STATE OF THE KATSE DAM CATCHMENT 2014

VOLUME I

SYNTHESIS OF THE 2013/14 MONITORING STUDIES

July 2014

Anchor Environmental Consultants Report No: AEC/1540/1

Kingdom of Lesotho
Lesotho Highlands Water Project (LHWP)
Lesotho Highlands Development Authority (LHDA)

LHDA Contract 1273:

Biological Resources Monitoring within
Phase 1 of the LHWP Catchments 2013/14

STATE OF THE KATSE DAM CATCHMENT 2014

Volume I:

SYNTHESIS OF THE 2013/14 MONITORING STUDIES

Jane Turpie[1], Nigel Barker[2], Barry Clark[1], Gerhard Diedericks[3], Gary Marneweck[4], David Allan[5], James Harvey[6], Nico Avenant[7] & Katherine Forsythe[1]

[1]*Anchor Environmental Consultants*
[2]*Department of Botany, Rhodes University*
[3]*Environmental Biomonitoring Services*
[4]*Wetland Consulting Services*
[5]*Durban Natural Science Museum*
[6]*Independent consultant*
[7]*National Museum, Bloemfontein*

Report submitted by:
Anchor Environmental Consultants
8 Steenberg House, Silverwood Close, Tokai 7945, South Africa
www.anchorenvironmental.co.za

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PREFACE AND ACKNOWLEDGEMENTS

This project was commissioned by the Lesotho Highlands Development Authority (LHDA) as a follow-up monitoring study to determine the impacts of the land use changes and other pressures related to the construction and operation of the Mohale Dam on its catchment area. The authors wish to acknowledge the LHDA project manager Lebohang Moleko and the LHDA Executive Committee for the assistance and support provided during the planning and execution of the project. We would like to thank our team's in-country co-ordinator Thuso Green and his staff for arranging the logistics and helping to ensure that our fieldwork went smoothly. The team leaders of the study components, listed as authors of this integration report, would like to thank their teams for the huge effort they made in the field, often times involving very long hours under extremely wet and trying conditions, and travelling by vehicle or on horseback in terrifyingly steep landscapes. In addition, Mark Thompson and Jens Hiestermann undertook the remote sensing work and Grant Benn produced all the maps for the fieldwork and for the final reports. We would also like to thank Jessica Hughes for imparting her experience of the AfriDev surveys, her valuable assistance with the design and logistics of the study, and for assistance with the review of some of the specialist reports. We are also grateful to Dave Allan and Dave MacDonald for the provision of past datasets on birds and flora that have made a huge difference to the success of this study.

Project leader	Jane Turpie
Project planning and co-ordination	Jessica Hughes and Thuso Green
Database and statistics	Katherine Forsythe
GIS analysis and maps	Grant Benn
Remote sensing	Mark Thompson and Jens Hiestermann
Vegetation study	Nigel Barker, Ralph Clark, Sauli Ramatla, Tony Dold, Khotso Kobisi, Mokone Kheekhe and Yolandi Norman
Wetland study	Gary Marneweck, Heinz Ortmann and Motlatsi Phasumane
River & fish studies	Barry Clark, Gerhard Diedericks, Thabo Sephaka and Jeremy Shelton
Amphibians & reptile study	James Harvey and David Maguire
Mammal study	Nico Avenant, Jurie Du Plessis, Tshediso Putsane and Jacob Senoge
Bird study	David Allan and Andrew Jenkins

LIST OF REPORTS UNDER LHDA CONTRACT 1273:

Biological Resources Monitoring within Phase 1 of the LHWP Catchments 2013/14

Katse	Topic	Authors	Report no.
Vol. I	Synthesis report	Turpie, J., Barker, N., Clark, B., Diedericks, G., Marneweck, G., Allan, D. Harvey, J., Avenant, N & Forsythe, K.	AEC/1540/1
Vol II	Land cover	Turpie, J., Forsythe, K, Benn, G., & Thomson, M.	AEC/1540/2
	Vegetation	Barker, N., Forsythe, K., Clark, V.R., Ramatla, S., Kheekhe, M., Dold, A., Kobisi, K., Norman, Y. & Turpie, J.K.	
	Wetlands	Marneweck, G., Ortmann, H. & Phasumane, M.	
Vol III	Rivers	Diedericks, G.	AEC/1540/3
	Fish	Clark, B. Shelton, J. & Sephaka, T.	
Vol IV	Amphibians & reptiles	Harvey, J.	AEC/1540/4
	Mammals	Du Plessis, J., Avenant, N. & Putsane, T.	
	Birds	Allan, D. & Jenkins, A.	

Mohale	Topic	Authors	Report no.
Vol. I	Synthesis report	Turpie, J., Barker, N., Clark, B., Diedericks, G., Marneweck, G., Allan, D. Harvey, J., Avenant, N & Forsythe, K.	AEC/1540/5
Vol II	Land cover	Turpie, J., Forsythe, K, Benn, G., & Thomson, M.	AEC/1540/6
	Vegetation	Barker, N., Forsythe, K., Clark, V.R., Ramatla, S., Kheekhe, M., Dold, A., Kobisi, K., Norman, Y. & Turpie, J.K.	
	Wetlands	Marneweck, G., Ortmann, H. & Phasumane, M.	
Vol III	Rivers	Diedericks, G.	AEC/1540/7
	Fish	Clark, B. Shelton, J. & Sephaka, T.	
Vol IV	Amphibians & reptiles	Harvey, J.	AEC/1540/8
	Mammals	Avenant, N., Du Plessis, J. & Senoge, J.	
	Birds	Allan, D. & Jenkins, A.	

EXECUTIVE SUMMARY

Introduction

The Katse and Mohale Dams were constructed in the Lesotho Highlands as the Phase 1A and 1B, respectively, of the Lesotho Highlands Water Project (LHWP), and are managed by the Lesotho Highlands Development Authority (LHDA). The Katse Dam was completed in 1996 and filled in 1997. Construction then began on the Mohale Dam, which was completed in 2002 and filled in 2003. Before their completion, the LHDA embarked on a monitoring programme comprising baseline studies and subsequent monitoring studies. Baseline studies of the Katse Dam catchment area were carried out during 1991/92 under Contracts 75 and 83, and monitoring was carried out in 1996-2000 under Contract 615. This study (under Contract 1273) comprises a further stage in the monitoring of the catchment areas upstream of the Katse and Mohale dam. This report summarises the findings for the Katse Dam catchment.

Study approach

The study was broken down into eight components: land use and vegetation cover (based on satellite imagery), flora, wetlands, rivers, fish, amphibians and reptiles (herpetofauna), mammals, and birds. This study placed considerable emphasis on the collation of past reports and data in order to set up the basis for comparison of the present situation with the baseline.

Remote sensing data were used to map land cover, vegetation types and habitat condition and their changes over time. Satellite data were acquired for all years from 1991-2014 in order to generate annual data on vegetation cover vigour and associated degradation status using the Normalised Difference Vegetation Index (NDVI) modelling approach. Landsat 4/5 and 8 imagery were also used to generate land cover maps for 1993, 2005 and 2013, showing basic physiognomic/structural vegetation groups within each assessment period. This included five categories of grassland ranging from intact to highly degraded. Findings for the 2013 data set were ground-truthed using data from the specialist field study on vegetation.

Field surveys were carried out in Spring 2013 (October-November) and Summer 2014 (January–March). The methods for the field surveys replicated those of the baseline study as far as possible. Sampling of wetlands and rivers was focused on using rapid assessment tools to determine their state of health. Sampling of flora, fish and birds was designed for quantitative assessment of diversity and abundance, using statistical analysis. Sampling of herpetofauna and mammals used a presence-absence approach. Thus the comparisons with past data involved both statistical analyses and expert opinion based on available evidence. Past and present data were collated in a database for use in future monitoring.

Land cover

The time-series data revealed that the Katse Dam catchment within 10 km of the dam inundation area showed lower NDVI values and a negative trend in biomass from 1991-2014, whereas both protected areas, at least one of which (Tsehlanyane) had been established within the period of analysis, showed slightly positive trends in biomass over the time period. Within 10 km of the dam, areas closest to the dam had the lowest NDVI values but areas further from the dam (5-7.5 km) showed the fastest rate of decline. Lower altitudes also showed the fastest negative rates of change from 1991-2014.

Over the period from 1993-2013, the two most intact categories of grassland decreased from 34% of land area to 28%, while the percentage area under subsistence farming more than doubled from 3% to 7%. There was also an increase in the area dominated by *Chrysocoma* shrubs from 4% to 8%. While both altitude and distance influenced land use patterns, and areas closer to the dam tend to be at lower altitudes, statistical analysis showed that proximity to the dam had a significant effect on land use and land cover when the effects of altitude were held constant.

These results present a clear indication that land cover has changed quite substantially within the Katse Dam catchment over the period 1993-2013. Most of the changes are indicative of rangeland degradation and transformation to agriculture. The relative stability of grassland condition in nearby protected areas during the same period suggested that these changes have been the result of human activities in the catchment rather than exogenous effects such as climate change. Furthermore, it appeared that human activities and their impacts were particularly concentrated around the dam. It was less clear how degradation due to *Chrysocoma* was occurring and how much is attributed to rangeland management (grazing and fire) vs. climatic changes.

Flora

The field study on vegetation assessed the changes in flora using detailed sampling of established plots. During a ten-day field trip in February 2014, 37 of the original 40 plots were sampled, producing approximately 22 200 data points. In addition to plot sampling, efforts were made to locate previously identified key indicator species and habitats, though no prior information on locations was available.

The vegetation was generally observed to be in a poor condition, being heavily disturbed, intensely grazed and under pressure in places from invasive species such as *Rosa rubiginosa*. There was a high density of 'rural urbanisation', particularly along the main tar road, and an overall high level of disturbance associated with the road and settlements. Exceptions to this were furthest from the dam, namely on the summit in Bokong Nature Reserve and in the Tiping area.

The study showed significant differences in species composition since the baseline study of 1997. These changes included a decrease in the palatable species *Themeda triandra,* increases in the unpalatable genus *Aristida*, increases in woody *Felicia* species and increases in poisonous *Senecio othonniflorrus*. These trends suggest a rangeland response to overgrazing/overstocking and possibly fire. Additionally there was a 32% increase in the amount of bare ground further indicating overgrazing.

With the exception of *Knipohofia thodei*, none of the key species or habitats specified by LHDA were found in the Katse Dam catchment, but this was not considered to be a concern. However, the discovery of two populations of another very rare species, *Euryops inops*, was significant. A population of *K. northiae* was also located.

The presence of alien invasive plant species in the area is of great concern. In particular, the crack willow *Salix fragilis* and wild rose *Rosa rubiginosa* pose serious threats to biodiversity and ecosystem processes. The introduction and spread of these species may have been a consequence of the improved access to the area as a consequence of roads and paths constructed in association with dam construction.

Wetlands

The objective of the Katse wetland monitoring survey in 2014 was to revisit the 28 wetlands that had formed the basis of the 1999-2000 baseline study. Each wetland was assessed using a modified rapid assessment method. Peat cores were also described where appropriate with the aim to find the deepest peat areas and investigate signs of oxidation and decomposition of the peat profile to assess change over the past 14 to 15 years.

The 27 wetlands that were surveyed during March of 2014 all exhibited some form of disturbance and/or negative impact. Several were so dry that it was not possible to get the peat auger into the substrate. From the field work done it could be concluded that all systems regardless of altitude, aspect or type had been affected in a negative way by changes that had taken place in the landscape since the 1999 and 2000 surveys.

Without intervention, a number of systems will be lost in the medium to long term. Some wetlands surveyed in 1999-2000 and now revisited have already been lost or dried up over this period. This suggests that there has been a loss of sub-surface flow, due to reduced infiltration capacity of the landscape as a result of decreased vegetation cover. The biggest concern and immediate threat to the remaining systems was that of overgrazing and trampling by livestock.

Rivers

Aquatic sampling surveys were carried out at 22 sites within the Katse Dam catchment during in October 2013 on the three main rivers entering the dam plus the Motete tributary. Sites selected were based on previous baseline surveys, combining monitoring sites for both fish and aquatic invertebrates. At each site, dissolved oxygen, pH and water temperature were measured *in situ*, and water samples for determination of nutrient concentrations (inorganic nitrogen and inorganic phosphorus) were collected and refrigerated for analysis at a laboratory. Instream habitats were described and their condition assessed using standard scoring methods. River integrity was assessed on the basis of macro-invertebrate sampling and identification in the field to family level.

All water quality parameters measured and analysed were within acceptable ranges. However, generally temperature, conductivity and nutrient concentrations increased downstream, whereas pH decreased downstream, there were also impacts were associated with human settlement and mining activities.

Pools were the dominant hydraulic biotope in the Katse Dam catchment followed by runs, glides and riffles. The substrates were dominated by cobbles, boulders, bedrock, gravel, silt and sand, in that order. Sites closest to the dam were characterised mainly by pools and glides with high proportions of silt. Marginal vegetation was mostly absent, with bank scouring dominant throughout the catchment. Habitat integrity scores ranged between 61-76% (percentage resemblance to expected natural condition) for the Pelaneng, 62-76% for the Malibamatso, and 75-88% for the Bokong-Malibamatso. The worst habitat integrity of 57% was recorded at the Motetse site.

The Katse rivers SASS5 scores ranged between B - marginally impaired and E - seriously impaired. The best conditions were recorded in the Pelaneng River and the worst in the Malibamatso River. The general trend was for best conditions at headwaters and worse conditions close to the dam. Notably the sites which did not fit this trend were the sites below the diamond mining and sites close to villages where people wash their clothes in the river.

Katse streams showed signs of degradation, especially those closer to the dam as well as those close to human settlements and the diamond mining area. These similar results were reflected in water quality, habitat condition and aquatic macro-invertebrates.

Fish

Five species of fish are known to occur in the Katse Dam catchment area. Three of these indigenous species: the smallmouth yellowfish *Labeobarbus aeneus*, Orange River mudfish *Labeo capensis* and the rock catfish *Austroglanis sclateri.* The other two species are non-indigenous species that were introduced well before the construction of the dam: rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta.* The indigenous species were probably once widespread in all major tributaries in the study area, but appear to have disappeared, or been reduced to very low numbers, at most sites as a consequence of habitat degradation and predation by trout.

Fish populations were surveyed at 18 sites on the main influent rivers (Pelaneng, Bokong, Malibamatso and Motete catchments), and at two sites in the dam itself, all of which had been sampled during previous surveys. Fish populations at each site were surveyed using a combination of complementary sampling gears including a range of gill and fyke nets, an electrofisher, hand nets, light fishing tackle and bank-side observations during October 2013.

Non-native rainbow trout were present in all major tributaries and formed the dominant component of the fish assemblage at the majority of the river sites sampled. Brown trout (which have narrower habitat requirements) were also present in the Bokong River. Native species occurred at very low densities in the rivers. The fish assemblage in Katse Dam was dominated by native yellowfish and mudfish. Rainbow trout was present in the dam, but at relatively low abundance.

Although the fish populations within Katse Dam catchment have been severely impacted by alien fish species in the past, it appears that they are remaining relatively stable since the construction of the dam. The Katse Dam, like the lower river sites, appears to function as a refuge for the native cyprinids (yellowfish and mudfish) from predation by rainbow trout allowing the native and non-native species to co-exist within the catchment.

Amphibians and reptiles

Herpetofaunal populations were surveyed at 25 sites in the Katse Dam catchment during January and February 2013 and compared with baseline studies completed in 1993. Seventeen sites that were surveyed during the original survey were re-sampled and an additional eight new sites were surveyed. Techniques similar to those used in previous surveys such as active searching, sweep netting, acoustic surveys and nocturnal searches were used. Additional records from bycatch of the fish study during the previous spring were also included.

This survey confirmed the continued presence of all amphibian species recorded during the baseline study (seven species), as well as recording two additional species. This study also recorded breeding activity in six amphibian species. The localised 'near threatened' *Amietia vertebralis* was recorded in the extreme upper catchment. Most species present could generally be considered habitat generalists. Three species are more specialised, being strongly reliant on riverine systems. The study recorded three snake and four lizard species. The majority of reptiles previously recorded were also detected (six out of ten species), with one previously unrecorded species being detected in the 2014 survey. Species that were not recorded during this survey are expected to still be present despite their lack of detection in the current survey, since habitats for all recorded species remain available.

Mammals
Some 33 species of mammals (bats excluded) have been recorded or could be expected to occur in the Katse Dam catchment area, including the red-listed white-tailed mouse and oribi, as well as the endemic ice rat. Following the methods used in the original mammal baseline survey in 1991/92, a combination of standardised small mammal trapping in predetermined areas, and indirect sampling methods in the general study area were used to record species presence, density, diversity and community structure While the base line studies took place over multiple seasons, sampling for current study was only conducted in January/February 2014.

In total seven species were collected on the various small mammal trap lines during January/February 2014 in the Katse Dam catchment area, compared with 11 species for the 1991/92 baseline. Overall, higher Shannon diversities were found at trap lines in the Upper Bokong Valley, followed by trap lines in the Ha Lejone/Ha Poli area, and then on trap lines in the Katse area.

Sixteen mammal species were observed through actual sightings or indirect signs in the Katse Dam catchment area during January/February 2014 compared with 14 in the 1991/92 baseline. The highest number of species were observed in the Katse area (n = 9), followed by the Ha Lejone/Ha Poli area (n = 8) and the Upper Bokong Valley and Mafika Lisiu Pass areas (n = 7 each).

Generally, lower densities and numbers of species were found in the current study when compared to the baseline. Efforts to protect the Upper Bokong Valley had proved worthwhile: the highest small mammal species richness, diversity and trap success were found here, as well as a diversity of larger mammals threatened by human activities in other parts of the Lesotho Highlands. A relatively large number of larger mammal species were also observed in the partially fenced-off area around Katse dam wall and lodge, likely due to the fact that they are less vulnerable to human disturbances such as cultivation, grazing and hunting.

Birds
The proportion of endemic or near-endemic bird species at the Lesotho highlands is extraordinarily high and this area also includes the remaining global/regional strongholds for a number of red data

species. This Katse Dam catchment is therefore particularly important for the conservation of avifauna.

Fieldwork entailed counts of cliff-nesting and waterbirds during October 2013 and 20-minute walked transects in each of four habitats: cultivated fields, low, mid and high altitude grasslands were conducted during February 2014.

Of the 126 non-vagrant species recorded at Katse, 12 species were not recorded during the 2013/14 survey: Swainson's spurfowl, jacobin cuckoo, diderick cuckoo, African snipe, Verreaux's eagle, cattle egret, barn swallow, Barratt's warbler, African reed-warbler, Layard's tit-babbler, yellow-crowned bishop and red-collared widowbird. For two of these species there was compelling evidence to suggest that local extinctions of previously common and widespread bird species had occurred in the catchment between the baseline/monitoring and 2013/14 surveys. These were the African reed-warbler and red-collared widow, both species previously largely associated with low-lying agricultural fields in the upper Malibamatso region of the catchment. Ten species were recorded at Katse for the first time during 2013/14, of which five were waterbirds. Examination of the distribution maps suggested large-scale reductions in distribution and hence abundance of helmeted guineafowl, neddicky and wing-snapping cisticola.

Both the number of bird species counted per transect as well as the number of groups of birds had declined since the baseline study. There were also higher numbers of bird as well as species found in the cultivated fields than in any of the grassland habitats. Some of the most obvious decreases were in species that are endemic or near-endemic to the area such as Drakensberg siskin and Drakensberg rock-jumper. A significant finding of the bird-transects counts at the high-altitude study site in Bokong Nature Reserve at Mafika Lisiu was that the globally threatened Yellow-breasted Pipit has become common there since the monitoring survey, with breeding confirmed, likely due to the protection of this area from overgrazing.

