to the buffalo enclosure. The North-South transects had more saplings relative to the seedlings than the East-West transects. At this stage we do not know yet whether this is a meaningful pattern.

We also record elephant damage. Primary branch broken, secondary branch broken and debarking are the most common types of damage on marula trees found. Out of 97 marula trees recorded with damage 36 trees suffered debarking, 31 primary branch breakage and 15 trees had secondary branches broken. Frequency analysis revealed no difference between Nkuhlu and the buffalo enclosure nor an effect of either exclosures (G-test: G_{adj} = 20.2, *df* = 20, $\chi^2_{0.05,\ 20}$ = 31.4, n.s.). It is anticipated that the effects of the exclosures will become manifest when we consider new damages in he next round.

THE ROLE OF SOIL SEED BANKS IN THE REGENERATION OF ACACIA SPECIES IN THE KRUGER NATIONAL PARK, SOUTH AFRICA

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The main aim of this project is to identify key factors influencing *Acacia* seed bank dynamics and consequently the regeneration of *Acacia* species in a savanna ecosystem. The seed banks of four *Acacia* species were sampled, with a sample size of eight trees per species. Only trees considered reproductively mature were selected for sampling i.e. trees >2m high for *A.grandicornuta, A.nilotica* and *A.tortilis* and trees >1.5m high for *A.senegal*. This resulted in ten main sites occurring in the Skukuza area. A site is defined as an area with a cluster of trees (each individual < 250m apart) that is at least 250m from the next cluster. *A. tortilis* has the largest seed bank overall, with a decrease in seed bank size as follows: *A. grandicornuta*; *A. nilotica*; and *A. senegal* (with a total of four seeds, all of which came from 2 of 8 trees sampled). Additional to having the largest seed bank, *A. tortilis* has the largest average stem diameter, while *A.senegal* has both the smallest seed bank and the smallest average stem diameter.

Artificial seed banks were "planted" in December 2005 in the Nkuhlu full exclosure on the 'non-fire' treatment. A preliminary examination of the exclosure showed an abundance of *A. grandicornuta* trees, but very few *A. nilotica* and *A. tortilis* trees. Consequently all seed banks were planted under *A. grandicornuta* trees (for *A. nilotica, A. grandicornuta* and *A. tortilis*), and *A. senegal* (for *A. senegal*); all trees were in close vicinity to one another (< 10 m apart).

Artificial seed banks were planted in April 2006 at the Wits greenhouse. Fifteen 30cm x 30 cm x 10 cm black plastic seed trays were used per watering treatment. Three separate years from KNP's rainfall history were selected for the watering treatments. The year 1999/2000 had the highest historical rainfall record at an average of 1123mm; year 1991/1992 was the driest year (237 mm); and year 1970/1971 had an average rainfall of 524 mm. Three greenhouse tables were set up, each representing a single watering treatment. Due to seed availability, each table has three trays per species (12 trays), with granitic soil and three trays with *A. tortilis* sown in basaltic soil (*A. tortilis* and *A. nilotica* both occur on basalts but seed availability meant only *A. tortilis* could be used here); 56 seeds were sown per tray.

To date only one seed has germinated; an *A. grandicornuta* seed in granitic soil from the 'wet year' table. This may be because the seed was possibly scarified before being collected from the field. No other data has been collected so far as the experiment will be running for another ten months.

BIOLOGICAL CONTROL OF *PARTHENIUM HYSTEROPHORUS*, PRE- AND POST-RELEASE STUDIES

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Parthenium hysterophorus has been rated as one of the ten worst weeds in the world. It is present and spreading in the savannah biome of South Africa, including Kruger National Park, and neighbouring countries. A research programme was initiated in South Africa in 2003 to introduce various natural enemies for the biological control of *P. hysterophorus*, pending the results of host range testing and permission to release these agents. Three species of insects and a rust fungus have been identified as good control prospects for parthenium in South Africa and several of these are currently under investigation in PPRI quarantine laboratories. The study in KNP aims to evaluate aspects of parthenium growth and soil seed bank, and relative composition with other plant species both before and after the release of biocontrol agents. These data can then be utilized to quantitatively assess the agents' impact on the weed and evaluate their efficacy in a control programme. This study has two phases: (i) To obtain baseline data on aspects of *P. hysterophorus* growth, biomass, soil seed bank and relative composition with other plant species at selected sites in KNP prior to the release of biocontrol agents; (ii) Following the establishment (pending proof of host-specificity and permission from relevant government authorities to release) of selected natural enemies (insects and pathogens) of parthenium, to collect data on parthenium so that the agents' impact on the weed can be assessed comparatively using the baseline data on parthenium. Our research has demonstrated an average of 92 mature *P. hysterophorus* plants per m^2 were present at the end of the growing season of 2006 at three sites in KNP. Of the three sites, the old Skukuza dump site had the highest density of parthenium per m^2, although the other sites also have dense infestations. After four months of seedling germination trials, results indicate that an average of more than 51 000 parthenium seeds per m^2 are present in the soil. The largest soil seed bank per unit area was more than 90 000 seeds per m^2 at one of the sites. These data indicate the huge potential that parthenium has to increase the density of current infestations and spread to new areas.