Of nine non-waterbird cliff-nesting species at Katse only two show evidence of a change of status in the catchment. The regionally 'critically endangered' bearded vulture supported 4-5 breeding pairs during the baseline and monitoring periods but the species no longer appears to breed in the catchment. There was a decrease in activity of jackal buzzard nests that were nearer to the dam (original territories partially submerged).

Of the changes to the waterbird community the most noteworthy were the disappearance of the black stork - a red data species, the large-scale decrease in African black ducks, the massive increase in white-breasted cormorants and the establishment of a major breeding colony by this species.

The results of the current survey reveal that substantial changes had taken place in the bird community of the Katse Dam catchment. These changes include both increases and decreases in the distribution and abundance of bird species. On the whole however, the number of species as well as the abundance of birds seems to have declined since the inundation of the Katse Dam as well as shifted the composition of the bird community.

Discussion

Land use and land cover within the Katse Dam catchment area has changed significantly over the past two decades, with the analysis of satellite data suggesting that more than half of the catchment area had changed in some way. These changes included a decrease in the biomass of grassland vegetation, increases in subsistence cultivation and increases in shrubby vegetation. These changes were associated with increased human activities in the area, notably livestock grazing and agriculture.

A decrease of grassland biomass occurred throughout the catchment between 1991 and 2014, especially in areas closer to the dam. The flora study found increases in bare ground as well as shrubby vegetation within grasslands. There was also an increase in the relative proportions of unpalatable grass species at the expense of important palatable grass species. These responses were all indications of a decline in rangeland condition caused by overgrazing by livestock.

The changes in grassland, along with conversion to agriculture, including on steep slopes, has decreased the infiltration capacity of the landscape and increased erosion. Sheet erosion on slopes was especially prevalent in the Katse catchment, this form of erosion is where almost all the soil is removed down to bedrock, aggravating gully erosion in the deeper soils at the base of these slopes. These factors have combined with overgrazing to result in severe damage of the wetlands in the catchment. Erosion of grasslands and wetlands, coupled with mining activities in some rivers, has led to increased sediment loads in rivers.

Invasive alien species have been found to be a significant problem in the Katse Dam catchment, both in terrestrial and aquatic habitats. These include species of plants, fish, mammals and birds that have arrived both before and since the construction of the Katse Dam. While some of the plants are believed to have been present before dam construction, with exception to the invasive trout, all other animal introductions are thought to have taken place since dam construction. Two invasive bird species (the common starling and the common myna) and one mammal species (the cane rat) were recorded for the first time in the study area.

These habitat changes, along with other human pressures, have also impacted on the flora and fauna of the area. While changes in amphibians and reptiles were not detected, possibly due to the coarse sampling methods, there were noticeable changes in the diversity and abundance of plants, mammals and birds. Fish, which have been historically impacted, were relatively unchanged apart from the populations that have colonised the dam.

The most serious degradation and modification appears to have happened at the habitat level and is only beginning to be seen in the faunal species (Table I). The exception being the fish community, which have been severely impacted by invasive trout. The interconnected nature of all these components makes the need to improve the health of the most degraded components even more critical. If not addressed, the degradation that has already occurred will likely continue to affect even the components that are now seemingly minimally impacted.

Table I. Summary assessment of qualitative health class (A-F) for each component examined for Katse catchment.

Component		Health Class
Land cover	☹	D – Largely Impaired
Vegetation	☹	D – Largely Impaired
Wetlands	☹ ☹	E – Seriously Impaired
Rivers	😐	C – Moderately Impaired
Fish	☹ ☹	E - Seriously Impaired
Amphibians	☺	B – Minimally Impaired
Reptiles	☺	B – Minimally Impaired
Mammals	😐	C – Moderately Impaired
Birds	😐	C – Moderately Impaired

Recommendations

In order to address the problems observed and documented in this study, a number of actions need to be taken. These include reducing pressure on rangelands, taking targeted restoration and conservation action, controlling invasive species and planning any future infrastructure carefully.

Reducing pressure on rangelands

Both fire and grazing regimes need to be properly managed within the dam catchment. Although a prescriptive list of management rules cannot be made without further research, the following principles, however, might be applied (1) Grazing pressure needs to be reduced and some form of rest period needs to be implemented, especially for wetlands. (2) Burning need to be more planned and controlled. Burning large continuous areas, or the same areas every year should be avoided. Generally the best timing for fires is during late winter or early spring in order to get rid of residual material and promote high quality graze in the following season. (3) Variability in both the timing and geographical location and extend of both grazing and burning. (4) Management of rangelands is vital and needs to be continually adapted to current conditions and informed by changes in grassland condition.

The first and most Important step in applying these principles is reducing stock numbers within the catchment. There are a number of potential options such as providing micro-financing options to discourage people from keeping excess livestock as storage of wealth/insurance policy, using incentives (either positive incentives like subsidies or negative incentives like taxes) to encourage people to lower the number of livestock they keep, and education on production-centred livestock management practices. However, none of these options should be undertaken without an in-depth socio-economic study of the dam catchments to determine the reliance on natural resources for local livelihoods and the likely response of the different stakeholders to any interventions.

Restoration and conservation action

Urgent interventions are required to prevent further deterioration and loss of wetlands within the catchment. A number of the wetlands surveyed have been recommended for rehabilitation efforts. However, the wetlands surveyed were only a subset of wetlands within the catchment. The success of any rehabilitation efforts and stemming wetland degradation generally will depend on addressing the rangeland management issues.

It is recommended that protection efforts in the Bokong Nature Reserve are continued. LHDA should also maintain controlled access to the current security zones around the Katse dam wall and lodge to act as conservation areas. The creation of more conservation areas, where grazing is excluded or limited, can provide protection for important vegetation as well as refuge for mammal (and other fauna) species. Particular areas in need to protection include high-altitude grassland, wetlands and riparian habitats.

The establishment of an artificial vulture feeding site could be of benefit to endangered vultures as well as act as a tourist attraction.

Control of invasive species
Controlling the spread of alien invasive plant and animal species needs to be addressed, although this needs to be linked with appropriate research on some of these invasive species. Community groups could be encouraged to help remove invasive shrubs and help improve the range condition. Stricter control of domestic dog numbers, or even exclusion from specific areas could have marked beneficial influence on mammal species diversity and ecosystem health. Eradication of the invasive brown trout should be attempted while population numbers are low.

Plan infrastructure carefully
Future infrastructure, including roads and other developments, need to be properly planned to take into account the impact they will have, especially on water run-off and subsequent erosion. Considering that the sensitive nature of the areas biodiversity, we recommend that future environmental impact assessments have a strong biodiversity components.

Monitoring & research
It is recommended that the monitoring programme be continued at least every five years, but with some improved protocols. Details are provided for each component. These include revisiting the key indicator species to be monitored.

In addition, LHDA should undertake continuous monitoring of the drivers of habitat change. These include rainfall, water flows, water quality, population, livestock, grazing and burning patterns.

Several areas of more intensive research are also recommended including researching the spread and impact of alien species, ecosystem function and response to threats, hydrological monitoring, the disappearance of ‘critically endangered’ bearded vulture and finally sociological studies within the catchment.

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1 INTRODUCTION

1.1 Background and rationale

The Katse and Mohale Dams were constructed in the Lesotho Highlands as the Phase 1A and 1B, respectively, of the Lesotho Highlands Water Project (LHWP), and are managed by the Lesotho Highlands Development Authority (LHDA) which reports to the LHDA Board and the Lesotho Highlands Water Commission (LHWC). The Katse dam was completed in 1996 and filled in 1997. Construction then began on the Mohale Dam, which was completed in 2002 and filled in 2003. The location of the dam inundation and catchment areas are shown in Figure 1.

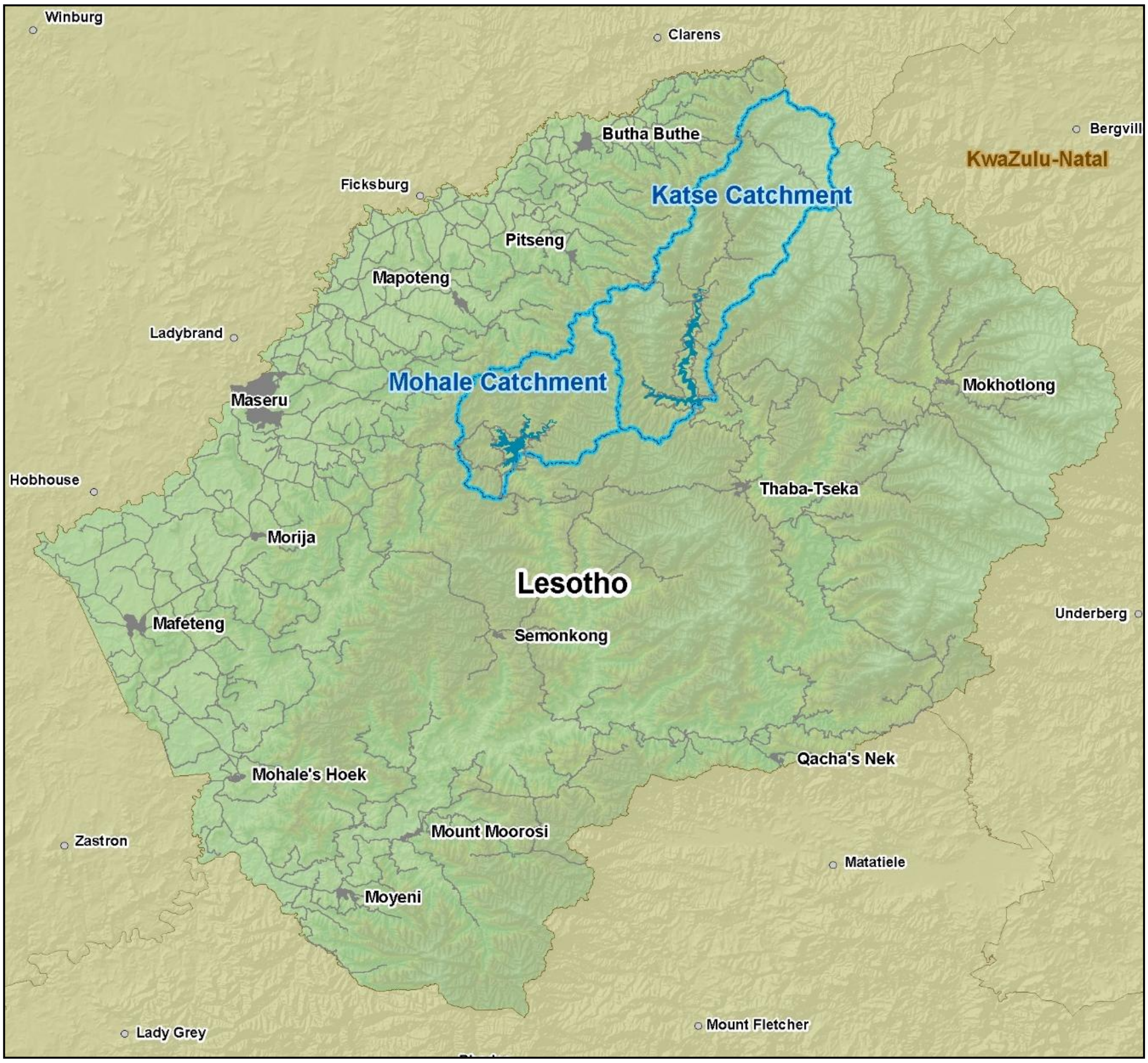

Figure 1. Map showing location of the Katse and Mohale catchment areas

As with the construction of any large dams, there were concerns that they may have negative impacts on biodiversity not only in the inundation area and downstream, but also in their catchment areas. While downstream impacts are mainly as a result of changes in flow, impacts in the inundation area arise as a result of loss of habitat and the change in aquatic habitat from a fast-flowing river to a large waterbody. Upstream of this, biodiversity in the catchment areas of the dam could be expected to result from an increase in livestock grazing, agriculture and use of natural resources in the catchment area. A combination of factors could lead to these, including the loss of land in the inundation area, leading to a geographic shift in activities, increased accessibility to the area as a result of the improved infrastructure associated with the dam, and increased numbers of people in the area as a result of job opportunities, and their demands for land, grazing and natural resources. In addition, the dams could lead to localised changes in ambient temperature in their immediate vicinity, potentially causing localised changes in plant composition, which may have knock on effects on fauna.

Figure 2. The Katse Dam wall.

1.2 Baseline and previous monitoring studies

In order to assess whether such impacts have occurred, the LHDA embarked on a monitoring programme comprising baseline studies and subsequent monitoring studies in both the Katse and Mohale dam catchment areas (Figure 1) and downstream of the dams, as required by the Natural Environment and Heritage Plan for Phase 1. Baseline studies of the Katse Dam catchment area were carried out during 1991/92 under Contracts 75 and 83, and monitoring was carried out in 1996-2000 under Contract 615. No further monitoring studies have been undertaken since then. The baseline and monitoring studies that have been done in the Katse Dam catchment are summarised in Table 1.

Table 1. A summary of the baseline and monitoring surveys conducted in the Katse Dam catchment.

KATSE	**Baseline study**		**Monitoring studies**	
Contracts	**Contract 75 – Loxton, Venn& Associates; Contract 83 - CSIR**		**Contract 615 – AfriDev Consultants**	
Component	**Date**	**Reference**	**Date**	**Reference**
Flora	1992	Loxton, Venn & Associates 1993a.	Feb 1996, 1997, 1998; 1999; 2000	McDonald, D. & Hennessy J. 1998
Wetlands	unknown		1999	Marneweck, G. & Grundling, P. 1999.
Rivers	Nov 1991-Oct 1992	CSIR 1993	Winter & summer annual survey 1996-2000	Davies, M. 1997. Rall, J & Rall, V. 1999. Rall, J & Rall, V. 2000.
Fish	Mar-Apr 1991 Jan 1992	Loxton, Venn & Associates 1993b.		
Amphibians	Mar, Apr, Sep Nov 1991 Jan-Feb 1992	Loxton, Venn & Associates 1993b.	No monitoring	
Reptiles	Mar, Sep-Oct, Dec 1991 Jan-Feb 1992	Loxton, Venn & Associates 1993d.	No monitoring	
Mammal	Mar, Sep-Oct, Dec 1991	Loxton, Venn & Associates 1993c.	No monitoring	
Birds	Feb, Apr, Jun-Jul, Nov 1991& Feb 1992	Loxton, Venn & Associates 1993e.	Feb & Sep 1996 Aug 1997 Feb 1998	Allan 1996 Allan 1998 Allan 2001

1.3 Objectives and scope of work

This study (Contract 1273) comprises a further stage in the monitoring of the catchment areas upstream of both dams. The Request for Proposals (RFP) for this study specifically highlighted the anticipated impacts of the project on flora, terrestrial and aquatic fauna with the expected focus of the current study, as follows:

Flora: Phase 1 was predicted to cause loss of available land to inundation and increased impact on the remaining biological resources in the surrounding catchments. In order to monitor this change, the RFP specifies the need to use remote sensing and GIS to monitor and analyse changes on the flora and specifically highlights rare and endangered plant species and habitats such as *Aloe polyphylla* (spiral aloe), *Delosperma ashtonii, Kniphofia thode*i, *Rhodohypoxi*s and *Leucosidea* woodland.

Terrestrial fauna: Phase 1 was predicted to cause changes to ecosystem linkages due to habitat alterations and loss and change in land use patterns. In order to provide data to assess the degree of change, the RFP specified the use of appropriate methods such as trapping, netting, catching and observation of terrestrial invertebrates, mammals, amphibians and reptiles. A number of key indicator species were named in particular including the mammals *Myosorex varius*, *Otomys* *irroratus*, *Otomys sloggetti*, jackal, caracal, African wildcat, grey rhebok, porcupine & rock hares, the birds white-breasted cormorant, black-shouldered kite, and Swainson's spurfowl, and the amphibians *Rana spp*., *Heleophryne* sp. and *Xenopus laevis*.

Rivers and aquatic fauna: Phase 1 was predicted to cause physico-chemical changes to water quality and increased levels of pollution and toxicity of the aquatic environment based on the linkage between distribution of macroinvertebrates and surface water quality as a reflection of ecosystem health. The RFP required an assessment of habitat integrity, river classification and sediment analysis, water quality sampling, aquatic macroinvertebrate sampling and fish population studies. Monitoring was to employ methods at the sites used in the baseline study and subsequent monitoring studies, or equivalent. Fish species that were specified to be monitored included small mouth yellow fish *Barbus aeneus*, *Labeo capensis, Austroglanis sclateri* and Maloti minnow *Pseudobarbus quathlambae*.

The scope of work for the project is provided in Appendix 1. The main aim of the proposed work for LHDA 1273 as specified in the Request for Proposals document (RFP) is to provide a long term database and information on the status of the flora and faunal species in the Phase 1 catchments, with a focus on the key flora and fauna species.

Key objectives specified in the RFP included:

a) Use GIS and remote sensing as primary tools to collect floral data from Phase 1 catchments of the LHWP and to validate information using the existing fixed vegetation transects in the sub-catchments;
b) Determine the seasonal changes in cover, species composition and extent of eroded surfaces using specific transects within the subcatchments;
c) Assess the impacts of land use, grazing and project related activities on vegetation cover, composition and associated fauna and their distribution;
d) Using relevant indicators, determine the impacts of the project developments and associated factors on vegetation and animals;
e) Identify mitigation measures to enhance vegetation cover and animal species and determine their optimal composition in the area, provided as recommendations in each specialist report; and
f) Provide long term database, information and complementary data on the key terrestrial fauna, vegetation cover, and aquatic fauna, taking into consideration occurrence, distribution, and abundance of rare species.

Note that while the RFP covers both the Katse and Mohale catchments, the requirement was to prepare a separate set of reports for each catchment. This report thus only covers the Katse Dam catchment, though comparisons between the findings from the two catchments are made where applicable. In the Discussion and Recommendations section, text highlighted in light grey pertains only to the catchment covered in the current report.

1.4 Purpose and structure of this report

The synthesis report provides a summary of the various specialist studies undertaken, and provides a synthesis of the overall changes in the study area, and recommendations for the way forward. Following the introduction, the report provides a brief description of the overall approach taken (Chapter 2). Following this, the systems/species, monitoring methods and key results and conclusions are described for each of the specialist studies in a series of chapters (Chapters 3 to 11). The details of these studies are contained in the accompanying set of volumes. The synthesis report then provides a discussion on the overall change in ecosystems and biodiversity that have taken place since the dam was constructed, and the extent to which different factors have played a role (Chapter 12). The final chapter then brings together and expands on the recommendations that have emanated from the various specialist studies into an overall set of recommendations for future management and monitoring of the study area (Chapter 13).

2 STUDY APPROACH

2.1 Components of the study

The study was broken down into eight components. The first three assessed the condition of habitats:

1. **land use and vegetation cover** (based on satellite imagery), supplemented with information from the flora study;
2. **wetlands** (based on field assessments); and
3. **rivers** (based on field assessments, including sampling of water quality and macroinvertebrate fauna).

The remaining five components focused on changes in species diversity and abundance, all based on field studies:

1. flora;
2. fish;
3. **amphibians** and **reptiles** (herpetofauna);
4. mammals; and
5. birds.

2.2 Review and collation of past data

This study placed considerable emphasis on the collation of past reports and data in order to set up the basis for comparison of the present situation with the baseline, and to understand whatever changes may have occurred over the intervening period.

Data were obtained for all the baseline studies apart from the flora study. The original flora study was not suitable for repeat sampling, and the data and protocols established in 1996 were used as a baseline instead. For fish, amphibians, reptiles and mammals, data were of a presence-absence nature and extracted from the reports. In the case of the monitoring studies, all the original flora data were obtained in raw form. The 1999 wetland study, which was used as the baseline, were obtained from G Marneweck. For the fish studies, only presence/absence data were available from 1996 (in the report) and no data were obtained for 1997, but all raw data were obtained for 1998, 1999, 2000 from the report appendices. All original bird data were obtained from DG Allan and converted to Excel format.