GLOBAL CLIMATE CHANGE AND PRIMARY PRODUCTIVITY: THE EFFECT OF INTER-RAINFALL INTERVAL ON GRASS GROWTH

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The productivity of grasslands and savanna is primarily determined by the response of the dominant grass species to rainfall. Both rainfall amount (total annual rainfall) and rainfall timing (within the growing season) may affect grass community productivity, and both are predicted to change significantly over the next 50 years as a result of global climate change. The primary aim of this study is to determine the magnitude of variation in the above-ground growth responses of dominant grass species to rainfall, for a range C_4 grass communities. A secondary aim to determine how grazing affects such variation. Research has been conducted at seven sites, three of which are located within the Kruger National Park. The KNP sites are located within the UCT Tree-Grass Programme exclosure on the Shabeni burn plots near Pretoriuskop, within the Nkuhlu exclosure and within the Tree-Grass Programme full exclosure in the buffalo camp near Satara. Above-ground growth has been measured by means of clipping target plants at regular intervals through the growing season. Repeated clipping was used to simulate the effects of grazing. At each site, volumetric soil water content is measured hourly at three depths in two clipped plots and two unclipped plots.
Preliminary analyses of the data indicate significant variation in the timing of growth of the four dominant species at each site. Some species complete the majority of their seasonal growth early on in the growing season, after which growth is apparently limited by self-shading or phenology. These species appear to be shallow rooted as their growth was correlated with the amount of soil water in upper soil layers (A horizon). Other species showed a growth pattern more dependent on rainfall. These species only showed maximum growth rates when soil water increased in deeper soil layers, and generally only achieved peak biomass towards the end of the growing season, once enough rainfall had fallen to wet the deeper soil layers. Repeated clipping reduced the variation in the timing of growth, as well as the soil depth at which soil water content was correlated with growth (with all species responding to shallow soil moisture when clipped). However the degree to which growth was reduced (or occasionally enhanced) by clipping varied greatly between co-occurring species. These results provide a basis for the functional grouping of common grasses with KNP according to growth responses to within-season rainfall patterns and grazing. Traits associated with these groups are currently being investigated.

BUFFALO-LION INTERACTIONS: THE ROLE OF BOVINE TUBERCULOSIS

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The project aims to determine the diet of lions in the Satara region with special reference to the proportion of buffalo that are being killed and consumed. The age and sex profile of the buffalo that are consumed will be compared to the available disease distribution in the buffalo population to determine the possible risk of lions contracting the disease from buffalo. Furthermore the spatial distribution and movement of buffalo and lion in the Satara region will be investigated. In the process of the investigation a new technique in determining lion prey preference will be tested.

Currently zebra are the most important prey item with buffalo making up approximately 10% of the diet out of a sample of 158 kills over the past 16 months. There is considerable bias towards larger species and certain smaller prey species are being missed due to the methods employed.

Incorporating the buffalo carcasses located by the buffalo-btb project in Satara and the current project (14 buffalo killed) 130 buffalo kills have been located with a bias towards adult males, and most probably the males located in bachelor groups. By incorporating all lion killed buffalo there is a weak relationship between the time of death and the seasonal rainfall cycles so that more buffalo are being killed during periods that have received less rainfall over the previous 6 months.

Lions are not killing prey species in vegetation that differs to where they prefer to spend their time resting between kills. The initiation of the hunting bouts may be in areas that offer some assistance to lions although based on previous results, unless lions are hunting buffalo they tend to kill their prey in a relatively short sprint, thus the point of initiating a hunt and the location of the stomach content may be relatively close together.

The scat analysis has been commenced and two kills that were missed have been identified thus far from the 9 scats that have been analyzed thus far. The scats have thus far revealed 5 impala, 1 zebra, 1 kudu, 1 waterbuck and 1 giraffe, adding evidence to the claim that small kills are being missed by the technique used and the scat analysis will reduce the observed bias. The scat analysis forms part of an attempt to produce an alternative multifaceted approach to determining lion diets and initial results suggest that the new approach may prove to be an alternative to the more used direct observation method.

For the duration of the project collars have been placed on 9 lions. The results for the Mananga male and female are still outstanding as the collars remained outside of coverage and have since gone flat. Efforts are being made to remove the collars and retrieve the data that is stored on the collars.

SALVADORA AUSTRALIS AS AN ECOSYSTEM ENGINEER OF SODIC SITES IN THE NORTHERN KRUGER NATIONAL PARK

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To infer from studies of soil, leaf chemistry and browsing responses, the potential role of *Salvadora australis* as a desalinating ecosystem engineer of bare sites along the Phugwane River. It has been demonstrated that *Salvadora australis* is an ecosystem engineer of sodic sites along the Phugwane River. It acts by modifying the resources of soil chemical and physical properties by accumulating sodium in the leaves, and by fluxes of solutes in the rhizosphere caused by evapotranspirational demands and increased infiltration in the soil under trees. This results in physical state changes of decreased sodicity, sodium, and magnesium concentrations; and increased calcium concentrations, nutrients and water infiltration. This creates islands of fertility and increases habitat heterogeneity and consequently vegetation diversity

This study has established the importance of this ecosystem engineer in creating habitat heterogeneity and increasing biodiversity of sodic sites which are often seen as unproductive elements in the landscape. It has also highlighted the heterogeneity of the sodic boundary between riparian and terrestrial ecosystems by exposing the complex interactions between soil, water movement, vegetation and animals that take place in these systems. The outcomes of this study demonstrate how biodiversity is enhanced by one organism, and thus have important conservation and managerial implications. In adopting this mission of Kruger it has become important to identify key agents and controllers of heterogeneity that managers can manipulate if they need to influence the nature and direction of heterogeneity and this study has identified such an agent, and the processes it modifies.

EVALUATING ECOLOGICAL AND SOCIO-CULTURAL EFFECTIVENESS IN NATIONAL PARKS: A COMPARATIVE CASE STUDY APPROACH

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The purpose of this research is to assess how effectively case study national parks address their socio-cultural and ecological management goals and objectives. This research evaluates socio-cultural and ecological effectiveness in case study national parks in Canada and South Africa by comparing parks that are intricately co-managed with local/ indigenous people to parks characterized by minimal co-management with local/indigenous people.