In addition, the original co-ordinates were obtained for the previous sampling locations from the reports and with the help of ex-AfriDev staff Jessica Hughes. These were superimposed on digital 1:50 000 maps of Lesotho to create large scale laminated field maps for each study team.

2.3 Analysis of satellite data

Remote sensing data were used to map land cover, vegetation types and habitat condition and their changes over time. Satellite data were acquired for all years from 1991-2014 in order to generate annual data on vegetation cover vigour and associated degradation status using the Normalised Difference Vegetation Index (NDVI) modelling approach. Landsat 4/5 and 8 imagery were also used to generate land cover maps for 1993, 2005 and 2013, showing basic physiognomic/structural vegetation groups within each assessment period. This included five categories of grassland ranging from intact to highly degraded. Findings for the 2013 data set were ground-truthed using data from the specialist field study on vegetation.

2.4 Field studies

Field surveys were undertaken of flora, wetlands, rivers, fish, herpetofauna, mammals and birds. The methods for the present study were based on careful inspection and discussion of the past studies and available data in a team workshop held soon after the start of the project, in August 2013.

This study was carried out with fewer resources than some of the earlier studies, some of which involved multiple trips per discipline, and was limited to a one year period, starting 1 July 2013. This meant that sampling was restricted to Spring and/or Summer (ideal in most cases). Emphasis was therefore on collecting data that would be comparable with past surveys as far as possible within the available survey period.

The design of this monitoring study was also limited by the design of the baseline and previous monitoring studies. In addition, technologies and methods have improved over the past 20 years, particularly in the area of remote sensing, but it was necessary to use methods and technologies similar to those used in the earlier studies in order to ensure comparability. However, methods were carried out in conjunction with more modern approaches wherever possible in order to better inform future monitoring studies.

Where past methods had differed between baseline and subsequent monitoring studies, the study attempted to be faithful to the baseline as far as possible, but in cases where the original baseline was unsuitable (as was the case for flora), the focus was on comparability with the earliest possible subsequent monitoring studies.

2.5 Analysis

Sampling of wetlands and rivers was focused on using rapid assessment tools to determine their state of health, expressed in a range of health categories. Sampling of flora, fish and birds was designed for quantitative assessment of diversity and abundance, using statistical analysis. Sampling of herpetofauna and mammals used a presence-absence approach. Thus the comparisons with past data involved both statistical analyses and expert opinion based on available evidence.

Methodological shortcomings in the earlier studies, such as the lack of control sites and lack of quantitative assessments for some biodiversity features, limited the degree of analysis possible. It should be noted that any observed biodiversity changes recorded by this study may be attributable to a range of factors that are directly related, indirectly related or even unrelated to the construction of the dams, such as grazing pressure, livestock numbers, local rainfall and temperature. Of these, only rainfall data were available. As a result, interpretation of the causes of changes was based largely on expert opinion, supported by inferences from available data where these are found and applicable.

2.6 Data storage

The data collated during the inception phase and field studies have been collated in a database and submitted to the LHDA for use in future monitoring studies. This includes the spatial data on vegetation and land cover, as well as the sampling locations. In addition, specimens of 197 plant species collected from the Katse Dam catchment area were positively identified and submitted to the herbarium at the National University of Lesotho in Roma.

3 LAND COVER

3.1 Introduction

The mountain grasslands of Lesotho are the basis of rural livelihoods and the economy of Lesotho, and the mountain catchments are a very important source of water for much of southern Africa (Nüsser & Grab 2002). The condition of these grasslands has direct implications not only for the livelihoods of many rural Basotho people but also for the long-term functioning of Katse and Mohale Dams. There is a concern that degradation of these grasslands, with decreases in vegetation cover and increases in erosion could result in silting up of the dams (Quinlan 1995). Degradation of the grasslands also negatively impacts the long-term grazing capacity and hence the ability for livestock rearing to provide a sustainable livelihood for the rural Basotho people.

Remote sensing is a component that has not been included in past assessments of the study area, but which could make use of past satellite data to provide a basis for comparison. Remote sensing datasets provide cost-effective multi-temporal data covering extensive areas, allowing for the assessment of changes over time for large geographic regions. Landsat data has the advantage of having long-term, easily-accessible data archives (going back to pre-dam construction years), and provides sufficient spatial detail to be useful for catchment-scale vegetative monitoring applications. The methods and products are reproducible, scientifically defensible and sustainable in terms of future satellite image data requirements.

This study assessed changes in land cover and land degradation which have occurred in the areas surrounding the Katse Dam from prior to construction to the present. This provides a complementary analysis to that of the field studies on vegetation which have focused on changes in floral species diversity and composition, plant cover and key plant populations or communities.

3.2 Methods

Time series Landsat 4/5 and 8 data were acquired for all years from 1991-2014 to generate annual data on seasonal vegetation cover vigour and associated degradation status. The vegetation vigour was modelled using the proven Normalised Difference Vegetation Index (NDVI) modelling approach. Data from years which had the most complete and reliable data were used, which gave a time-series from 1991-2014. Analysis of average slope of NDVI was examined to determine the average rate of change in biomass/productivity. The average rate of change in NDVI was compared between Katse Dam catchment and two nearby protected areas (Bokong and Tsehlanyane Nature Reserves) as well as among distance bands from the dam inundation area and altitude.

Landsat 4/5 and 8 imagery was used to generate land cover maps for 1993, 2005 and 2013, showing basic physiognomic/structural vegetation groups within each assessment period. Land cover was divided into eight main categories (ridgelines, sandstone paving, waterbodies, wetlands, grassland, *Chrysocoma*-dominated shrubland, *Leucosidea* communities and subsistence farming). The grassland was further divided into five categories based on quantitative NDVI data ranges indicating state of the grassland from intact (high biomass/NDVI) to highly degraded (low biomass/NDVI).

Findings for the 2013 data set were ground-truthed using data from the specialist field study on vegetation.

Changes in land cover types between the time periods (1993, 2005 and 2013) were examined at the catchment and sub-catchment level and compared to nearby protected areas. Change in land cover types within Katse Dam catchment were also examined at different distances from the dam inundation area and altitudes. Rate of change in land cover types as well as categorising broad types of land cover change (no-change, NDVI increase, NDVI decrease, to subsistence farming and other) were also analysed for different distances from the dam.

3.3 Changes in biomass/productivity (NDVI)

The time-series data revealed that the Katse Dam catchment within 10 km of the dam inundation area showed lower NDVI values and a negative trend in biomass from 1991-2014, whereas both protected areas, at least one of which (Tsehlanyane) had been established within the period of analysis showed slightly positive trends over the time period (Figure 3). Within 10 km of the dam, areas closest to the dam had the lowest NDVI values but areas further from the dam (5-7.5 km) showed the fastest rate of decline. Lower altitudes also showed the fastest negative rates of change from 1991-2014.

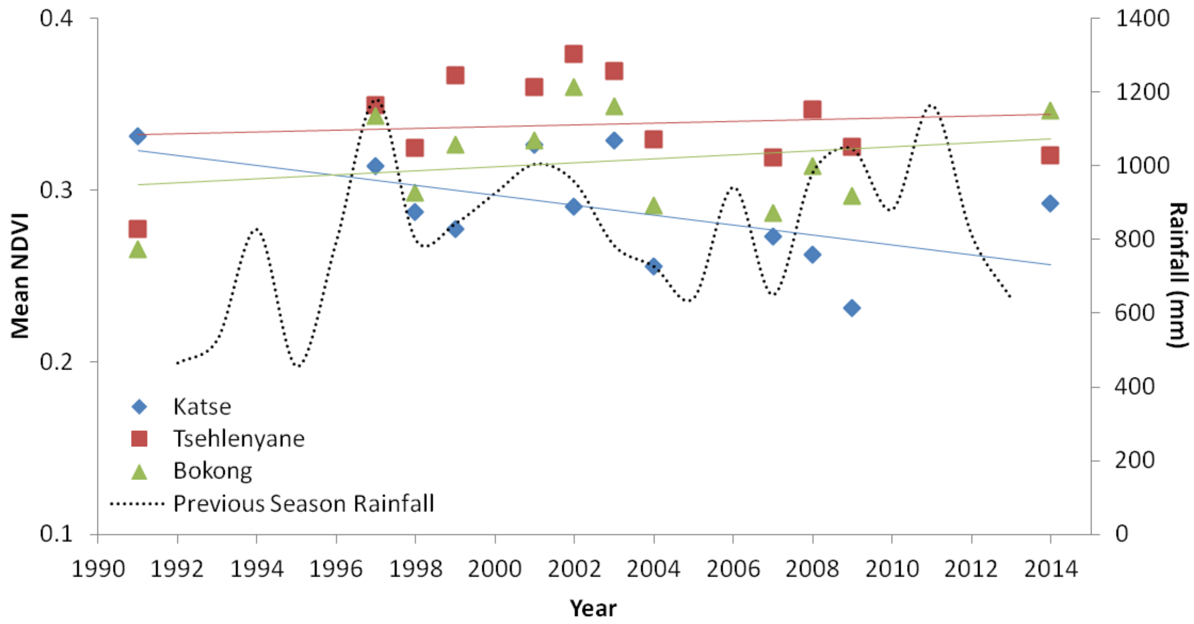

Figure 3. Mean NDVI slopes for the period 1992 to 2014 for Katse (within the 10km buffer), Tsehlanyane and Bokong nature reserves. Dotted line represents rainfall from the previous growing season.

3.4 Changes in land cover

Across the entire Katse Dam catchment, the main land cover changes seen from 1993-2013 were decreases in the most intact grassland category (Figure 4). This is in contrast to nearby protected areas which showed increases in grassland condition over the same period. Increases in *Chrysocoma*-dominated vegetation were seen in Katse Dam catchment as well as in protected areas. Increases in the percentage area under subsistence farming were also detected over the time period.

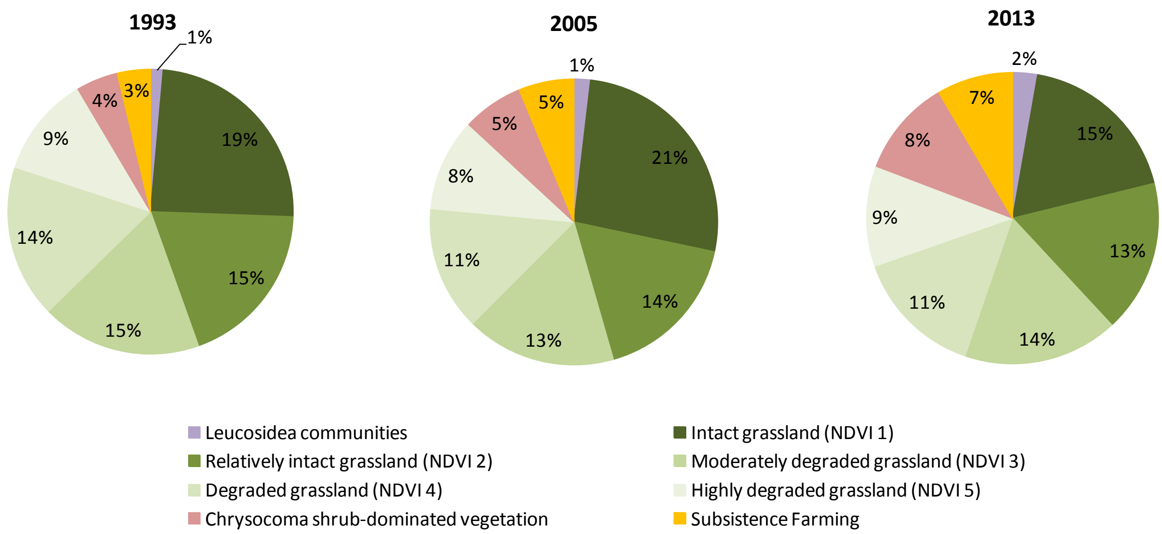

Figure 4. Change in land cover types in Katse Dam catchment 1993-2013

Patterns of land cover change were not uniform across sub-catchments, however. The Malibamatso sub-catchments (upstream and downstream) had the highest levels of transformation and grassland degradation. Pelaneng sub-catchment showed higher levels of conversion to *Chrysocoma*-dominated vegetation than the other sub-catchments.

Land cover varied with altitude. The highest altitudes (>3 000 m) were dominated by degraded grassland. While it is likely that the lower biomass in these areas are at least partly natural due to altitude and the accompanying climatic conditions. Mid altitudes (2 250-2 750 m) had the most intact grassland, but also had the highest incidences of *Chrysocoma*-dominated vegetation. Lower altitudes (<2 250 m) tended to be more impacted by increases in subsistence farming and degraded grassland, suggesting overgrazing.

Patterns were also seen with distance from the dam. While the areas beyond 10 km from the dam had changed little over time, there was a clear pattern of increasing degradation as one moves closer to the dam (Figure 5). Prior to dam construction, areas within 5 km of the planned inundation area had the highest levels of subsistence farming, but still had over 50% of the area under intact and relatively intact grassland (Figure 5). Following inundation, the condition of the remaining grassland decreased dramatically. Subsistence farming increased across all distances, but more so within 5 km of the dam. Areas further than 5 km from the dam changed less than areas closer to the dam, but experienced greater increases in *Chrysocoma*-dominated vegetation.

While both altitude and distance influenced land use patterns, and areas closer to the dam tended to be at lower altitudes, statistical analysis showed that proximity to the dam had a significant effect on land use and land cover when the effects of altitude were held constant.

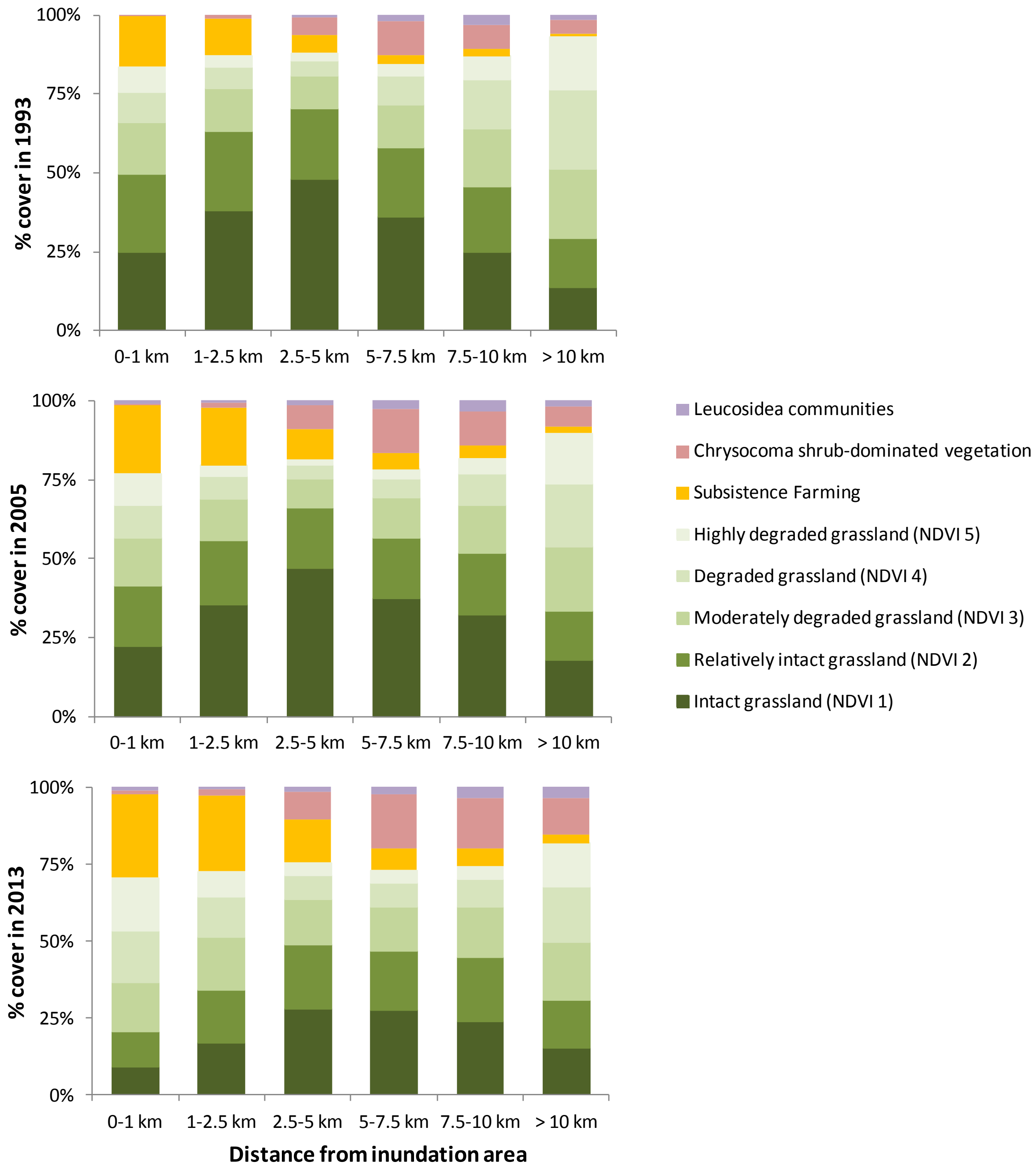

Figure 5. Percentage cover for each land cover type within each of the altitudinal bands over the time periods observed.

Changes in land cover between 1993 and 2005 were relatively small (+/- 5%) and mainly consisted of increases in subsistence farming, especially close to the dam. From 2005-2013 changes in land cover types were more extensive, the largest being decreases in intact grassland of up to 15% in the areas within 5 km of the dam.

The percentage of the area in which land cover had changed from 1993 to 2005 or from 2005 to 2013 increased with proximity to the dam (Table 2). The percentage area converted to subsistence farming and decreasing in biomass (NDVI) was greatest close to the dam. Other changes were small but included changes from intact grassland to *Chrysocoma*-dominated vegetation.

Table 2. Percentage cover of broad land cover change categories within the six distance bands of Katse Dam for periods 1993-2005 and 2005-2013.

	Percentage Area											
	0-1 km		1-2.5 km		2.5-5 km		5-7.5 km		7.5-10 km		> 10 km	
Broad land cover type	**1993-2005**	**2005-2013**	**1993-2005**	**2005-2013**	**1993-2005**	**2005-2013**	**1993-2005**	**2005-2013**	**1993-2005**	**2005-2013**	**1993-2005**	**2005-2013**
No change	46.4	54.3	53.8	51.4	59.3	54.4	60.3	60.5	56.0	59.0	60.4	70.9
NDVI decrease	22.5	30.4	16.8	31.6	14.0	29.8	13.6	22.0	13.1	20.3	12.4	10.0
NDVI increase	19.6	9.4	18.4	10.9	17.6	10.5	18.4	12.6	23.5	14.5	23.1	13.0
To subsistence farming	7.9	4.6	7.9	5.4	5.1	3.9	3.0	2.0	2.5	1.8	1.0	0.6
Other changes	3.6	1.4	3.2	0.8	4.0	1.4	4.8	2.8	4.9	4.5	3.1	5.6

3.5 Conclusions

These results present a clear indication that land cover has changed quite substantially within the Katse Dam catchment over the period 1993-2013. Most of the changes are indicative of rangeland degradation and transformation to agriculture. The relative stability of grassland condition in nearby protected areas during the same period suggested that these changes have been the result of human activities in the catchment rather than exogenous effects such as climate change. Furthermore, it appeared that human activities and their impacts were particularly concentrated around the dam. It was less clear how degradation due to *Chrysocoma* was occurring and how much is attributed to rangeland management (grazing and fire) vs. climatic changes.