Preliminary results from the socio-cultural evaluation are demonstrating that national parks with more involved co-management and support from indigenous groups appear to be more socio-culturally effective overall, but that they may be less ecologically effective than parks with lower levels of indigenous co-management. For parks with less stringent levels of co-management, it appears that they provide for local employment perhaps as an easier solution to dealing with more difficult issues such as access to resources and participation in decision-making. Several of the national parks in this study also appear to be co-managed in name only. By this, I mean that while a joint or co-management board may exist, delegated decision-making to the board may not have occurred or occurs on a partial basis.

From the ecological effectiveness evaluation, it appears that there is a strong link between the explicitness of a national park's management plan objectives, the depth of the park's monitoring program, and the effectiveness with which the park addresses ecological management objectives. Thus, it appears that a national park with very explicit ecological management objectives often is accompanied by a strong monitoring program; further analysis will reveal whether these types of parks are also more ecologically effective. It also appears that parks are more effective at addressing the finer scale *Biological Diversity* indicators than the larger scale *Ecosystem Processes* indicators.

CAN TREES IMPROVE GRASS QUALITY AND THEREFORE ATTRACT GRAZING WILDLIFE? A STUDY ON THE SUB-CANOPY HERBACEOUS VEGETATION IN EASTERN AND SOUTHERN AFRICAN SAVANNAS

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The main purpose of this study is to determine the importance of trees in savanna ecosystems for grazers. These data were collected within savanna regions of different rainfall and soil fertility as it was hypothesized that in areas of low rainfall and poor soil quality trees will improve sub-canopy grasses to a greater extend than in savannas where environmental conditions are already favourable. Both Nitrogen-fixing and non-Nitrogen-fixing trees were sampled since Nitrogen-fixers such as Acacia trees might have a larger impact on soil and grasses than non-Nitrogen-fixers.
Twenty four trees were selected in the Roan enclosure, three trees were included outside of the enclosure as comparison as well as three trees in the Capricorn enclosure further south in the Mooiplaas region. Tree canopies increased the leaf N content of the grass bulk samples by 30% compared to the surrounding open savanna. In the Capricorn and Roan enclosures values were similar while outside of the Roan enclosure, where grazing was more pronounced, N leaf contents were elevated by 50% both sub- and outside of tree canopies, and N-fixing trees slightly elevated this effect. P leaf contents were only slightly higher sub-canopy at some sites but by about 1/3 lower outside of the enclosure than inside-enclosure values. NDF leaf contents were slightly higher outside of canopies. More dead grass material and a higher percentage of grass stems were found in grasses outside of tree canopies. The grass layer biomass was slightly elevated and the grass sward was taller sub-canopy. Grass sward structure was composed of a higher dead material and a higher stem:leaf ratio outside of canopies. Data on grass species composition show *Panicum maximum* to be dominant underneath trees, a preferred fodder grass species high in N and P content.
It can be concluded that tree canopies significantly enhance the grass quality, i.e. higher N-content, lower NDF-content, more alive grass and leaf grass material, taller grass sward, high abundance of palatable grass species, during the wet season. With the results, combined with further wildlife feeding behaviour studies, we can quantify the importance of trees for grazers in different savanna habitats. As they represent “grass nutrient-hotspots”, a loss of trees might lead to a loss of certain grazer species which are dependent on high quality forage from the ungulate guild. Thus, quantifying the overall tree impact and focusing on areas where trees enhance the grass quality to the greatest extend, will help conservation of trees and future wildlife management of the park.

THE ECOLOGICAL RELATIONSHIPS OF EPAULETTED FRUIT BATS AND SYCOMORE FIG TREES IN KRUGER NATIONAL PARK, SOUTH AFRICA

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Epauletted fruit bats, *Epomophorus wahlbergi* and *Epomophorus crypturus*, were studied to determine their potential roles as dispersers of *Ficus sycomorus* seeds in Kruger National Park, South Africa. Bat identifications were based on photographs of palatal ridge structure. At Skukuza, a study of feeding behavior was conducted with three newly captured *E. wahlbergi*. Captives were presented with single ripe figs. The mean number of seeds per a fig was found to be 979 ± S.D. 62. In a single night one bat processed 24.4 figs (132 g) containing approximately 23,888 seeds. Seeds are spit out in pellets of fiber (spats) during feedings, and also are eliminated in feces. Mean time between "spats" was 243 ± 153 s and mean time between defecations was 1207 ± 611 s. Thus, bats process large numbers of seeds nightly, but the seeds in spats are eliminated more quickly than those in feces. At Shingwedzi bats were captured by netting, and radiotransmitters were attached to eleven *E. crypturus*. Freed bats were radiotracked over a period of ten nights, and GPS/GIS technology was used to create maps of foraging patterns as the bats fed on sycomore figs. Radiotelemetry data also were used to determine the timing of repeated movements between the fruiting fig tree (where a fig was plucked) and the feeding–roost tree (where the fig was processed). This cycle-time was 314 ± 116 s. During these cycles when bat movement are ≤ 100 m from the fruiting tree, seeds in both feces and spats would fall within that radius. However, the mean long axis of nightly foraging ranges along gallery forest was 490 ± 722 m. This indicates that bats change feeding venues during the night, creating longer seed dispersal distances in appropriate fig habitat. During these flights seeds in feces, since they are retained longer, would be dispersed farther. Thus, cage-study data as well as radiotelemetry data support the hypothesis that epauletted fruit bats play a significant role in the dispersal of *Ficus sycomorus* seeds.

RAPID ASSESSMENT OF THE POPULATION DEMOGRAPHY OF ELEPHANTS IN THE KRUGER NATIONAL PARK

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There is a dual interest in the dynamics of the elephants that live in the Kruger National Park (KNP). The first stems from the value that population variables may have for managers in conservation. The second focuses on academic interest to study the spatial forces that may limit elephants across their distributional range. Information on the birth and death rates also provides an opportunity to calculate intrinsic growth rates independent of counts. Counts have inherent biases that detract from their value in calculating growth rates. For instance, the KNP elephants increased at 6.6% in numbers per year during a period when they were confined. At the same time the estimates of survival and reproductive outputs predicted that their numbers were only increasing at 2.5% per year. Such discrepancies confuse the decisions that managers have to take when designing conservation actions. The project thus focuses on extracting age-specific survival and reproductive rates to model population growth rates for the elephants in the KNP.