4 FLORA

4.1 Introduction

The Katse Dam catchment falls within the Lesotho Highland Basalt Grassland vegetation type (Mucina & Rutherford 2006). The underlying geology of this region is basalt, and the soils derived from this lithology have a high water retention capacity. This vegetation type occurs across much of the Maloti–Drakensberg highlands into South Africa, and forms the major component of the Drakensberg Alpine Centre (DAC) of plant endemism. Yet there appears to be no comprehensive survey of the vegetation of the mountains of Lesotho. The terrain is rugged, access is difficult (though access roads have improved in Katse Dam catchment) and few botanical studies have been conducted in this region, other than the baseline and monitoring studies for LHDA. Thus this monitoring programme, which has involved comprehensive sampling over a long time period, is particularly valuable.

This study addresses the changes in flora between 1997 and 2014, some 17 years later. The initial plots were established with the intention of them being used as sites for long-term monitoring, and the sampling methodology was clearly spelled out by AfriDev (1996a). Studies such as this one, with this much data collected over a 17-year time period are rare, and the importance and scientific value of these data cannot be overestimated. This, as well as the fact that there appears to be no comprehensive survey of the vegetation of the mountains of Lesotho, makes this study (and these data) extremely valuable. As such, the interpretation of these results must be undertaken responsibly.

The aims of the flora study were:

- To describe and assess the past and present state of vegetation and species composition in the survey areas upstream of the Katse Dam, as reflected by changes in habitat quality, biomass, land cover and presence of rare/unique species and species composition;
- To assess whether there has been any change in vegetation composition between the 1995-6 survey prior to the construction of the Katse Dam and the present day, highlighting potential causes of observed changes;
- Suggest measures for mitigating the detrimental impacts of Phase 1 developments, where appropriate; and
- Identify and describe Key Indicators that can be used for future long-term monitoring, where relevant, including recommended changes to the monitoring protocol based on observed changes.

4.2 Methods

The vegetation in the Katse Dam catchment was sampled in February 2014 in a manner identical to that employed in the 1997 vegetation survey. The original plots were placed in a variety of positions so as to enable the statistical testing of the effects of altitude, aspect and distance from the Katse Dam's high water mark. Most of the same plots sampled in 1997 were located and re-sampled.

Where the original plots were not found, new plots were placed in positions as close as possible to where the original plots were thought to have been located (Figure 6).

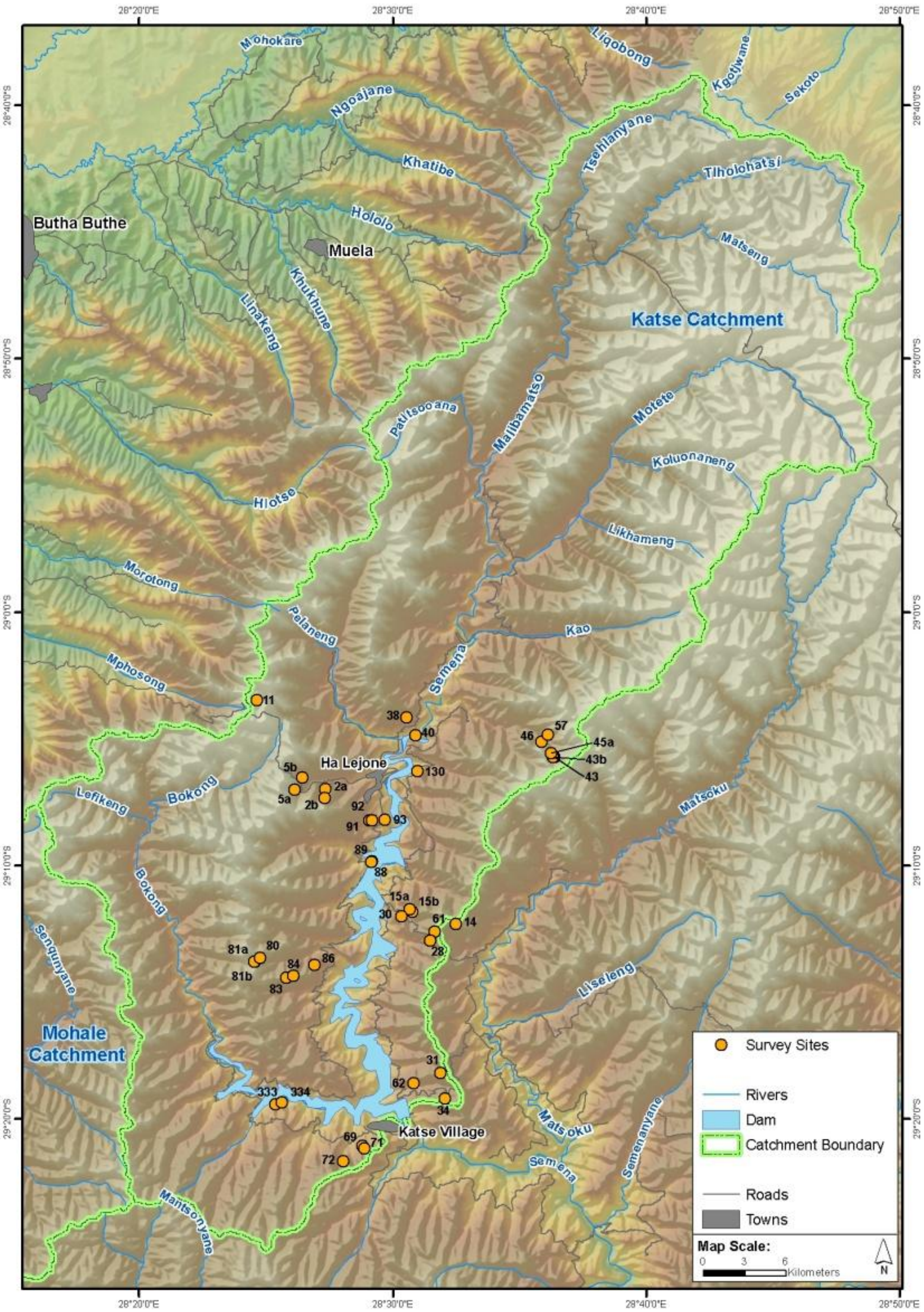

Figure 6. Map of the Katse catchment showing the plots sampled in 2014.

Each 50 m plot provided 600 data points, providing an adequate representation of the species richness in the plot, and this was assumed to reflect the plant diversity of the immediate area in which the plots were placed. Travelling on foot and horseback, a team of six botanists (three South African, three Basotho) sampled 37 of the original 40 plots during a ten-day field trip in February 2014, producing approximately 22 200 data points.

These data were analysed using modern statistical-ecological methods, and relevant and appropriate statistical tests were applied to test hypotheses about the effect of factors such as aspect, altitude, etc. so as to obtain a contemporary understanding of the vegetation of the region. The 2014 data was then compared to that obtained in 1997 to assess the amount and direction of any changes in species richness, composition, frequency of important ecological indicator groups such as shrubs, 'increaser' and 'decreaser' grasses[1], as well as invasive or weed species. In addition, an indirect assessment of bare ground was also obtained.

In comparing the 2014 data to the 1997 (baseline) data, it must be noted that the baseline data obtained for this study were not the final data used in the AfriDev 1996 report, but were the raw data. The data thus needed substantial checking and cleaning, and this process was difficult given that none of the team were involved in the 1997 expedition. A number of steps were taken to minimise possible sources of error when making comparisons between the data from the two sampling periods, and we are confident that the results presented here are a reasonable reflection of changes that have occurred.

In addition to plot sampling, efforts were made to locate previously identified key indicator species and habitats. These included the spiral aloe *Aloe polyphylla*, the ice plant *Delosperma ashtonii*, Nelson's poker *Kniphofia thodei, Rhodohypoxis* species, the mountain bamboo *Thamnocalamus tessellatus* and endangered habitats (ouhout *Leucosidea* woodland and dykes). Of the six species listed, only two are considered to be rare, and neither of these occurs in the Katse area. It is thus unclear as to why most of these species were listed, as there are no details on them in any previous report. In the absence of any locality data or information on these species from previous reports, it was hoped that populations might be found by chance.

4.3 State of vegetation 2014

The vegetation in 2014 was, at first glance, generally in a poor condition, being heavily disturbed, intensely grazed and under pressure in places from invasive species such as *Rosa rubiginosa*. There was a high density of 'rural urbanisation', particularly along the main tar road, and an overall high level of disturbance associated with the road and settlements. Exceptions to this were furthest from the dam, namely on the summit in Bokong Nature Reserve and in the Tiping area.

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[1] Increaser grasses tend to be less palatable species that increase under degradation, while decreaser grasses are more palatable species that are less abundant in overgrazed areas.

The plots were generally similar to each other, with the exception of Plot 11 in the Bokong Nature Reserve, the vegetation of which is generally in an excellent condition compared to the adjacent communal lands. An average of 40.2 species was found in each plot. As had been found by the authors of earlier reports, aspect and altitude were important factors in determining species composition as well as the abundance of shrubs and increaser grasses. Lower altitudes as well as warmer north-facing slopes had a higher percentage of shrubs (Figure 7).

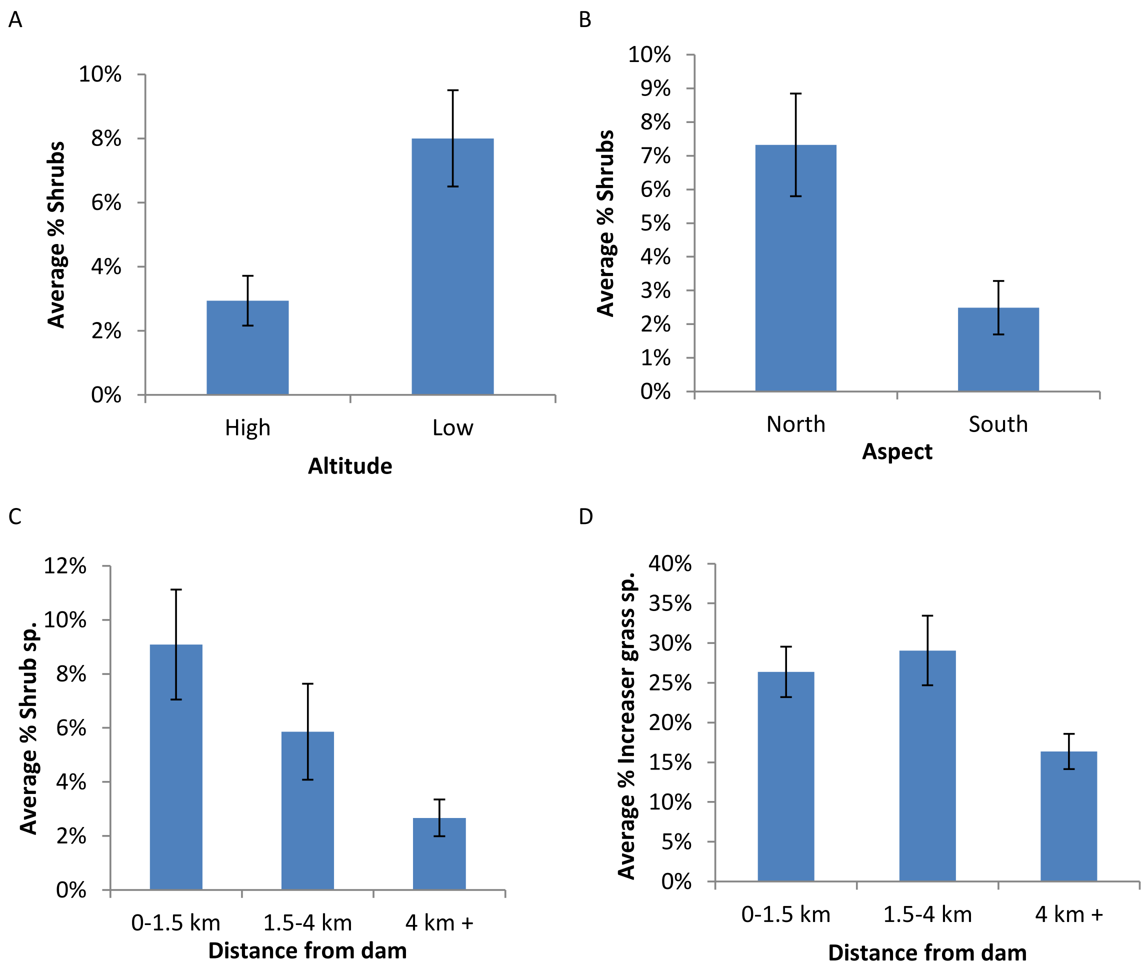

Figure 7. Significant differences in means for A) the percentage of shrubs from the two altitude categories. B) The percentage shrubs from the two different aspects. C) The percentage shrubs with distance from the dam. D) The percentage of increaser grass species with distance from the dam.

Distance from the dam was also an important factor; plots closer to the dam had a higher percentage of shrubs whereas plots furthest from the dam had a lower percentage of shrubs and unpalatable increaser grasses.

While generally not detected in the plot data, it was noted that a number of invasive species have become locally common. These present a major threat to the biodiversity of the greater Katse Dam catchment as well as to livestock carrying capacity. These include the aliens *Salix fragilis* (which now lines many stream banks, changing and displacing the indigenous riparian vegetation) and *Rosa rubiginosa*, a thorny shrub that is spreading rapidly and is already dense on some south-facing slopes. The indigenous but ecological pioneer *Artemisia afra* is also becoming common in this catchment, probably as a consequence of disturbance.

4.4 Change in vegetation since 1997

When the 1997 and 2014 data were analysed for similarity based on species composition, all plots showed differences between the sampling periods, suggesting that plots comprised a suite of species common in the long-term, as well as a suite of species that showed a short-term turn-over that may be related to factors such as fire or grazing history. The main drivers of differences between time periods were changes in the composition of grass species. These changes included a decrease in the palatable species *Themeda triandra,* increases in the unpalatable genus *Aristida*, increases in woody *Felicia* species and increases in poisonous *Senecio othonniflorus* from 1997 to 2014. These trends suggest a rangeland response to overgrazing / overstocking and possibly fire.

The relative abundance of the more palatable decreaser grasses had diminished by 4.3% (Figure 8) and the less palatable increaser grasses had also decreased by 2.4%. However, the frequency of shrubby species had remained relatively stable within the plots.

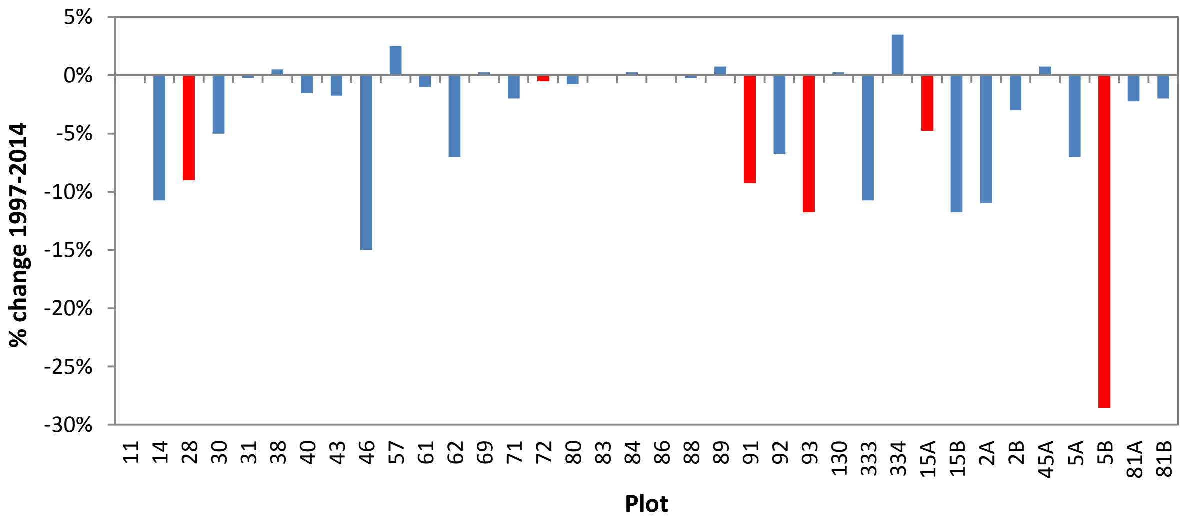

Figure 8. Percentage change in frequency (out of 400 data points per plot) of Decreaser grasses between the 1997 and 2014 sampling periods. Bars in red indicate plots placed in new sites in 2014, but close to the original 1997 sites.

There was a 32% increase in the amount of bare ground between the sampling periods, as assessed by the distances measured from a vertical pointer to the base of the nearest species (Figure 9). This implied that plant density had been reduced, probably as a consequence of inappropriate land use practises (overgrazing in particular, and the associated trampling).

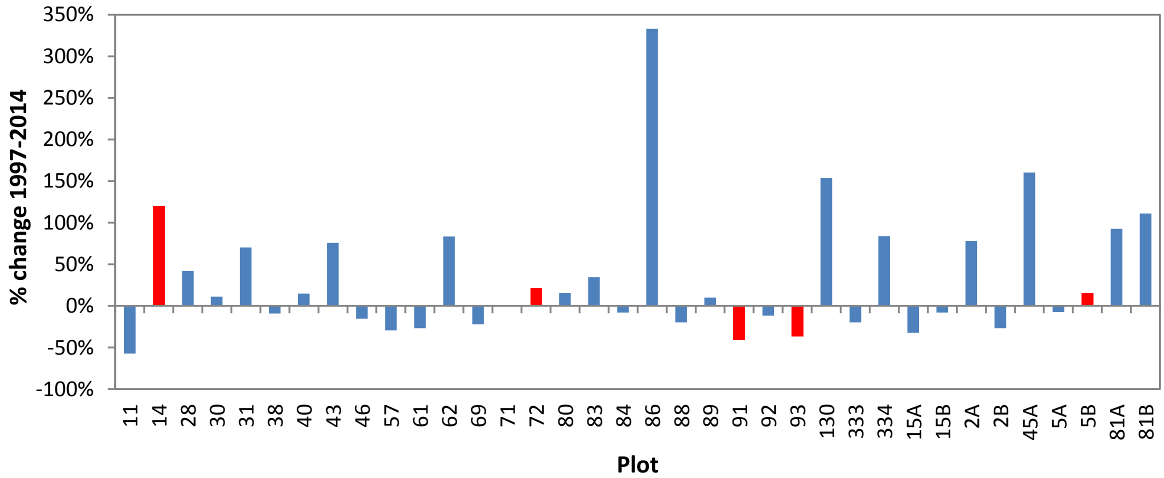

Figure 9. Percentage change in point to nearest species distances for each plot between 1997 and 2014 sampling periods. A positive value indicates an increase in distance, and hence bare ground. Bars in blue indicate plots placed in new sites in 2014, but close to the original 1997 sites.

4.5 Key indicators

With the exception for *Kniphofia thodei*, none of the key species or habitats specified by LHDA were found in the Katse Dam catchment. It is possible that they might exist within the catchment, however without any information on their previous location, the chance of encountering them was low. However, the discovery of two populations of another very rare species, *Euryops inops*, was significant. Similarly, a population of *K. northiae* was found, and this species, too, could be added to the list of species to monitor, as it is infrequent.

4.6 Conclusions

Most of the results indicated the degradation of vegetation in the study area. These changes were reflected in the change in relative abundance of increaser (~unpalatable) vs. decreaser (~palatable) grass species, with a general reduction in the abundance in palatable grass species. This suggests that grazing practises are affecting the rangelands, and that overgrazing, and possibly overstocking, is occurring. Somewhat surprisingly, there has not been an increase in the proportion of shrubs, but this might be as a consequence of the harvesting of species such as *Chrysocoma* for fuel.

A further indication of ecosystem decline was the increase in bare ground as expressed by distances between plants. Excess grazing pressure, trampling by livestock, and perhaps fire regimes, may have prevented plants from germinating, growing and filling the spaces between other plants. This bare ground is of concern, as it will expose bare soil to erosive processes, leading to siltation problems in the rivers and dam.

In addition, the introduction and spread of alien invasive species has become a major concern in the study area.