A Canon 10D single-reflex digital camera with a 70-200 mm Canon F4 lens to make 10 to 20 digital images of each of the elephant herds encountered was used for both the helicopter surveys and ground-based surveys. Individual relationships were determined and elephants were grouped into one of 15 age classes based on shoulder heights and back lengths that were digitally measured.

During September 2003 the number of elephants in Kruger was 11672 of which 641 in 41 herds were sampled from the air. Herd sizes ranged from 2 to 57 individuals with a mean value of 16±2 (S.E.) elephants. During ground-based surveys 274 elephants in 19 breeding herds and 40 bull groups were sampled. Herd sizes ranged from 5 to 39 with a mean value of 14±2 (S.E.) elephants.

Population variables from age structures and observations of cow-calf relations were modelled. The estimated age at first calving is 14.1±0.3 (mean±SE; 95% CI: 13.2 - 15.0, n = 40) years. Cows were giving birth every 3.9±0.3 (mean±SE; 95% CI: 3.6 - 4.3, n = 98) years. Survival rate irrespective of age was 0.984 (95% CI: 0.941 - 0.995) per annum. These demographic variables predict that KNP's elephant population should be growing at 3.91% (95% CI: -0.31 - 8.10). Growth rates calculated from recent counts were noted as 4.04% (95% CI: -0.39 - 8.47).

DNA BARCODING OF THE KRUGER NATIONAL PARK'S FLORA FOR CONSERVATION AND BIODIVERSITY

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DNA barcoding is a diagnostic technique in which the DNA sequence of a portion of a single gene is used for species identification. It is intended to promote rapid and inexpensive species identification. The KNP provides an ideal environment for such a study since it is one of the largest official conserved natural areas in the world. It is also botanically diverse with at least 16 macro ecozones. Since the beginning of this project in September 2005, we have collected more than 1500 specimens of plants. Although the focus has been on three diverse ecozones namely, the Sabie/Crocodile thorn thickets (Ecozone D), Sandvelds communities (Ecozone N) and the alluvial plains (Ecozone M), duplicates were collected throughout the Park. This represents already the most complete and recent inventory of the KNP's Flora. This is also the largest and most diverse sampling ever made for barcoding purposes in a protected area. For around 60% of this material collected, positive identification has already been made.

We have produced a set of herbarium specimen (with one duplicate which will be send to the herbarium of the scientific Services in Skukuza the other to Kew Botanical Gardens and SANBI PRE). Our spirit collection (flower and /or fruit stored in Ethanol) contains more than 100 specimens. The plant material collected and stored in silica gel has been processed for more than 800 specimens; total DNA is store in an -80C freezer (condition ideal for long storing of DNA) at University of Johannesburg. DNA extracts will be duplicated and available to scientists at the DNA bank of the South African Biodiversity Institute (SANBI) in Kirstenbosch. As DNA will be centrally available to researchers it limit bio prospecting and thereby relieve pressure on wild populations from repeated collections. All information (Voucher number, Plant identification (Family, *Genus, species*), Ecozone, Collecting point (GPS value), Altitude, pictures, Scans of herbarium specimens, DNA bank number) is database on Access. We are currently in negotiation with Bob Hammer from the Barcoding of life database (BOLD) which forms part of the Consortium of Barcoding to transfer our data to their website (http://www.BOLD.org) where is would be available for other scientists.

In addition to this, approximately 200 *rbcL* sequences have been sequenced and added to the matrix of the South African Tree of Life Project (Darwin Initiative). This will assist identifying areas of endemicity, which should be granted high priority for its biodiversity conservation. Evolutionary biologist would also be able to utilise these results for inclusion in their own work on the history of the vegetation of southern Africa.

A SURVEY OF THE COMPOSTING FUNGI IN A MOPANI LANDSCAPE AND THE EFFECT OF DIFFERENT FIRE REGIMES ON THEIR SPECIES COMPOSITION

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The Kruger National Park (KNP) has conducted studies on different fire regimes for the past 51 years, but the effect of these fire regimes on fungal populations has not been studied. The National Collection of Fungi has no records of fungi on, or surrounding, *Colophospermum mopane*. It was therefore decided to conduct a survey of fungi in the mopani landscape in the KNP. Twelve of the possible fourteen fire regime plots in the KNP were sampled within the time period. Samples of leaves and twigs, as well as plant debris and soil surrounding five mopani trees in each burn plot, were collected. All samples were plated out onto four different media: potato carrot agar (PCA), PCA + antibiotics, selective *Fusarium* agar and moist chambers. All soil samples were plated out directly, as well as serial dilutions made. Colony forming units were recorded for the soil samples. Plant material (a combination of twigs and leaves) was plated out directly as well as surface sterilized. Debris was only plated out directly as we are particularly interested in the composting fungi present.

Colonies were recorded, isolated and, preserved in ultra low freezing facility. At present this represent 300 purified fungal cultures. DNA extractions were completed for twenty six soil samples. Total DNA obtained from eighteen of these samples was used to determine the population dynamics of the soil sample. This is done by means of the denaturing gradient gel electrophoresis technique. The cluster analysis of the 18S gene resulted in a profile representing the prokaryotic populations present in the different samples. Two bands were identified to be present in almost all the samples, these bands will be further characterized. The three main clusters contain samples that represent the 4-year, 3-year, the 2-year burn plots and the virgin fields, respectively. None of the treatments clustered out separately. These results will be repeated and the additional samples will be included. Unfortunately the eukaryotic population profiles were not characterized in time for the report.