5 WETLANDS

5.1 Introduction

The wetlands in the Lesotho highlands can largely be found in the headwaters of the Senqu River (Orange River in SA), which is an international watercourse (Olaleye *et al*. 2012). In general mountain systems and the ecosystems and habitats occurring in mountainous areas should be considered amongst the world's most important conservation areas as they are often watercourses and hold important biological diversity (Messerli & Ives 1997). Lesotho's wetlands are a critical grazing resource for local herdsmen's livestock (Olaleye *et al*. 2012). These wetland systems support over 300 000 households in Lesotho through agricultural practices and other activities such as fishing (Olaleye *et al*. 2012). Concern around accelerated soil erosion due to overgrazing and subsequent degradation of the soils is growing. Essentially the continued degradation of wetland systems not only threatens the livelihoods of those directly dependent upon them, but also the flow regimes of the rivers and other dependent ecosystems and users of the water downstream. The integrity of the wetlands in the upper catchment areas is vital as they support perennial runoff with low sediment loads (Nüsser & Grab 2002), an aspect particularly beneficial for downstream dams such as Katse.

5.2 Methods

The objective of the Katse wetland monitoring survey in 2014 was to visit 28 wetlands that had formed the basis of the 1999-2000 reports by Marneweck & Grundling (1999 & 2000). Each wetland was assessed using a modified rapid assessment method suitable to the specific systems that the wetland team was to visit and taking into consideration realistic available field time per wetland. Peat cores were also described where appropriate with the aim to again try and find the deepest peat areas and investigate signs of oxidation and decomposition of the peat profile to assess change over the past 14 to 15 years. Noticeable changes to the wetlands and current impacts were also points of focus for this survey. 27 of the 28 wetlands were visited during this trip (Figure 10). Only one wetland was excluded, being the degraded fen in the Khubelu catchment (Wetland Ka 19). This wetland was not thoroughly sampling compared during the 2000 survey and was visited at the time predominantly to provide an example of a degraded system.

5.3 Results

The 27 wetlands that were surveyed during March of 2014 all exhibited some form of disturbance and/or negative impact (Table 3). Similar to many of the systems surveyed in the Mohale Dam catchment area there were a number of systems so dry that it was not possible to get the peat auger into the substrate to sample and describe the peat profile for that particular system e.g. Ka 18 and parts of Ka 08. The surveyed wetlands included systems located at different topographical levels and at different altitudes with a varying aspect. From the field work done it could be concluded that all systems regardless of altitude, aspect or type had been affected in a negative way by changes that had taken place in the landscape since the 1999- 2000 surveys.

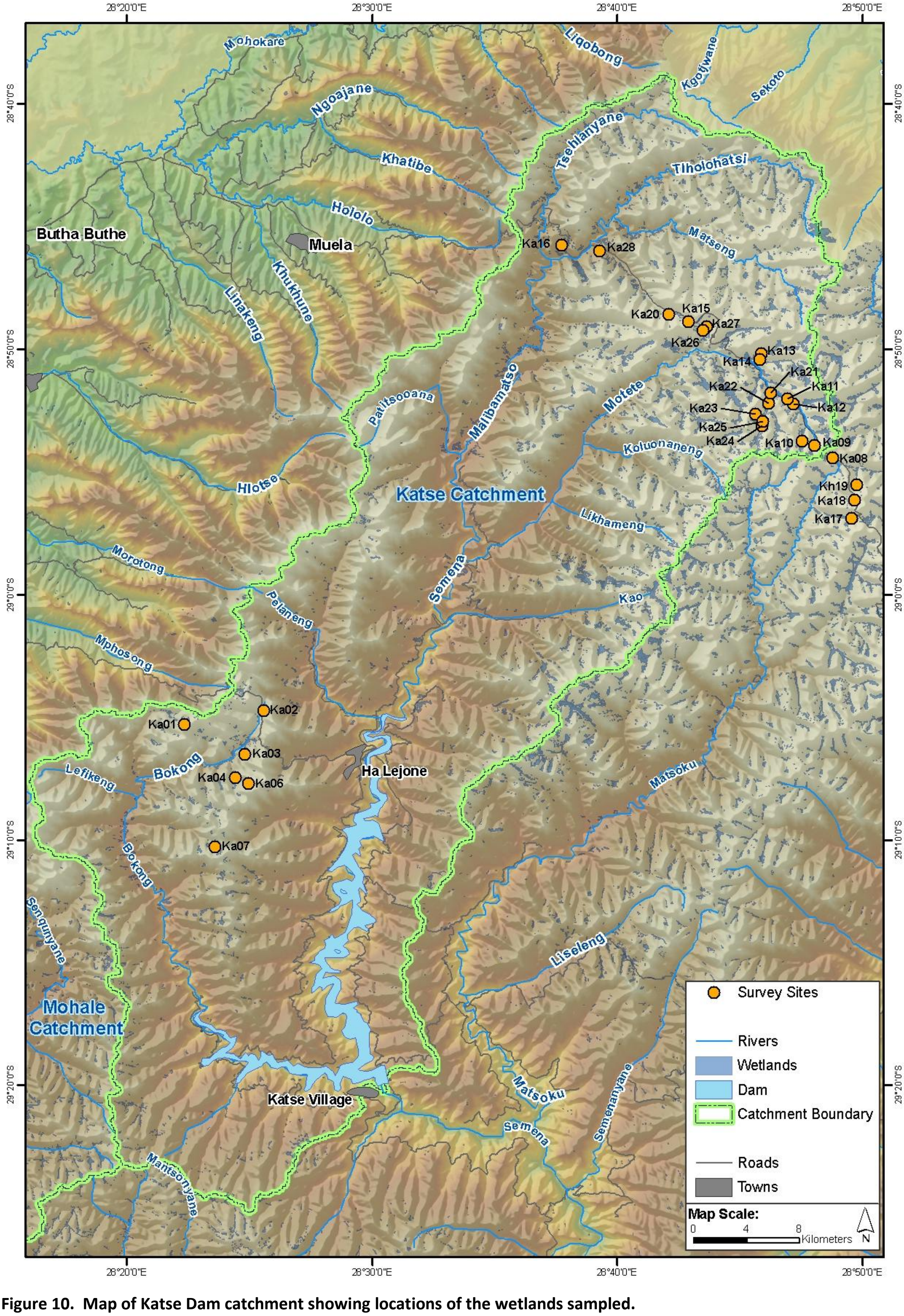

Figure 10. Map of Katse Dam catchment showing locations of the wetlands sampled.

Table 3. Likely trajectory of Katse wetlands. * indicates wetlands that have undergone some form of rehabilitation.

Wetland	Alternative name	Wetland Type	Trajectory of the Wetland
Wetland 1	KA 01	Hillslope seepage wetland – fen	**Negative**
Wetland 2	KA 02	Valleyhead seepage wetland – fen	Stable if lateral cutting addressed
Wetland 3	KA 03	Crest wetland – fen	**Negative**
Wetland 4	KA 04	Footslope seepage wetland	Mainly **lost**
Wetland 5	KA 05	Midslope seepage wetland	Either **lost** or incorrect GPS
Wetland 6	KA 06	Valleyhead seepage wetlands – fen	**Negative**
Wetland 7	KA 07	Valleyhead fen	**Negative**
Wetland 8	KA 08	Valleyhead fen	**Negative**
Wetland 9	KA 09	Valleyhead seepage wetland - fen	**Negative** but slowed*
Wetland 10	KA 10	Valleyhead fen	**Negative** but slowed*
Wetland 11	KA 11	Valleyhead seepage wetland - fen	Stable but will deteriorate
Wetland 12	KA 12	Valleyhead seepage wetland - fen	Mainly **lost**
Wetland 13	KA 13	Valleyhead seepage wetland - fen	**Negative**
Wetland 14	KA 14	Valleyhead seepage wetland - fen	**Negative**
Wetland 15	KA 15	Valleyhead seepage wetland - fen	**Negative**
Wetland 16	KA 16	Floodplain – paleo-oxbow	Stable but will deteriorate
Wetland 17	KA 17	Valleyhead fen	**Negative**
Wetland 18	KA 18	Valleyhead seepage wetland - fen	Mainly **lost**
Wetland 19	KA 19	Valleyhead seepage	**Lost**
Wetland 20	KA 20	Footslope seepage wetland - fen	**Negative**
Wetland 21	KA 21	Footslope fen	**Negative**
Wetland 22	KA 22	Midslope fen	**Negative**
Wetland 23	KA 23	Midslope fen/seepage	**Negative**
Wetland 24	KA 24	Valleyhead fen	**Negative**
Wetland 25	KA 25	Footslope seepage	Mainly **lost**
Wetland 26	KA 26	Valleyhead fen	Stable due to bedrock keypoint
Wetland 27	KA 27	Midslope fen	**Negative** but stable in places
Wetland 28	KA 28	Crest seepage wetland – remnant fen	**Lost**

Drying out of the fens is a cause for concern. By becoming drier these wetlands are slowly providing favourable conditions for terrestrial plants such as *Chrysocoma* and animal species such as ice rats to successfully colonise areas within the wetland boundaries. These areas would previously have been permanently saturated. The drying out and oxidizing of the peat also makes these systems more susceptible to erosion. Evidence on site suggests that changes in hydrology from mostly subsurface seepage to surface runoff was observed at many sites (Ka 01, Ka 07, Ka 15, Ka 17 for example) and the rate of erosion is accelerating. Only systems with bedrock keypoints or some other stabilising factor such as exposed rock talus that prevents eroding out of the system over time appear to be relatively stable from an erosion perspective (e.g. Ka 26). This would suggest that as with the systems in the Mohale catchment, the overall trend for the wetlands in the Katse Dam catchment is that of a negative trajectory i.e. there has been continued deterioration in most of the systems since 1999-2000 and this is only expected to continue going forward.

At a number of sites it appeared that peat had been lost. Sites such as Ka 28 no longer contain any peat. Other sites such as Ka 08 were too dry to determine beyond a depth of 1.9 m whether or not peat still occurred to a depth of 4.3 m as recorded during the 1999 survey. Accurate conclusions with regards to peat loss and the subsequent water storage capacity loss of these peatlands can only be made by doing intensive peat sample transects at these sites. It is suggested that more detailed peat sampling of selected sites form part of the monitoring programme going forward. Based on observations in the field it is obvious that most sites have become considerably drier than was the case in 1999-2000 as shown by the dryness of peat samples and evidenced in the oxidation and decomposition recorded in the profiles. This supports the anecdotal and other evidence at the sites which suggest there has been, and continues to be, a general change in hydrology in the catchments as subsurface flow reduces and surface runoff increases. This only serves to accelerate the loss of peat from, and further erosion of, these systems.

Figure 11. Examples of erosion features and drying of wetlands in the Katse Dam catchment.

5.4 Conclusions

The overall trend of the systems visited was that of a negative trajectory i.e. the changes taking place or that had taken place were causing continued deterioration of the systems. Without intervention, a number of systems will be lost in the medium to long term. It is plausible that in as little as 20 years there may be no more extensive peatlands remaining in the Highlands of Lesotho if the current rate of degradation continues unabated. Some wetlands surveyed in 1999-2000 and now revisited have already been lost over this period. In wetland Ka 28 for example, the fen habitat has been lost with only remnant areas of wetness remaining. This appears predominantly due to changes in hydrology of the surrounding catchment. The biggest concern and immediate threat to the remaining systems was that of overgrazing and trampling by livestock and the resulting drying out and loss of peat. The indirect result of the drying out of the systems is the loss of the vital water storage function of these systems. Peatlands are vital in slowly releasing water to the surrounding landscape over an extended period of time. This function may already be largely lost in the catchments as shown by the apparent change in hydrology to surface flow dominated. This is an issue that was raised in the 1999-2000 reports as a cause for concern. The results of the 2014 field survey would suggest that the changes in the systems are due in most part to the intense and continuous grazing pressure that these wetlands are exposed to combined with hydrological changes emanating from the surrounding catchments. Any recommendations for rehabilitation or restoration of these systems will therefore have to include addressing the issue of rangeland management in general, and not just in regard to the utilisation of the wetlands.

6 RIVERS

6.1 Introduction

The study area is at high altitude and is characterised by steep slopes and gradients, shallow soils and extreme and variable climate with rapid changes in water levels after rainfall events. The drainage density of the Katse catchments has not been determined, but due to the mountainous terrain is expected to be relatively high. Drainage density is one of the main factors controlling the speed of run-off after precipitation, with high drainage densities associated with more rapid run-off (Smith & Stopp 1979). The dominance of bedrock sheets as stream substrate in many of the rivers and streams in the Katse catchment is testament to the flow volumes experienced over eons.

Three river systems feed the Katse Dam. The largest of these is the Malibamatso River and its several tributaries which drain the northern half of the catchment, including the highest areas. The Motete and Kao are the two major tributaries of the Malibamatso. In the middle of the catchment, the Pelaneng flows from the west to join the Malibamatso at the northern point of the dam. The Bokong River rises near the Pelaneng, but flows south to enter the Katse Dam in the south.

The construction of the Katse dam at what was once the confluence of the Malibamatso and Bokong Rivers, has led to the loss of large stretches of rivers, and their replacement with a lotic environment in the form of a large, deep reservoir. Aside from these direct changes, there were concerns that the increased activities in the catchment area resulting directly or indirectly from the construction of the dam could further impact on the remaining river habitats, including their water quality.

The aims of this study were:

- to determine the physico-chemical characteristics of the rivers upstream of the Katse Dam;
- to assess the status of rivers and streams, based on instream habitats and aquatic macro-invertebrates;
- to describe and quantify observed changes relative to the baseline conditions; and
- to recommend possible ameliorative measures for any perceived negative changes or trends.

6.2 Methods

Field surveys were carried out at 22 sites within the Katse Dam catchment during in October 2013 (Figure 12). These were located on the three main rivers entering the dam plus the Motete tributary. Sites selected were based on previous baseline surveys, combining monitoring sites for both fish and aquatic invertebrates.

At each site, dissolved oxygen, pH and water temperature were measured *in situ*, and water samples for determination of nutrient concentrations (inorganic nitrogen and inorganic phosphorus) were collected and refrigerated for analysis at a laboratory.

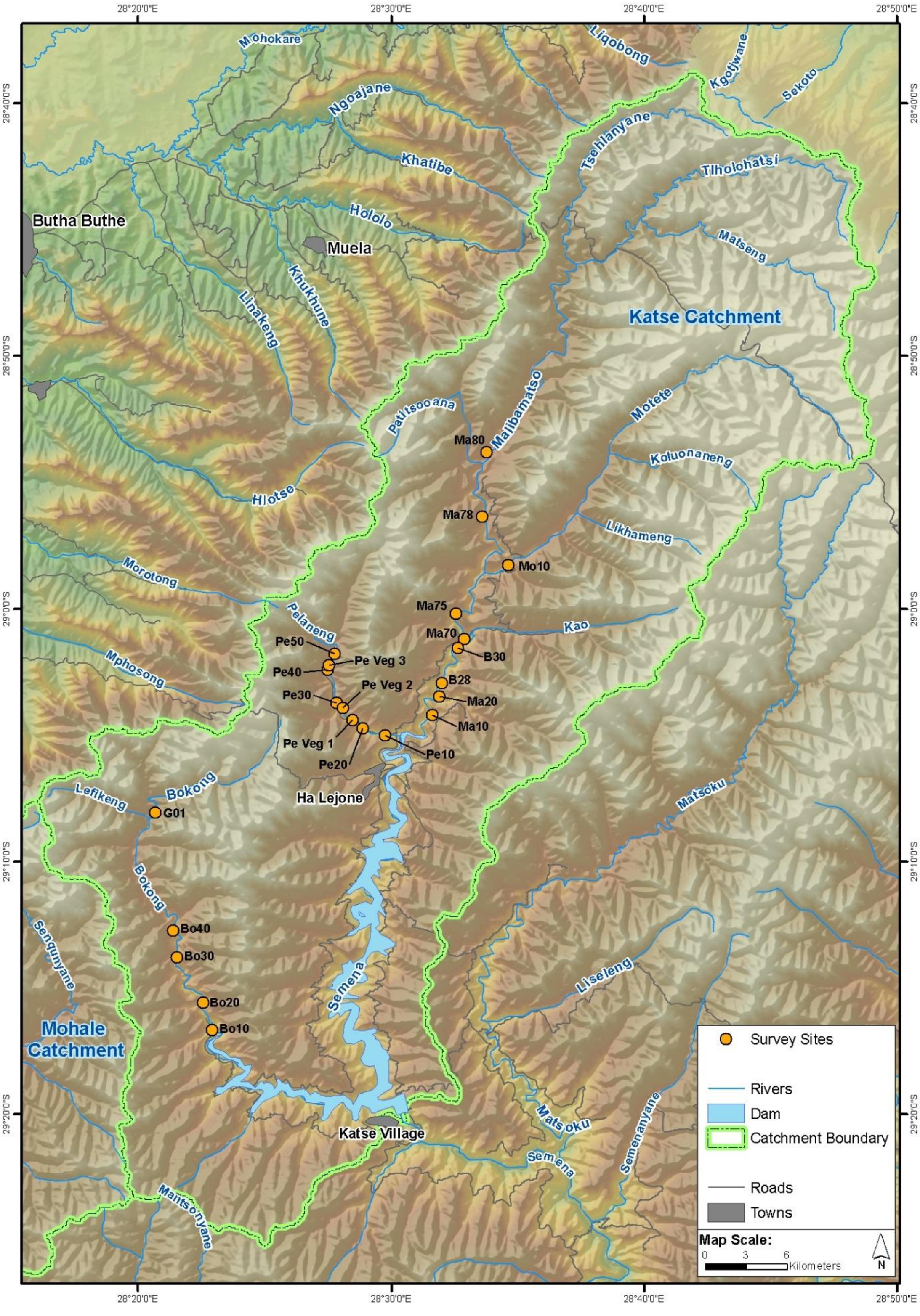

Figure 12. Map showing the location of river monitoring sites.

Instream habitats were described in terms of the relative abundance of five hydraulic biotopes (cobbles, boulders, bedrock, gravel, silt and sand). Habitat condition was then described and assessed using two scoring systems: the Integrated Habitat Assessment System (IHAS, *sensu* McMillan 1998) previously also used by NUL (2003) in their monitoring study of Mohale catchment, and the Habitat Assessment Method For High Gradient Streams using scores as prescribed by Barbour *et al.* (1999).

Overall river condition was assessed using the South African Scoring System, Version 5 (SASS5) methodology (Dickens & Graham 2002). This is a family based index, where common macro-invertebrate families have been allocated sensitivity ratings, mainly based on expert knowledge of responses to flow and water quality.

All three of these assessment methods rate the condition of rivers on a scale of A (90-100% of natural) to F (representing a critically modified condition with less than 20% resemblance to the natural state). In South Africa, the National Water Policy states that no river should be allowed to fall below a D-category (40-60% resemblance to natural condition).

No habitat assessment or SASS sampling tools were available at the time of the baseline study. Later on the NUL used the IHAS system in the Mohale catchment, but this is not as widely accepted as the Habitat Assessment Method For High Gradient Streams. Thus while the habtiat assessments carried out during this study could describe the current status of systems there was no basis for comparison. The baseline study did, however, describe the macro-invertrate fauna, and this could be used to generate the SASS5 scores applicable to the baseline condition.

6.3 Physico-chemical characteristics (water quality)

All water quality parameters measured and analysed were within acceptable ranges, with daily fluctuations in water temperature and dissolved oxygen. Electrical conductance increased down the rivers towards the dam. Nitrate levels were highest in the Malibamatso River. Based on nutrients measured, the trophic status of the Katse Rivers during the October 2013 survey ranged between oligo- and mesotrophic, with oligotrophic conditions dominant, which is expected for rivers at this elevation.

All of the sites were situated within the grassland vegetation type, and several of them had some degree of woody riparian vegetation present. Levels of disturbance tended to increase downstream, with the uppermost sites being in near-pristine condition, and the lowermost sites being the most degraded.