DETERMINATION OF BUFFALO AND GIRAFFE HEART WEIGHTS

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The main purposes of this project were, therefore, a) to obtain data that will add to our understanding of the origin of giraffe blood pressure, and b) to establish the vascular mechanisms that protect the viscera of giraffes from high blood pressure. These aims can be achieved by comparing aspects of giraffe morphology with the same morphology of a similar sized but short-necked ungulate (buffalo).

If neck length is the origin of high blood pressure we would expect that heart mass will correlate better with neck length than body mass. If the high blood pressure is a consequence of high peripheral resistance then we would expect heart mass to correlate better with body mass than neck length. Thus in giraffe we would expect a good correlation between heart mass and neck length but in buffalo we would expect heart mass to correlate with body mass. Similarly, if the heart is generating high blood pressure in giraffe we would expect the internal arteries to have a morphology that would allow them to resist high pressures and limit blood flow to internal organs, that is, vessel walls would be thick as are those in the lower limb and skin. In buffalo we would expect internal arteries to have the typical morphology that other mammals have.

To date we have obtained data on heart mass, body mass and neck length in 32 buffalo (20 females and 12 males). Eight of the buffalo (5 females and 3 males) had TB, and 14 of the 20 females were lactating. Body mass correlated better with age in the males ($r=0.989$) than it did in the females ($r=0.611$) possibly because most females were lactating and five of the twenty had TB. Having TB negatively affected the correlation between age and body mass. In the eight animals that had TB the relationship between body mass and age was 0.468, whereas in animals that did not show macroscopic evidence of TB the correlation was 0.764.

Despite the effect of these factors on body mass, the correlation between heart mass and body mass in the buffalo was a 0.958. Conversely the correlation between heart mass and neck length was weaker (0.794) suggesting that in buffalo neck length is less good a predictor of heart mass than is body mass, despite a good correlation between neck length and body mass ($r= 0.809$). We can conclude therefore that blood pressure in buffalo is not affected by the distance between heart and head to the same extent as it is by body mass. This is the expected result for most mammals.

Similar analysis have not been done on giraffe because unlike buffalo where data can be obtained during culls, obtaining giraffe data is opportunistic, but we are predicting a converse finding in them to that found in buffalo. Also because of lack of specimens we have not been able to make a comparison of blood vessel morphology in the two species.

A HISTORICAL AND ARCHAEOLOGICAL INVESTIGATION OF THE CULTURAL REMAINS OF THE DIFFERENT OUTPOSTS OF THE STEINAECKER'S HORSE MILITARY UNIT IN THE KRUGER NATIONAL PARK

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The research was undertaken to show a connection between historical information and the archaeological evidence with regards to Steinaecker's Horse on the Sabi Bridge post. The Sabi Bridge site is one of a number of sites found during a survey of sites linked to the Steinaecker's Horse military unit. Historical information indicates that the site was used as second headquarters by the unit. Steinaecker's Horse was a voluntary unit who fought on the side of the British during the Anglo-Boer War (1899-1902). Extensive historical research was conducted and archival information from the South African National Archives Depot and the Skukuza Archives was included in the scientific report. Archival information was also obtained from the British Archives, but is still being studied and will be included later on. The research aimed at comparing cultural material from the site with that excavated at the Northern outpost of the unit at Letaba.

Six excavations were conducted, two on refuse middens, two on clay rubble (possible remains of huts), one on some kind of structure, and the last excavation was done on a pile of stones which was not a natural occurrence.

A large amount of artefacts were uncovered, in comparison with the site at Letaba, there is a similarity between these two sites. The artefacts also clearly indicate that a military unit was present on the site. The large number of artefacts uncovered further indicates the utilisation of the site by a reasonably large group of people for a considerable time. The different types of material also corroborate with historical information of different social groups on the site and seem to relate to different units. This undoubtedly gives information on the participation and role of black people on the site especially in connection with their lifestyle and their position regarding the Anglo-Boer War as a whole.

The quantities of the material are so much, that it had been decided not to collect everything in future, but only those pieces that have the potential of providing more information during analysis thereof. During the excavation seasons to follow, the other material will be discarded on site and inside of each excavation where it came from. It also seems as if some structures existed on the site, but none of these was completely uncovered. This will be done during the second excavation season in 2006 and the activity areas on the site as well as the extent thereof will then be more clearly for interpretation.

It is concluded that more excavations are needed in order to obtain information on structures that might have existed on the site during the Anglo Boer War. This is especially true since erosion does seem to threaten the cultural material on site. In the process more archaeological material will be uncovered which will lead to a better understanding and interpretation of the site.

THE ECOLOGY AND DISTRIBUTION OF THE SOUTHERN BARRED MINNOW (*OPSARIDIUM PERINGUEYI)* IN SOUTHERN AFRICAN RIVER SYSTEMS

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The lack of a clearly defined research method to determine a fish species population and conservation status could be detrimental to fish conservation management. Water Research Commission Project funding was granted to a group of researchers from the University of Limpopo (lead organization), the University of Venda, Eastern Cape Parks Board and Rhodes University to develop a conservation model for African threatened fish species, applicable to South African conditions that will lead to an effective conservation strategy. The aims of this research were to determine the current distribution of *Opsaridium peringueyi* and other species in the genera in its historical distribution range, to characterize its habitat and habitat preference, to determine the effect of biotic, abiotic and human induced factors on its distribution, and to use the relevant gathered information to develop a conservation framework for *Opsaridium peringueyi*.

Since the start of the project two surveys have been undertaken in the Kruger National Park. The sites in each of the surveys were sites where *O. peringueyi* historically occurred. At the majority of the sites all the proposed sampling procedures were carried out and in this report this type of survey will be referred as a "full survey". The other survey sites, where only selected procedures were carried out are referred to as "partial surveys". Reason for the partial surveys varied from security (hippos and crocodiles) to the absence of suitable habitat.

The fact that no *O. peringueyi* was collected at any of the historic sites in the KNP is cause for concern. It should however be pointed out that because of the high level of the water during the first and to a lesser extent during the second survey the pools and specifically the deeper pools could not be safely surveyed. The depauperate fish diversity, when compared to the data provided by Deacon (pers com), in the Crocodile River was of greater concern to the team. In this river at one site only six species were collected. Deacon (pers com) reported that according to KNP records more than thirty species had been collected in surveys in this river. This situation remains a concern, even if the fact that the pools were not surveyed is taken into consideration. However the team noted that a high concentration of algae and specifically filamentous algae was present at all the sites in the Crocodile River. Based upon this, and because preliminary results on the water samples was inconclusive as far as pollutants were concerned, it has been decided that a follow-up survey will be undertaken to investigate the diurnal cycle of the oxygen levels at two sites in the river.

EXPLORING THE ROLE OF WATER AND NUTRIENTS IN DETERMINING SAVANNA STRUCTURE AND FUNCTION

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This study focuses on two major environmental gradients in savannas: water and nutrients. The aim of this research is to provide more insight in the functioning of savanna ecosystems, by assessing the water use and nutrient uptake of trees and (to a lesser extent) grasses, using a multi-faceted comparative approach. Studying tree-grass interactions is of great importance for the understanding of savanna ecosystem functioning. The results of the current study are anticipated to contribute to the understanding of the mechanisms that determine the co-occurrence of trees and grasses on the savanna.

Knowledge of the physiology of woody plants and grasses is of paramount importance, as diversity in physiological traits reflects differences in resource utilization. The understanding of resource use is a prerequisite for the understanding of inter life-form coexistence in a natural, heterogeneous environment. Coexistence of trees and grasses in savannas may be possible if trees and grasses occupy different niches when exploiting limiting resources such as water and nutrients. Walter (1971) was the first to propose that trees and grasses compete for water in the upper soil profiles, where grasses are the better competitors, whereas trees can persist in the system because they have sole access to water in deeper soil layers.

Another competition-based hypothesis for tree-grass coexistence, which has as yet not been tested, was suggested by Scholes and Archer (1997). It developed from the observation that some drought-deciduous tree species start forming leaves before the first rains of the growing season. These drought-deciduous trees discard their leaves long after the last rain shower in the dry period. This way, trees are able to extend their growing season and thus have exclusive access to resources early and late in the growing season. In this scenario, grasses must be the better competitors in the time that they have their peak flush if they are to persist in the system. This phenomenon has been interpreted as a strategy of trees to avoid competition for resources with grasses, making co-existence of grasses and trees possible (Scholes and Archer 1997).

Understanding of the proximate causes of pre-rain flushing is needed for a better interpretation of the observed strategy. One objective of this study is to obtain insights by investigating the relationship between water and nutrients in the period between leaf expansion and the first rain shower. It will also be verified how much the water balance must change for trees to abandon their leaves at the end of the growing season and how plastic species are in their response.

THE EFFECTS OF TRANSLOCATION ON THE STRESS BEHAVIOUR OF AFRICAN ELEPHANT

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A free-ranging animal is in a state of stress if it is required to make abnormal or extreme adjustments in its physiology or behaviour in order to cope with adverse aspects of its environment or management. Since stress includes psychological and physiological responses, an integrated approach using both measures is necessary to quantify this state. Physiological responses can be measured through hormonal excretions (faecal glucocorticoids) and psychological responses by elephant vegetation interactions.
Most studies on vegetation impact by elephants tend to concentrate on the impact of an entire population, in large ecosystems, using predetermined survey plots. The Kruger National Park's management objectives are based on a system of thresholds of potential concern (TPC's). In determining these thresholds at any population level, emerging evidence is showing that the impact on woody vegetation is sexually dimorphic and this study can contribute to the setting of and refining of the current TPC's. The study area is situated in the southeastern part of the Kruger National Park (KNP). The area is approximately 250 000 ha in extent and covers most of the Lower Sabie section as well as parts of the Crocodile Bridge and Tshokwane sections.
Knowledge of the normal faecal glucocorticoid levels of African elephant family groups and its variability can serve as a useful baseline to measure the stress-related effects of translocations, management actions and the impact of chosen land use activities. Enzymatic-immunoassay analysis (EIA) for the measurement of cortisol metabolites in animal faeces has been validated, but its use has only recently been exploited in wildlife populations. Although faecal glucocorticoid levels have been measured in captive African elephants, there are limited data on such concentrations in free-ranging elephants. In this document we establish a baseline for free ranging elephant herds in the Kruger National Park by determining the typical faecal glucocorticoid concentrations that could be expected within age classes and between seasons.
Much of the vocal communication of elephants is infrasonic and thus requires radio collars, each with a unique transmitting frequency, to determine which animal made which call. Many of these calls are used in intra-group social dynamics which mobilizes elephants to move away together. Long distance acoustic communication can assist in deciphering some aspects of elephant social behaviour and would help to measure the effect of translocation on social behaviour.