The average water temperature tended to increase moving downstream in all three rivers. On average, dissolved oxygen in the Bokong River was somewhat lower than that in the Malibamatso and Pelaneng Rivers, and there were no discernible downstream trends in dissolved oxygen for any river. Conductivity in the Pelaneng River was lower than that in the other two rivers. Conductivity increased steadily moving downstream in all three rivers. The average pH in the Malibamatso was somewhat higher than that in the other two streams. Water pH tended to decrease moving downstream in the Pelaneng and Malibamatso Rivers.

Average nutrient concentrations in the three streams were similar, except for nitrate levels which were approximately three times greater in the Malibamatso River than in the other rivers. In general, nutrient levels appeared to increase slightly from the headwater sites to the lower sites in all rivers. The mean particle size of fine sediments was greatest in the Bokong River, lowest in the Pelaneng River and intermediate in the Malibamatso River. Mean particle size among sites within rivers was highly variable, and there were no obvious downstream trends except for a steady increase in mean particle size moving downstream in the Bokong River.

6.4 Habitat Assessment

Pools were the dominant hydraulic biotope in the Katse Dam catchment followed by runs, glides and riffles. The substrates were dominated by cobbles, boulders, bedrock, gravel, silt and sand, in that order. Sites closest to the dam were characterised mainly by pools and glides with high proportions of silt. Marginal vegetation was mostly absent, with bank scouring dominant throughout the catchment.

The instream habitat was rated as marginal to moderate using IHAS. The IHAS scores in the Katse Dam catchment ranged from 53% to 72%, averaging 59%.

Habitat quality was mostly categorised as moderate and habitat integrity as moderately modified. Habitat integrity scores ranged between 61-76% for the Pelaneng, 62-76% for the Malibamatso, and 75-88% for the Bokong-Malibamatso. The worst habitat integrity of 57% was recorded at the Motetse site (Mo10). Sites closest to the dam had some of the worst ratings for both habitat quality and habitat integrity.

6.5 River integrity (SASS5)

The Katse rivers SASS5 scores ranged between B - marginally impaired and E - seriously impaired. The best conditions were recorded in the Pelaneng River and the worst in the Malibamatso River (Figure 13). The general trend was for best conditions at headwaters and worse conditions close to the dam. Notably the sites which did not fit this trend were the sites below the diamond mining and sites close to villages where people wash their clothes.

Comparisons were made between the baseline and the 2013 data collected, as well as the differences in taxa recorded per ecoregion, season, elevation and differences taxa represented in the two catchments. Seasonal differences and elevation ranges highlighted trends with certain taxa, with some families present and abundant at high elevations during high flow, but absent during low flow and visa versa. The data also suggest that SASS taxon diversity and the number of sensitive taxa have increased since the dam was constructed. This is not necessarily the case. Baseline monitoring did not take into account the sampling of marginal vegetation, stones-out-of-current and sand/mud/silt biotopes, all of which support distinct taxa. Differences between the average SASS scores for the 2013 spring results highlight differences in the aquatic invertebrate communities between the Katse and Mohale catchments.

The rivers in the Katse and Mohale catchments are located within the same aquatic ecoregions, and are therefore expected to be similar in terms of aquatic macro-invertebrate communities associated with them. Taxa associated with the marginal vegetation biotopes were absent from rivers in the Katse Dam catchment, but present in the Mohale. Chlorolestes, an epibenthic species was present in the rivers of the Mohale (where no exotic trout were recorded) but absent from the rivers in the Katse. Changes in community composition can be attributed to several causes, both natural and anthropogenic, and more detailed studies are required to distinguish between specific causes.

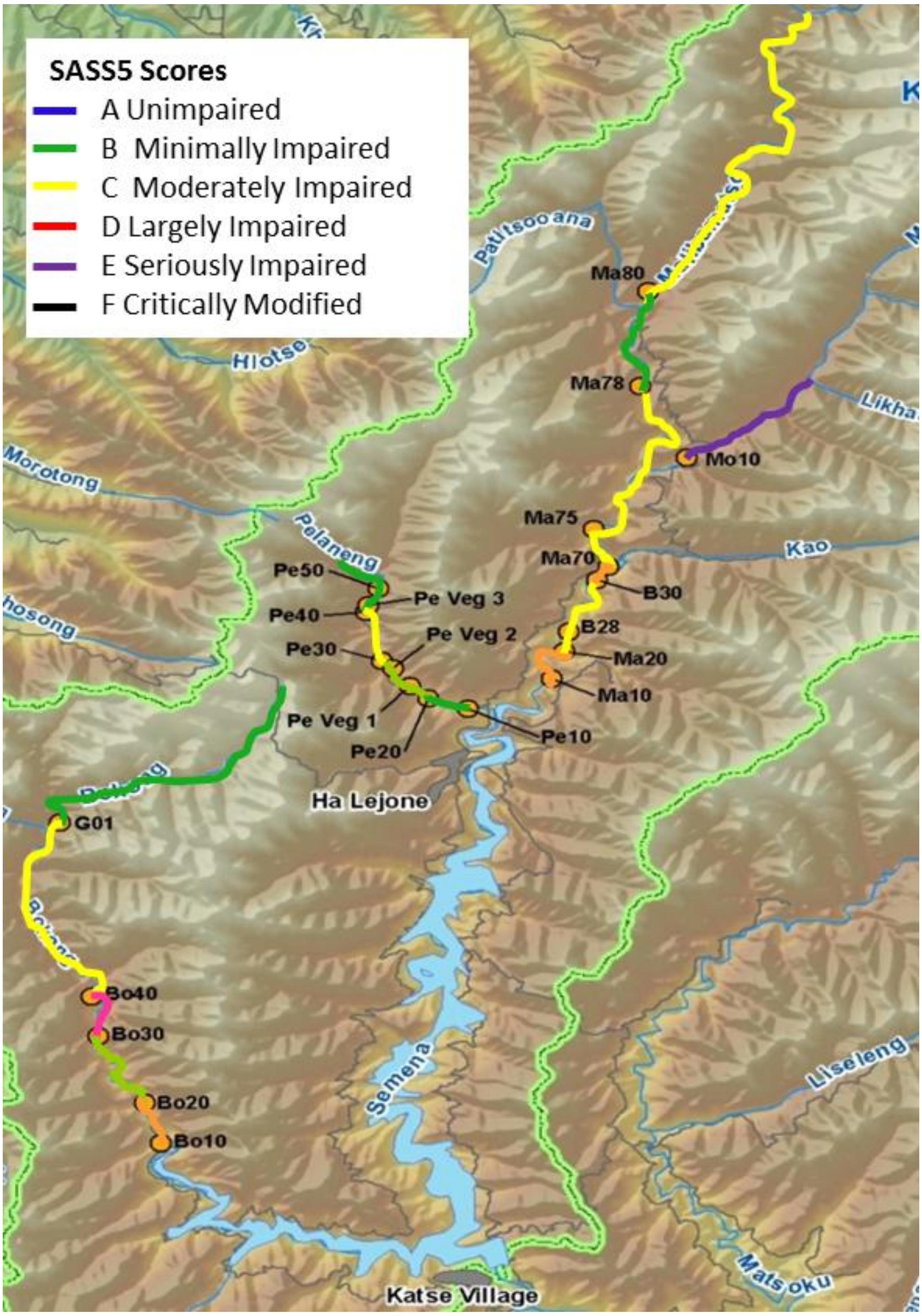

Figure 13. SASS5 biomonitoring results for sites sampled in the Katse Dam catchment during October 2013.

6.6 Conclusions

Unfortunately lack of comparable baseline data makes it hard to determine changes in river habitats since the building of the dam. However, given widely applicable stream health assessment tools, it was possible to determine the current state of streams in the Katse Dam catchment. Katse streams do show signs of degradation, especially those closer to the dam as well as close to human settlements and the diamond mining area. These similar results were reflected in water quality, habitat condition and aquatic macro-invertebrates.

In the rivers and streams upstream from the dams, the main concerns are overgrazing, associated with increased peak flows, stream bank and bed scouring, increased nutrient inputs due to an increased in the number of people and livestock coupled with reduced filtering capacity of the natural vegetation. Other concerns include the increased growth of exotic woody species in the riparian zones, which suppresses and replaces indigenous vegetation and potentially affects stream bank stability and food inputs.

In the Katse system, other concerns include the increased pressure from exotic predatory fish (*O. mykiss* & *S. trutta*) which benefit from the lotic environment created by the dam. Their presence and density potentially alter trophic levels in the rivers feeding the dam, to the detriment of indigenous aquatic species and the ecosystem as a whole.

7 FISH

7.1 Introduction

The construction of the Katse Dam will have led to the replacement of inundated river habitats with a large deep reservoir, having a direct impact on fish populations in this area. Upstream of this, impacts on the fish fauna may have occurred as a result of changes in riparian habitat quality due to increased pressures in the catchment, as well as due to introductions from the Dam. In addition, transfer tunnels between dams could potentially allow aquatic species into catchment areas from which they were previously absent – a reshuffling of aquatic species among historically isolated river catchments. The aim of this study was to determine whether and how the fish community structure has changed since the construction of the Katse Dam, to assess the probable reasons for the changes observed, and to make recommendations for future management.

7.2 Fish species of the Katse Dam catchment area

Five species of fish are known to occur in the Katse Dam catchment area. Three of these are indigenous species: the smallmouth yellowfish *Labeobarbus aeneus*, Orange River mudfish *Labeo capensis* and the rock catfish *Austroglanis sclateri* (Figure 14). The other two species are non-indigenous species that were introduced well before the construction of the dam: rainbow trout *Oncorhynchus mykiss* and brown trout *Salmo trutta.* There are also anecdotal reports that the Maloti minnow *Pseudobarbus quathlambae* historically occurred in the Katse Dam catchment area, but none have been observed during previous baseline and monitoring studies (Loxton, Venn & Associates 1993b, Davies 1997, Rall & Rall 1998-2001, Rall 1999). The five species are briefly described as follows:

Smallmouth yellowfish are large (up to 500 mm) cyprinid fish endemic to the Orange-Vaal River system. They prefer large, clear-flowing river habitats, but also survive in dams. They migrate upriver to spawn on gravel river beds. They feed on algae, detritus, fish, crabs, amphibians and invertebrates.

Orange River mudfish is a large (up to 500 mm) cyprinid fish endemic to the Orange-Vaal River system, where it prefers large rivers with good flow, but also does well in large dams. They aggregate at the base of rapids to spawn in summer. They feed on algae and aquatic invertebrates on the stream bed.

Rock catfish is a relatively small (<300 mm) riverine catfish endemic to the Orange-Vaal River system. They live amongst rocky substrates in flowing water. They feed on benthic invertebrates from stone surfaces although larger individuals may also consume fish. They are sensitive to sedimentation and water abstraction.

Rainbow trout were introduced to the study area in 1957 and have established self-sustaining populations. They prefer the cooler (<20˚C) swift-flowing streams. They breed on gravel beds in mountain streams during summer high flows. They are opportunistic predators that consume invertebrates, crabs, amphibians and fish.

Brown trout are listed among the World's 100 Worst Alien Invasive Species (Lowe *et al*. 2000). They were introduced to Lesotho in the early 1900s, but have only established self-sustaining populations in a limited number of rivers (Skelton & Rall 2001). Like rainbow trout, they breed on gravel beds in mountain streams during summer high flows. They are more aggressive predators than rainbow trout, consuming a diet largely of large prey items like fish, amphibians and crabs.

The indigenous species were probably once widespread in all major tributaries in the study area, but appear to have disappeared, or been reduced to very low numbers, at most sites as a consequence of habitat degradation and interactions with non-native predatory trout (Davies 1997, Rall & Rall 1998-2001). The lack of historical data on native fish populations prior to the introduction of trout makes it difficult to quantify the extent of trout impacts in the Katse Dam catchment area (Loxton, Venn & Associates 1993).

Figure 14. Freshwater fish species that are native to the Katse Dam catchment area: the Vaal-Orange River smallmouth yellowfish *Labeobarbus aeneus* (top left), the Orange River mudfish *Labeo capensis* (top right), and c = the rock catfish *Austroglanis sclateri* (bottom).

7.3 Methods

Fish populations were surveyed at 18 sites on the main influent rivers (Pelaneng, Bokong, Malibamatso and Motete catchments), and at two sites in the dam itself, all of which had been sampled during previous surveys. Fish populations at each site were surveyed using a combination of complementary sampling gears including a range of gill and fyke nets, an electrofisher, hand nets, light fishing tackle and bank-side observations over the period 1-12 October 2013. Assessments of environmental conditions including site descriptions, channel morphometry, biotype and substrate composition, fine sediment composition and water quality were made at each sampling site. The fish sampling was conducted together with the river sampling, at the same sites. Results from the fish surveys are summarised here while the reader is referred to Chapter 6 for a summary on environmental conditions in the rivers.

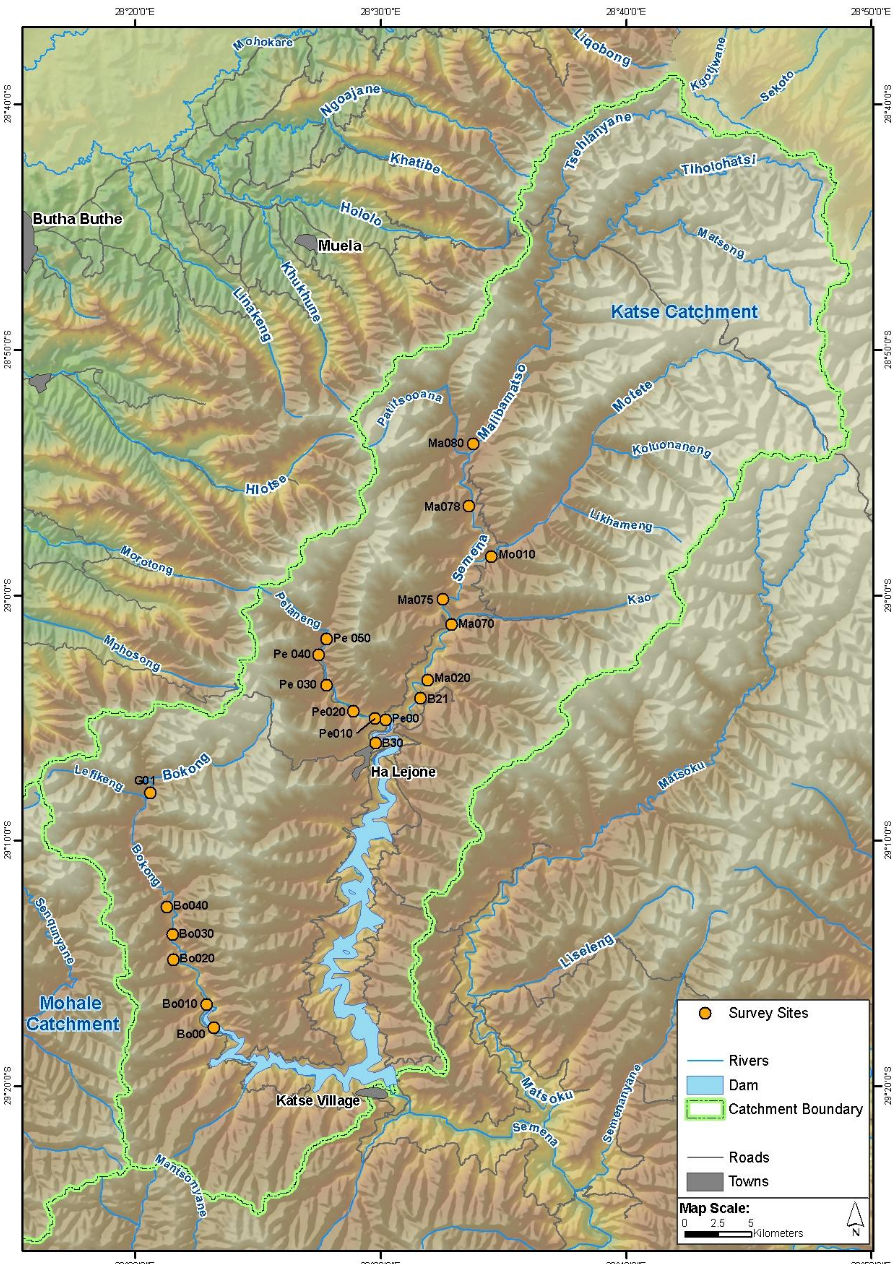

Figure 15. Sites in the Katse Dam catchment sampled in this study.

7.4 Results

Non-native rainbow trout were present in all major tributaries and formed the dominant component of the fish assemblage at the majority of the river sites sampled (Figure 16). Non-native brown trout were present in the Bokong River. The large size of some of the individuals (>400 mm) in both the river and the dam (near the Bokong inlet) raises concern about potential impacts on remaining native fish populations in the catchment. The native fish species, including the Vaal-Orange River smallmouth yellowfish, the Orange River mudfish and the rock catfish, were absent from the majority of the river sites sampled, and where they did occur, their abundance was relatively low.

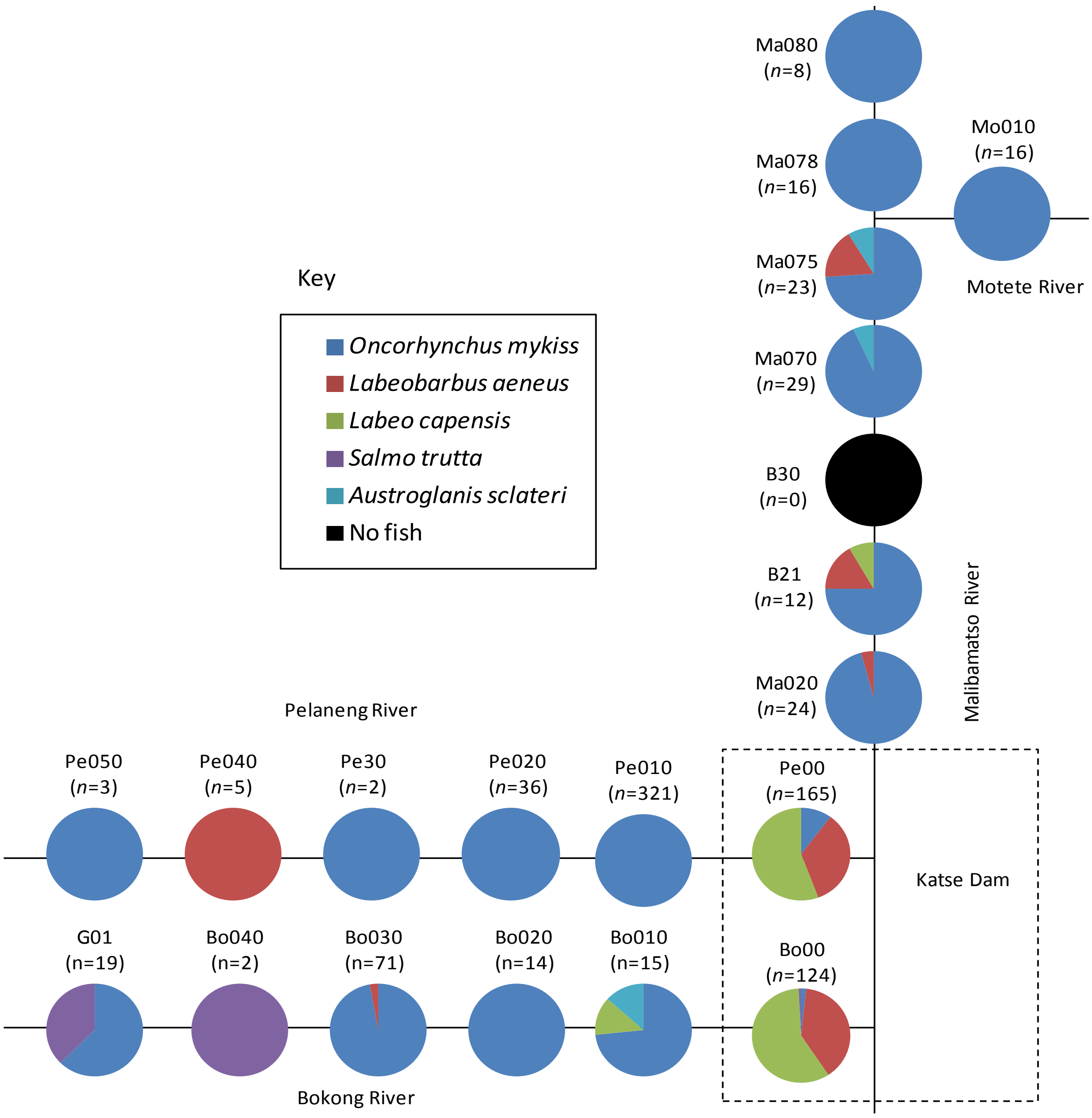

Figure 16. Schematic diagram showing fish assemblage composition at each sampling sites. Assemblage composition is based on the total number of fish collected using all sampling methods . All major tributaries are shown, as well as the location of the dam (dashed line). The total number of fish captured at each site using all sampling methods is shown in parentheses.