A PRELIMINARY SURVEY OF THE SHINGWEDZI RIVER CATCHMENT – ALIEN PLANT INFESTATION, AQUATIC BIOTA, GEOMORPHOLOGY, AND RIPARIAN ZONE INTEGRITY

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The main focus of the study is to get a better understanding of the Shingwedzi River catchment, with reference to the anthropogenic activities on the water quality, biota (fish, macro-invertebrates, riparian vegetation and the geomorphology) and the impacts of pollution on the organisms, including bioaccumulation and eco-toxicological essays.
Twelve sites upstream of the Kruger National Park boundary were surveyed as part of a pilot survey to identify sites for the more comprehensive study. A preliminary monitoring of the fish, macro-invertebrates, riparian vegetation and water quality was done during the site visit and some samples of fish, invertebrates and diatoms were collected.
All sites visited were deemed to be useful as sites for the more comprehensive study and the data collected will be used as reference information. This survey will be followed up with a similar pilot survey inside the Kruger National Park. As was the case during this first survey, we need to identify suitable sites inside the park for the comprehensive surveys planned for year two and three of the study.
Because the survey was conducted towards the end of the winter, flow in most cases was very limited. A large number of dams and weirs restrict natural flow and the water that is available is further abstracted through pumping and people collecting it for household purposes. No formal water points for cattle were seen, resulting in cattle using the rivers as a source of water. This result is serious erosion and siltation. In addition to this, organic pollution with resultant possible bacterial problems can be present.
In many instances the river is used as dump sites for solid waste as people expect the waste to be removed during the next flood. As no infrastructure is present in most of the rural villages in the area, sanitation is a problem. Most of the soils are sandy and the erosion potential is high. Associated with this is the potential that pit latrines dug near the river, will leak into the surface water. In general, the area has a low people density. Most of the people living in the area are concentrated near the rivers, as this is the only reliable source of water for humans and their animals.

A STUDY OF THE CHARACTERISTICS OF *NOTHOBRANCHIUS* FISH HABITATS IN THE GREAT LIMPOPO TRANSFRONTIER PARK AND THE GEOLOGICAL FACTORS CONTROLLING THEIR DISTRIBUTION

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The overall objective of this research is to study the characteristics of *Nothobranchius* fish habitats in the Great Limpopo Transfrontier Park with an emphasis on the geological characteristics of the habitat substrates and the geomorphological factors controlling their distribution. It is expected that such a study will lead to an enhanced understanding of the ecology of these fishes for possible application in future conservation programs.
Three periods of field investigations have been carried out, involving an investigation of:
a) The Pumbe Picket and N'tomeni Spruit localities in the KNP, b) the southwestern part of the Coutada 16 part of the GLTP in Mozambique, c) the area in Mozambique immediately east of the Pumbe Picket locality, and d) the northern part of the Coutada 16 part of the GLTP bounded by the Limpopo River and the KNP-Mozambique border. All three sites included forms of *N. rachovii* and *N. orthonotus* having color patterns identical to those of the same species present at the Pumbe Picket locality. These close similarities, indicate that these species once populated an ancient land surface, an elevated remnant of which now hosts the Pumbe Picket locality.
Nothobranchius furzeri was also found at two of the Mazimechopes locations. The fact that *N. furzeri* is found only on the modern floodplain areas at relatively low elevation, and not on the ancient floodplain (or peneplain) remnant, suggests that this species evolved later than both *N. rachovii* and *N. orthonotus*. The ancient erosion surface/peneplain in the Pumbe area is probably Late Tertiary in age and the overlying deposits of cobbles, pebbles and sand, on which the mud substrate of the Pumbe locality occurs, are of Quaternary age. This in turn suggests that the two older species date back at least 2 million years while the development of *N. furzeri* would be substantially younger than that.
Field investigations in the southwestern, west-central and northern parts of the Coutada 16 section of the GLTP in Mozambique, have indicated that most of these areas are probably not suitable for *Nothobranchius* habitation.

POPULATION DYNAMICS AND THE EFFECTS OF HERBIVORY AND FIRE ON THE REGENERATION ECOLOGY OF *ACACIA NIGRESCENS* AND *DICHROSTACHYS CINEREA* IN THE KRUGER NATIONAL PARK, SOUTH AFRICA

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The aim of the present study is to contribute to a better understanding of savanna woodland regeneration dynamics, through an investigation of the effects of herbivory and fire on the population dynamics and regeneration ecology of *Acacia nigrescens* and *Dichrostachys cinerea. D. cinerea* is a typical bush encroacher in disturbed habitats (regenerates),whereas *A. nigrescens* is one of the most widespread acacias tolerating a wide range of disturbances and seldom encroaching (persistent). Long-term experiments are set up at the Nkuhlu exclosures, providing the unique opportunity to gather experimental evidence on the effects of disturbances such as elephant impacts and fire on each stage of the regeneration process. Initial results indicate that not only total annual rainfall, but rather the timing of rainfall events within the season are particularly important in seed production. In 2004 good winter rains resulted in one of the single biggest flowering and seed production events (in terms of both synchronization and total production) in *A. nigrescens* in the park in many years. Large seed production events such as this are thought to be the key to the inputs of seed reserves to the soil. No seedlings were found despite large rainfall events in the rainy season of 2004. This is probably due to the lack of seeds from previous seasons.

In a small experiment undertaken in conjunction with other researchers, it was shown that rodents predate heavily on both *A. nigrescens* and *D. cinerea* seeds. Furthermore, there is a much higher density of rodents within the full exclosure than outside. It has never been shown before that rodents are major predators of savanna seeds. This is a significant finding and may explain, in part, why the successful germination of seedlings is so rare in African savannas.

The effects of fire frequency and intensity (season of burn) on population structure of each species will be investigated at the experimental burn plots (EBP's) at Satara in October 2006. In particular, the role of bark thickness in determining fire resistance will be investigated in a novel approach utilizing the relationship between bark thickness and trunk circumference at various trunk heights. In addition to this, another objective is be added where seedlings will be planted on some of the burn plots and monitored for a few weeks before a fire is put through the plots. Burning of the relevant Satara plots is scheduled for 2006. The survival and growth of seedlings following fires will give invaluable insight into the regeneration of woody species following fire. In particular concerns have been expressed by rangers regarding the encroachment of *D. cinerea* in certain areas. If time and logistics permit, the regrowth of small resprouting individuals will be monitored following destructive burns aimed at reducing encroachment in these areas.

MOVEMENTS AND FEEDING BEHAVIOR OF EPAULETTED FRUIT BATS AND IMPACT ON REGENERATION OF SYCOMORE FIG TREES

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Captive bats processed an average of 24.4 figs per bat per night containing a total of nearly 24,000 *Ficus sycomorus* seeds. These seeds would be dispersed both in spats and in feces. Spats were produced approximately every 5 minutes by captive bats when feeding. Feeding bats remained within 10 – 100 m of the fruiting tree. Therefore, most seeds ejected in spats are dispersed w/in 100 m of the parent tree. On the other hand, when changing feeding sites or flying to day roosts bats potentially disperse seeds longer distances. For example, one bat flew 11,000 meters in 29 minutes during a non-stop commute (412 m/s). Since defecation intervals were approximately 20 min, a commuting bat could carry seeds as much as 8 km. In addition, bats flying from fig tree to fig tree along riverine corridors would deposit seeds where seedlings are most likely to become established.

We found no evidence that either *Epomophorus wahlbergi* or *E. crypturus* fed on anything other than *Ficus sycomorus* fruits during our study (dry season). On the other hand, numerous direct observations of bats feeding on figs in the wild and in captivity sustain the assumption that figs are staples in the diet of these bats.

Further, the distribution and abundance of Sycomore figs in KNP, as mapped during the previous years of this study, and the extraordinary size of the fruit crops on asynchronously fruiting individual trees, suggest that dry season resources are more than adequate to sustain the observed population of bats.

Based on these data, the 88 - 90 bats roosting in Skukuza Rest Camp would consume approximately 2100 figs and distribute over 2 million seeds per night. Thus, we suggest that Epauletted Fruit bats are major dispersers of Sycomore Fig seeds, and that the bats and the figs are mutually dependent.

INVESTIGATING THE KRUGER NATIONAL PARK MOLLUSC DIVERSITY, INCLUDING THE MIGRATION OF CURRENT INVADER SPECIES AND IDENTIFICATION OF NEW ONES

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The objectives of this project are to study the biodiversity of freshwater molluscs in the Kruger National Park and the influence of variations in the rainfall patterns on these aquatic organisms. Another objective was to establish which invader freshwater molluscs occur in the park, whether there are any changes in their distribution through the Park, as well as if there is an increase in the species diversity as far as these organisms are concerned. Comparisons between the respective habitats surveyed in 2001 and 2006 revealed slight differences in the mollusc species diversity of the Letaba, Timbavati and Sabie Rivers but no differences in the total number of species collected. Although there was a decrease in the mollusc species diversity in five of the habitats during the 2006 survey and no molluscs were found in another 12 habitats as compared to only one during the 2001 survey, it would seem premature to conclude that there was an overall decrease in the species diversity. The fact that the recent survey was done shortly after high rainfall through nearly the entire Park could have had an influence on the species diversity recorded.
With regard to the alien invasive snail species, four species, namely *Lymnaea columella*, *Physa acuta, Aplexa marmorata* and *Tarebia granifera* are present in the Park. The three species first mentioned were also found during previous surveys, while *T. granifera* was only found during the last survey during which it was already present in large numbers in 12 of the 43 habitats. In three of these habitats a decrease in the overall species diversity was observed. In comparison with *T. granifera* the progress of invading the Park of the first mentioned three species seems to be less aggressive. This is rather unexpected in view of the fact that *L. columella* is the third most widespread species in South Africa and is also considered elsewhere in the world as an aggressive invader. A logical explanation for the limited progress of *P. acuta* in colonizing the Park could be ascribed to the phenomenon that this species commonly occurs where pollution from sewage is obvious, and that it seems to be closely associated with human activities.

TEMPORAL TRENDS IN ELEPHANT DISTRIBUTION AND NDVI IN THE KRUGER NATIONAL PARK

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Growing numbers of elephants (*Loxodonta africana*) confined to protected areas may impact on biological diversity. Such impact may be mediated by the way that elephants use landscapes as reflected by patterns of incidence-density. Using elephant count data from 1998 to 2004, we determined if increasing elephant numbers influenced their distribution in Kruger National Park. We studied how elephant density and distribution changed at four spatial scales (1 km^2, 25 km^2, 100 km^2, 400 km^2) and in landscapes defined by vegetation, geology, climate and soils. Since resource limitations may induce temporal patterns in spatial use, we then investigated whether elephant distribution was associated with the remotely sensed Normalized Difference Vegetation Index (NDVI) as a measure of productivity.

We found that the distribution of elephants across the Kruger National Park changed from year to year during our seven-year study. The number of patches occupied by elephants increased with population size, while patch-specific density became more similar. Concurrently, the distribution of elephant groups (bull groups and breeding herds combined) became less clumped and more random. The decrease in clumping among elephant groups as population size increased in Kruger suggests that elephants may distribute themselves more evenly across the landscape when their numbers increase. Elephants may therefore improve foraging in as far as their distribution being driven by density. This was supported by the decrease in variability of density on patches.

The influence of density on elephant distribution is poorly explained by productivity during the dry season. NDVI only weakly explained elephant distribution in both the month of elephant surveys and the 12 months preceding the surveys. We interpreted NDVI at the time of the surveys (September) to reflect on the quality of vegetation then, while total sum of NDVI in the 12 months preceding the surveys reflected on the quantity of vegetation available. However, we also found that the dry season range of NDVI-values provided limited choice for elephants during September. Hence the influence of density on elephant distribution may be more strongly expressed during different times of the year.

This study suggests that increasing numbers of elephants in Kruger influenced their distribution during the dry season. However, the influence of density on distribution that could induce negative impacts on vegetation seems weak at present densities and during the dry season. Changes in distribution at higher densities may give rise to elephants having a more homogenous impact on vegetation in the dry season or at other times of the year. We therefore argue that management which aims to reduce elephant impact should not only account for numbers, but also for the factors other than density that influence elephant distribution.

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