The fish assemblage in Katse Dam was dominated by native yellowfish and mudfish. Rainbow trout was present in the dam, but at relatively low abundance. The Katse Dam, like the lower river sites, appears to function as a refuge for the native cyprinids (yellowfish and mudfish) from predation by rainbow trout.

The 2013 survey also provided the first record of yellowfish in the Pelaneng River, and mudfish in the Bokong River. It is difficult, however, to say whether the records of these species in the present survey are the result of recent colonisations from the populations in Katse Dam, or simply an artefact of variations in sampling effort among surveys. Fish distributions in the influent rivers appear to have remained largely relatively stable in the Katse Dam catchment area over the past two decades (Figure 17). There was some evidence to suggest, however, that non-native trout numbers had increased in recent years, particularly in the Malibamatso River

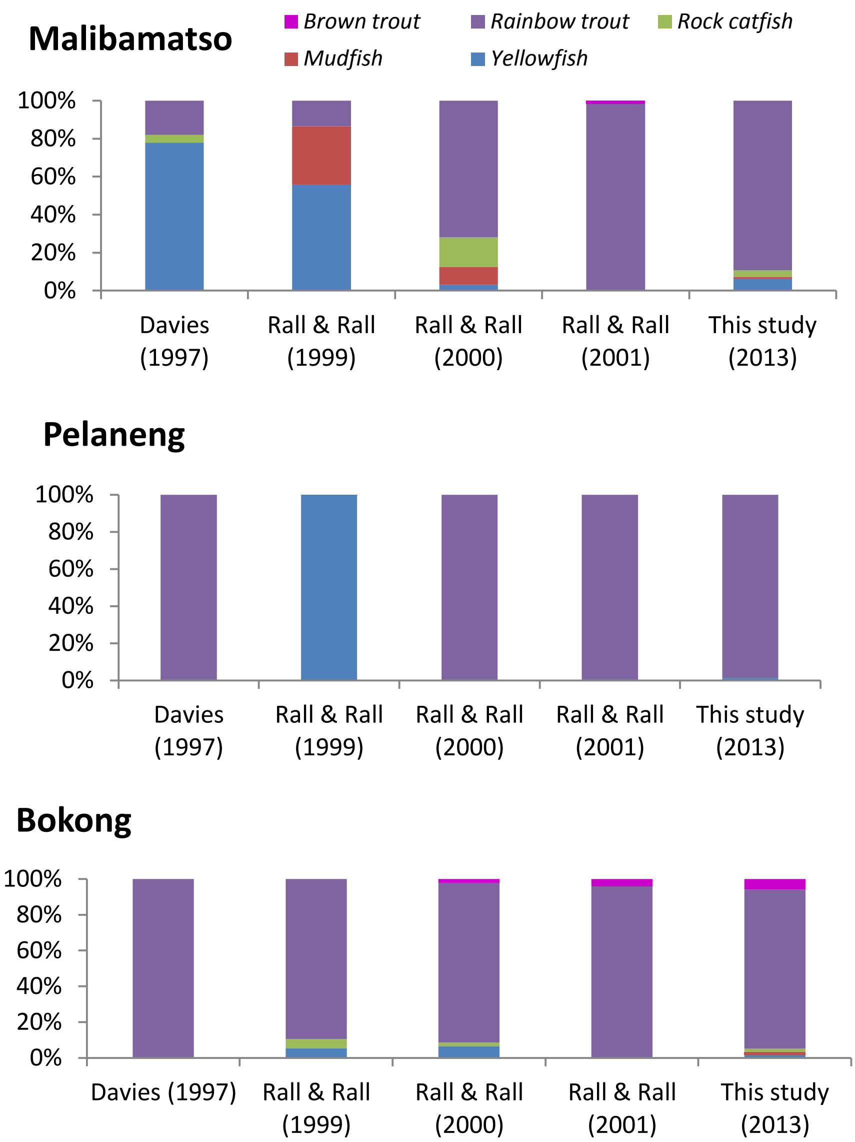

Figure 17. Proportional composition of fish assemblages in the Malibamatso, Pelaneng and Bokong tributaries in 1996 (Davies 1997), 1998 (Rall & Rall 1999), 1999 (Rall & Rall 2000), 2000 (Rall & Rall 2001) and 2013 (present survey). The composition of the fish assemblage within each tributary was determined based on all individuals captured using all sampling methods.

7.5 Conclusions

Analysis of the environmental data revealed that the river habitats at the lower sites on the influent rivers were generally in a more degraded state than were the sites further upstream. Furthermore, the lower sites generally had higher densities of people and experienced higher levels of livestock grazing, cultivation and use of detergent and soap in the river channel. This appears to have resulted in increased erosion, sedimentation and pollution at lower sites relative to upper sites.

The distribution patterns suggest that rainbow trout have had a negative impact on the native fish populations. In general, the native species only co-occurred with rainbow trout at the lower sites (near to the dam interface) where habitat integrity was relatively poor, and environmental conditions less favourable for rainbow trout than at sites further upstream. The native fish species may be more tolerant to habitat degradation and harsh river environments than are the non-native salmonids, and it is hypothesised that differential tolerances of native and non-native species to environmental variability and harshness may be an important factor enabling co-occurrence, and ultimately the persistence of riverine native fish populations in the Katse Dam catchment area. It is suspected, however, that the rock catfish rock catfish may be particularly sensitive to the effects of human-induced sedimentation in river beds.

The present survey has revealed that fish populations in the Katse Dam catchment area appear to be relatively stable. The non-native rainbow trout was the dominant member of the fish assemblage at the majority of sites and native and the native yellowfish, mudfish and rock catfish generally only co-occurred with rainbow trout at the more degraded sites close to the dam interface, or in the interfaces themselves, suggesting that such sites function as refugia for native fish from trout impacts. An exception to this is the appearance of brown trout in the Bokong River and Katse Dam. It is possible that this aggressive piscivore will compound the already severe impact of non-native rainbow trout on native species in the rivers.

8 AMPHIBIANS AND REPTILES

8.1 Introduction

Phase 1A of the Lesotho Highlands Dam Project was predicted to cause physico-chemical changes to water quality and increased levels of pollution and toxicity of the aquatic environment. Amphibians, given their lifecycles that integrate both terrestrial and aquatic ecosystems and their reliance on aquatic ecosystems for breeding, could be similarly affected. The frogs *Amietia quecketti*, *Xenopus laevis*, *Amietia umbraculata*, and *Hadromophryne natalensis* were suggested as possible sensitive indicators of water quality (Loxton, Venn & Associates 1993b).

8.2 Methods

Herpetofaunal populations were surveyed in the Katse Dam catchment during January and February 2013 and compared with baseline studies completed in 1993, in order to determine whether any major changes to these communities had occurred in the intervening period and thus assess the potential impacts of the Katse Dam on these populations. Herpetofaunal sampling took place at 25 sites, at points in the upper, mid and lower catchments during summer 2014 (Figure 18). Seventeen sites that were surveyed during the original survey were re-sampled and an additional eight new sites were surveyed. Techniques similar to those used in previous surveys such as active searching, sweep netting, acoustic surveys and nocturnal searches were used. Additional records from bycatch of the fish study during the previous spring were also included.

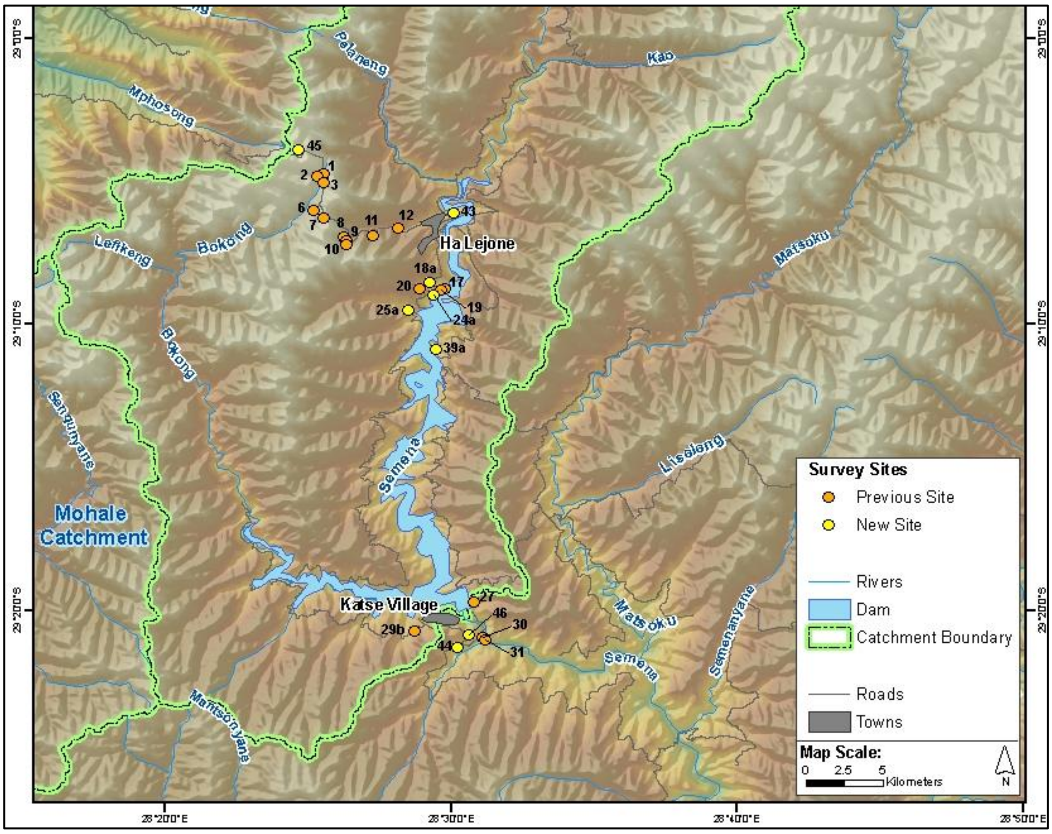

Figure 18. Herpetofauna sites surveyed during 2014.

8.3 Amphibians

The study recorded nine amphibian species, compared with seven species recorded during the baseline study (Table 4). All species previous recorded were detected and an additional two species were also recorded. Of note is the detection of the Phofung River frog *Amietia vertebralis*, which is a fairly localised endemic, habitat specialist and currently listed as 'near threatened' on the IUCN red-list, in the upper catchment. Comparison on a site-by-site basis with the baseline results show some differences as expected, given the design of the two studies, but overall a high degree of similarity to the baseline findings was recorded.

Of the nine amphibian species recorded, there was some evidence for breeding activity in six of these. Given that this monitoring has taken place over 20 years after the baseline study, the results suggest that amphibian populations within the broader catchment are continuing to maintain themselves.

Figure 19. Amphibian species found in Katse Dam catchment. L-R, T-B, raucous toad *Amietophrynus ranger;* karoo toad *Vandijkophrynus gariepensis;* Phofung river frog, *Amietia vertebralis;* Maluti river frog, *Amietia umbraculata;* common river frog, *Amietia quecketti*; common platanna, *Xenopus laevis;* Natal cascade frog, *Hadromophryne natalensis*; clicking stream frog *Strongylopus grayii*; plaintive rain frog, *Breviceps verrucosus.* All photgraphs taken by the herpetologist, J. Harvey.

Table 4. Amphibian species recorded during the 1993 baseline survey and the 2014 survey. + = Present, - = Absent.

Species	Loxton, Venn & Associates (1993)	This study (2014)
Common river frog *Amietia quecketti*	+	+
Phofung river frog *Amietia vertebralis*	-	+
Maluti river frog *Amietia umbraculata*	+	+
Raucous toad *Amietophrynus rangeri*	+	+
Karoo toad *Vandijkophrynus gariepensis*	+	+
Natal cascade frog *Hadromophryne natalensis*	+	+
Plaintive rain frog *Breviceps verrucosus*	-	+
Common platanna *Xenopus laevis*	+	+
Clicking stream frog *Strongylopus grayii*	+	+
Total species	7	9

8.4 Reptiles

This study recorded fewer reptiles than the baseline. This is somewhat in contrast to the results for the amphibian fauna, and reflects the relatively greater difficulty in detecting reptiles within a relatively short timeframe. A total of seven reptile species were recorded during this assessment, comprising three snakes and four lizards, compared with the original study, which recorded ten species, comprising four snakes and six lizards (Table 5). One species recorded during this survey, a snake – rhombic skaapsteker *Psammophylax rhombeatus*, was not detected during the original study.

Table 5. Reptile species recorded during the 1993 baseline survey and the 2014 survey. + = Present, - = Absent.

Species	Loxton, Venn & Associates (1993)	This study (Anchor 2014)
Rinkhals *Hemachatus haemachatus*	+	+*
Puff adder *Bitis arietans*	+	+
Rhombic skaapsteker *Psammophylax rhombeatus*	-	+
Cross-marked grass snake *Psammophis crucifer*	+	-
South African slug-eater *Duberria lutrix*	+	-
Drakensberg crag lizard *Pseudocordylus melanotus*	+	+
Cape skink *Trachylepis capensis*	+	-
Speckled rock skink *Trachylepis punctatissima*	+	+
Burchell's sand lizard *Pedioplanis burchelli*	+	+
Southern rock agama *Agama atra*	+	+
Essex's mountain lizard *Tropidosaura essexi*	+	-
Total species	10	7

Of the species not recorded during this survey, two were snakes, a group that are typically difficult to survey during rapid assessments and one of the others was a lizard that is likely to be uncommon and possibly absent from much of the study area. Given the cryptic nature of reptiles and the sub-optimal sampling conditions (rainy and cold weather and the substantially lower sampling effort in comparison with the baseline study) the findings represents a fair proportion of the reptile community that was originally recorded.

8.5 Conclusions

This survey confirmed the continued presence of all amphibian species recorded during the baseline study, as well as recorded two additional species. This study also recorded breeding activity in six species. The localised 'near threatened' *Amietia vertebralis* was recorded in the extreme upper catchment. Most species present can generally be considered habitat generalists. Three species are more specialised, being strongly reliant on riverine systems. The majority of reptiles previously recorded were also detected, with one previously unrecorded species being detected. Habitats for all recorded species remain available, despite increased vegetation degradation and loss within portions of the catchment. Species that were not recorded during this survey are expected to still be present and their lack of detection is likely due to factors such as reduced survey effort, suboptimal weather condition, seasonality and the cryptic nature of many of the fauna (particularly reptiles) involved, rather than to any negative impacts that have occurred within the catchment thus far. These findings suggest that currently the herpetofaunal communities are in a similar condition to during the baseline surveys of 1991/92. Although most species present are tolerant of current conditions, it is possible that this could change in the future, if land cover degradation intensifies. Herpetofauna play an important role in the ecological community, with amphibians integrating the aquatic and terrestrial environments.

9 MAMMALS

9.1 Introduction

The presence of mammal species in a specific area can, especially, be considered a good indicator of environmental integrity (Joubert & Ryan 1999, Letnic *et al.* 2004, Avenant 2011). In particular the presence or absence of small mammals species (rodents and shrews in this case), together with their composition and community structure, has been demonstrated to provide a good indication of successional change in a specific habitat (Kuyler 200, Avenant 2005, 2011). In general, small mammal species numbers, diversity, evenness and the presence/absence of specific indicator species are expected to change with changes in ecosystem health, condition and vegetative changes over time. Together with a comparison of the presence and distribution of larger mammal species, a comparative study of these variables will give a good indication of the impact that environmental changes have had on the study area since the baseline.

The densities and distribution of mammals in Lesotho are generally not well studied. Some checklists on the distribution of mammals in Lesotho exist (Lynch 1994, Ambrose 2006), while most available data are based on incidental collections (Loxton, Venn & Associates 1993c) or focused surveys in localised areas, particularly associated with the LHWP (e.g. Lynch & Watson 1990, Avenant 2002a, 2004, 2007). Mammal diversity is naturally low in Lesotho (52 species are known to occur here) possibly due to a combination of environmental factors such as high altitudes, cold winter conditions, short summer periods and homogenous vegetation (Lynch 1994). However, due to a combination of human induced factors such as hunting, overgrazing, cultivation and uncontrolled fires, mammal diversity and densities were expected to be lower than in recent historical times (Lynch 1994, Avenant 2002a, 2004).

9.2 Mammals of the study area

Only two previous surveys have been conducted on the mammals in the Katse Dam catchment area (Meakins *et al.* 1988, Loxton, Venn & Associates 1993c). Based on these, 33 species (bats excluded) have been recorded or could be expected to occur in the Katse Dam catchment area (Table 1).

This includes one South African red-listed species, the white-tailed mouse *Mystromys albicaudatus* (endangered - IUCN 2013; endangered in South Africa - Friedmann & Daly 2004). Another one, oribi *Ourebia ourebi* (least concern – IUCN 2013; endangered in South Africa - Friedmann & Daly 2004), was also listed as an expected species by Loxton, Venn & Associates (1993), but its absence from the Katse Dam catchment is now commonly expected (Lynch 1994, Ambrose 2006). Furthermore the ice rat *Otomys sloggetti,* which occur in the area, is endemic to the Maloti-Drakensberg range where they are common at high altitudes (Skinner & Chimimba 2005).

Table 1. List of mammals (excluding bats) expected in the Katse Dam catchment area (Meakins *et al.* 1988, Loxton, Venn & Associates 1993c, Ambrose 2006).

Species	IUCN Status[1]	Habitat preference[2]
***Myosorex varius* (Forest shrew)**	**Data deficient**	**Moist, densely vegetated habitat**
***Crocidura flavescens* (Greater red musk shrew)**	**Data deficient**	**Variety of vegetation types; moist habitat**
Crocidura cyanea (Reddish-grey musk shrew)	Least Concern	Dry, grassland habitat
***Chlorotalpa sclateri* (Sclater's golden mole)**	**Data deficient**	**Alpine shrubs, sedges and grassland**
Papio hamadryas (Chacma baboon)	Least Concern	Highest mountain peaks
Canis mesomelas (Black-backed jackal)	Least concern	Wide habitat tolerance
Aonyx capensis (African clawless otter)	Least concern	Aquatic bodies
Ictonyx striatus (Striped polecat)	Least concern	Wide habitat tolerance
Genetta tigrina (South African large-spotted genet)	Least concern	Open grassland and vlei with woodland association
Galerella pulverulenta (Cape grey mongoose)	Least concern	Wide habitat tolerance
Ichneumia albicauda (White-tailed mongoose)	Least concern	Habitat with adequate cover
Atilax paludinosis (Marsh/Water mongoose)	Least concern	Aquatic bodies
Caracal caracal (Caracal)	Least concern	Open grassland/woodland
Felis silvestris (African wild cat)	Least concern	Wide habitat tolerance
Procavia capensis (Rock hyrax)	Least concern	Rocky outcrops
Sylvicapra grimmia (Common duiker)	Least concern	Wide habitat tolerance
***Ourebia ourebia* (Oribi)**	**Endangered**	**Open grassland**
Pelea capreolus (Grey rhebok)	Least concern	Rocky hills, rocky mountain slopes and rocky plateau with grass cover
Redunca fulvorufula (Mountain reedbuck)	Least concern	Mountain slopes and plateaus with grass cover
Oreotragus oreotragus (Klipspringer)	Least concern	Rocky habitats
Hystrix africaeaustralis (Cape porcupine)	Least concern	Wide habitat tolerance
Cryptomys hottentotus (African mole-rat)	Least concern	Wide diversity of substrates
Otomys irroratus (Vlei rat)	Least concern	Grasslands; Wetlands
***Otomys sloggetti* (Sloggett's vlei rat)**	**Data deficient**	**Rocky habitats; Grassland**
***Mystromys albicaudatus* (White-tailed mouse)**	**Endangered**	**Rocky habitats; Grassland**
Dendromus melanotis (Grey climbing mouse)	Least concern	Grassland
Rhabdomys pumilio (Four-striped grass mouse)	Least concern	Grassland
Mus minutoides (Pygmy mouse)	Least concern	Wide habitat tolerance
Micaelamys namaquensis (Namaqua rock mouse)	Least concern	Rocky habitats
Graphiurus murinus (Woodland dormouse)	Least concern	Wide habitat tolerance; sufficient cover
Mastomys coucha (Southern multimammate mouse)	Least concern	Wide habitat tolerance
Lepus saxatillis (Scrub hare)	Least concern	Grassland; Shrubland
Pronolagus rupestris (Smith's red rock rabbit)	Least concern	Rocky outcrops

[1]IUCN 2013; [2]Skinner & Chimimba 2005

9.3 Survey methods

A baseline study of mammals was conducted in the Katse Dam catchment area prior to dam construction during 1992/93 (Loxton, Venn & Associates 1993c) but no further mammal monitoring was done post-dam construction and inundation..

Following the methods used in the baseline survey, a combination of standardised small mammal trapping in predetermined areas, and indirect sampling methods in the general study area were used to record species presence, density, diversity and community structure. Sampling was conducted mid-summer, from 27 January to 5 February 2014; not precisely as in the baseline study, when sampling was conducted on four field visits during autumn, spring and early to mid-summer.

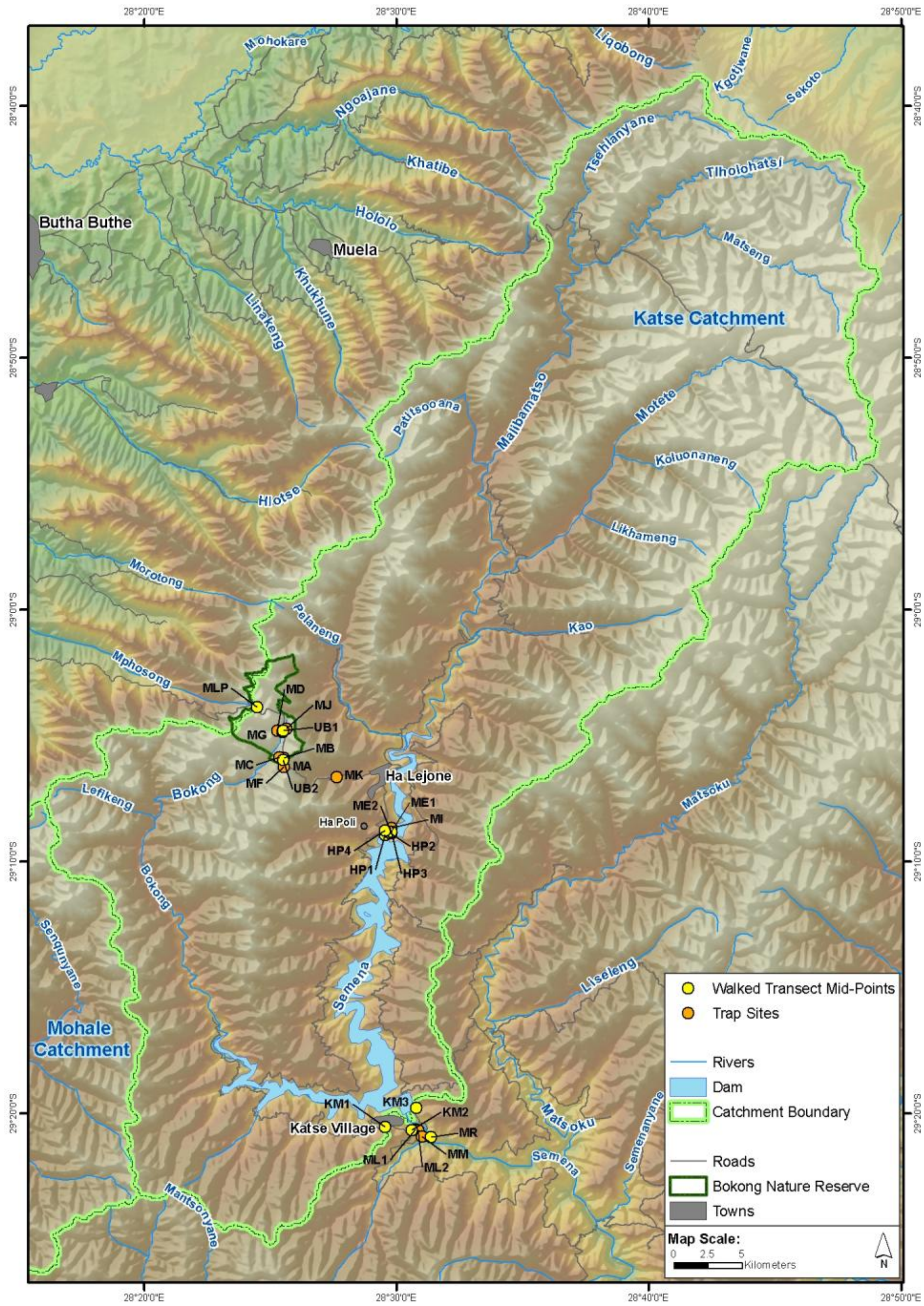

Figure 20. Mammal sampling sites in 2014.

9.4 Survey results

In total, seven species were collected on the various small mammal traplines during January/February 2014 in the Katse Dam catchment area, with the most (n = 4) collected in the Upper Bokong Valley and in the Ha Lejone/Ha Poli area; while only two species were recorded in the Katse area (Table 5). The highest species richness found on any trapline was four (traplines MD and MJ in the Bokong Nature Reserve, Upper Bokong Valley). Two traplines yielded only one species, and on three traplines no species were caught. On one trapline, MF, no assessment was possible due to continuous disturbance of traps by dogs and herders.

The shrew *Myosorex varius* was the most often trapped (8 traplines), followed by striped mice *Rhabdomys pumilio* (5 traplines) and *Otomys irroratus* and *O. sloggetti* (3 traplines each). *Micaelamys namaquensis* was trapped on two traplines, and *Mastomys coucha* and *Crocidura flavescens* on one each.

Figure 21. The southern multimammate mouse *Mastomys coucha*.

Overall, higher Shannon diversities were found at traplines in the Upper Bokong Valley, followed by traplines in the Ha Lejone/Ha Poli area, and then on traplines in the Katse area. Within the different areas there was a noticeable difference in species diversity between the different traplines in the Upper Bokong Valley area, with a higher diversity on traplines MD, MG and MJ (> 1.00). Such difference was less apparent in the other two areas, where diversities were all smaller than 0.7.

Trapping success was also highest in the Upper Bokong Valley (mean = 5.3%) and lowest in the Katse area (mean = 1%). Within the different areas, trapping success were less variable in the Ha Lejone/Ha Poli (min: 0%; max: 5%) and Katse (min: 0%; max: 3%) areas than in the Upper Bokong Valley (where variation ranged between 1% and 11%).

Sixteen mammal species were observed through actual sightings or indirect signs in the Katse Dam catchment area during January/February 2014. The highest number of species were observed in the Katse area (n = 9), followed by the Ha Lejone/Ha Poli area (n = 8) and the Upper Bokong Valley and Mafika Lisiu Pass areas (n = 7 each). The presence of two very secretive species: Striped polecat *Ictonyx striatus* and African wild cat *Felis silvestris (lybica)*, was confirmed for the larger Katse Dam catchment area.

9.5 Changes since the baseline study

When combining the results from the small mammal traplines and the sighting and observational records, the most species were recorded in the Katse and Ha-Lejone/Ha Poli areas, followed by the Upper Bokong Valley, and then the Mafika Lisiu Pass area in 2014 which was different to that seen in 1991/92 (Table 7).

Table 7. Combined number of mammal species trapped and observed through sighting and indirect observations in the Katse Dam catchment area in the 1991/92 baseline study (Loxton, Venn & Associates 1993) and during the current study, January/February 2014. Numbers in brackets represent the numbers caught by mammals trapping (T) and those observed through direct sightings or signs (S). Note that T + S does not always add to the total number of species as there is sometimes overlap in species trapped and sighted.

General area	Studies	
	1991/92 baseline	2014 study
Mafika Lisiu Pass	Combined with Upper Bokong Valley results	8 (8S)
Upper Bokong Valley	15 (7T, 11S)	8 (4T, 7S)
Ha-Lejone/Ha Poli	8 (7T, 3S)	11 (4T, 8S)
Katse Area	9 (4T, 5S)	11 (2T, 9S)

Although the overall numbers of mammal species increased between the baseline and current study, in both the Katse and Ha-Lejone/Ha Poli areas, this is attributable to increases in animal sightings not the number of small mammals trapped. In fact in all three areas, the number of small mammals trapped has almost halved.

The overall trap success in the current study (mean = 3.9% ± 3.2%) was also markedly lower compared to the 1993 baseline (15.8% ± 13.4%). Considering that the baseline was conducted over a longer period spanning different seasons, differences could therefore be expected. While the trap success for the current study are not low for the time of year (see Avenant 2011, Avenant & Du Plessis 2012), the big differences in mammal density between the two surveys are a good indication that primary productivity (= food availability) and cover have generally decreased in the study area, and or predation threat (e.g. by dogs) has increased since 1993. This view is supported by the fact that highest densities, species richness, diversities and a large number of shrews were observed in the Bokong Nature Reserve where grazing is controlled and the presence of humans and dogs (predation) are limited; and this despite the fact that a large part of the area has burned during the winter (c. 5 months earlier)!

A comparable number of mammal species were recorded during walks in the current study compared to the 1992/93 baseline. This is noteworthy, considering the almost constant rainfall that was experienced during the current study which could have had an impact on the number of spoor and scats that were visible. Of note is the fact that more direct sightings of mammals were recorded in the current study. Nonetheless, numbers of larger mammal species are still relatively low. This also conforms to the general low abundance and small group sizes of larger mammals in other parts of the Lesotho Highlands (see Avenant 2002a&b, 2004, 2007, Avenant & Du Plessis 2012).

It is worth mentioning that the highest number of mammal species was observed in the Ha Lejone/Ha Poli and Katse areas; different from the baseline where the most mammals were observed in the Upper Bokong Valley. This can likely be attributed it to the fact that these areas are at a lower altitude compared to the Upper Bokong Valley, which may naturally have fewer species present. In addition, large parts of the Katse area where sampling occurred has been controlled by LHDA since the dam were built and access by the local community is now restricted. It can, therefore, be expected that the larger mammals are less threatened in this area than in the communal grazing and agricultural areas.

9.6 Conclusions

Human-induced disturbances, such as cultivation, overgrazing, predation and dam flooding, appears to have adversely impacted both the small and larger mammal communities since Katse Dam construction. Generally, lower densities and numbers of species have been found in the current study when compared to the baseline. Efforts to protect the Upper Bokong Valley have proved worthwhile: the highest small mammal species richness, diversity and trap success were found here, as well as a diversity of larger mammals threatened by human activities in other parts of the Lesotho Highlands. A relatively large number of larger mammal species were also observed in the partially fenced off area around Katse dam wall and lodge, likely due to the fact that they are less vulnerable to human disturbances such as cultivation, grazing and hunting.

10 BIRDS

10.1 Introduction

Birds occupy a variety of aquatic and terrestrial habitats in the study area. The construction of Katse Dam has dramatically altered many of these habitats including submerging low-lying riparian habitats and low-lying cliffs-faces. The inundation also submerged agricultural fields and this likely resulted in new fields being established higher up on the slopes above the inundation zone at the cost of natural vegetation. In addition to changes in habitats, changes in prey species such as small mammals and fish could also be expected to alter the distribution and abundance of bird species within the Katse Dam catchment.

The proportion of endemic or near-endemic bird species within the Lesotho highlands is extraordinarily high and this area also includes the remaining global/regional strongholds for a number of red data species. This highlights the importance of the Katse Dam catchment for the conservation of avifauna.

10.2 Survey methods

Fieldwork to examine the distribution of bird species including cliff-nesting and waterbirds in the Katse catchment spanned six days during 8-13 October 2013. Additionally 20-minute walking transects in each of four habitats: cultivated fields, low, mid and high altitude grasslands were conducted between 17-23 February 2014 (7 days). Thus a total of 13 days of field work were carried out.

This comparison of the current (2013/14) state of the avifauna of the Katse catchment with the earlier baseline (1991) and monitoring (1996-2000) periods was based on four primary lines of investigation. These were:

- Comparisons between the presence/absence and broad distribution of bird species between the three periods;
- Comparisons between transect counts of birds made in four different altitude/habitat classes in the catchment between the three periods, both in terms of avian community structure and relevant to particular individual species;
- Comparisons between the diversity and abundance of large cliff-nesting bird species between the three periods; and
- Comparisons between waterbird diversity and abundance between the three periods.

10.3 Overall status and distribution of the avifauna

Of the 146 bird species recorded at Katse to date, 108 (74%) are either resident or could occur in the area at any time of year, 18 are long-distance migrants (12%), and 20 (14%) are vagrants. The regular avian community therefore comprises some 126 species. In terms of habitat, 118 species (81%) inhabit terrestrial habitats, i.e. grassland, shrubland, agricultural fields, villages, etc., and 28

(19%) are waterbirds. Eighty-five species have been confirmed breeding at Katse, an additional 20 species probably breed there, 13 further species possibly breed there, 15 species are considered unlikely to breed there, and 13 species are non-breeding migrants to Katse.

Thirty-eight species (26%) are endemic or near-endemic to southern Africa and the majority of these, 27 (19%), are endemic or near-endemic to the even more restricted region covered by Lesotho, South Africa and Swaziland. Three species essentially endemic to the Lesotho highlands (Drakensberg rock-jumper, mountain pipit and Drakensberg siskin) are particularly important in this regard. For eight red data species, Katse can be considered to lie within their remaining global/regional strongholds (bearded and cape vultures, black harrier, lanner falcon, southern bald ibis, black stork and African rock and mountain pipits).

Of the 126 'non-vagrant' species recorded at Katse, 12 species were not recorded during the 2013/14 survey: Swainson's spurfowl, jacobin cuckoo, diderick cuckoo, African snipe, Verreaux's eagle, cattle egret, barn swallow, Barratt's warbler, African reed-warbler, Layard's tit-babbler, yellow-crowned bishop and red-collared widowbird. For two of these species there was compelling evidence to suggest that local extinctions of previously common and widespread bird species had occurred in the catchment between the baseline/monitoring and 2013/14 surveys (Figure 22). These were the African reed-warbler and red-collared widow, both species previously largely associated with low-lying agricultural fields in the upper Malibamatso region of the catchment.

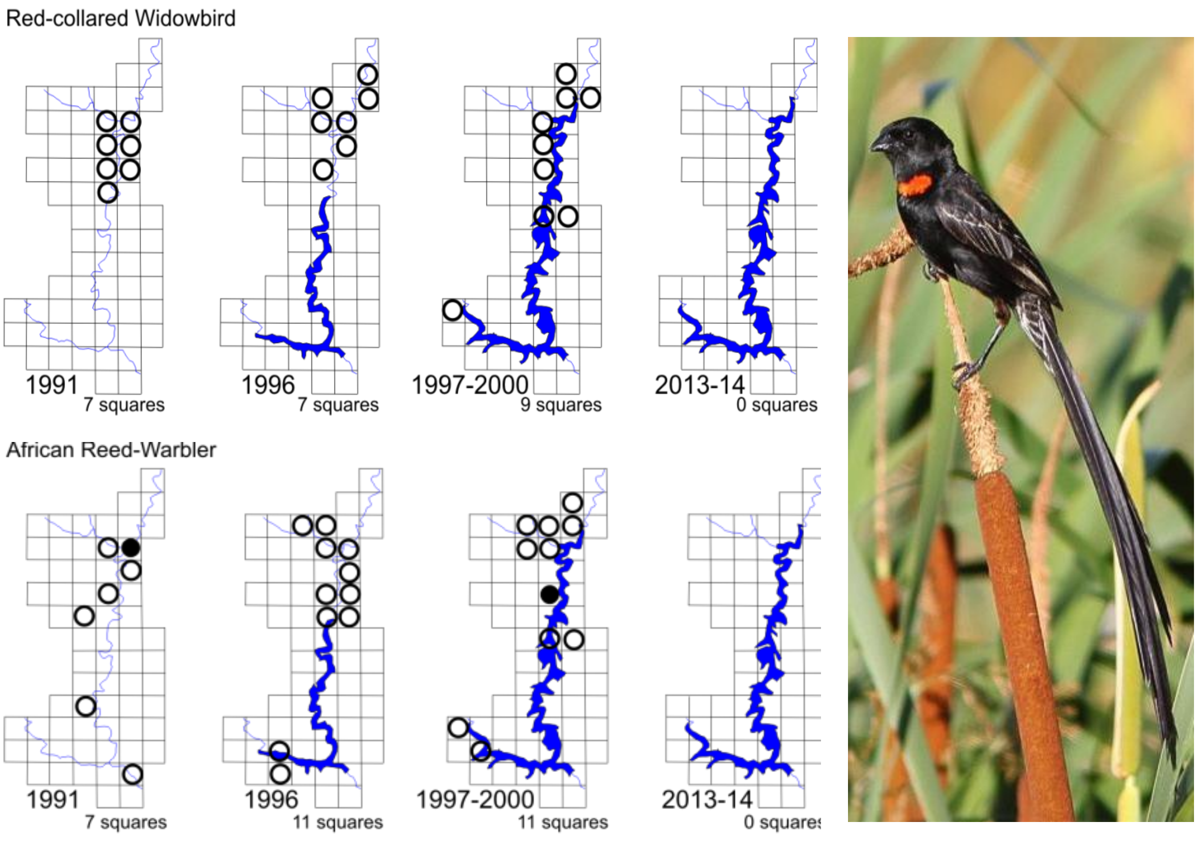

Figure 22. Distribution changes for the red-collared widowbird (top and right) and African red-warbler (bottom) in the Katse Dam catchment 1991-2013/14.

Ten species were recorded at Katse for the first time during 2013/14. Five of these were waterbirds, of which two (white-backed duck and common moorhen) were found localised to, and apparently resident at, the shallow-water habitat of the Katse Quarry, one (Egyptian goose) was found to be widespread on the dam as well as at the quarry, and the remaining two (spur-winged goose and African sacred ibis) comprised singletons recorded as apparent vagrants on the dam. Of the five 'non-waterbird' species, three (African hoopoe and the two alien invasives, common starling and common myna) are considered recent permanent breeding colonists attracted as commensals to human settlements, and the remaining two are considered vagrants in the face of little information to the contrary (red-headed finch and amur falcon).

Examination of the distribution maps suggested large-scale reductions in distribution and hence abundance of helmeted guineafowl, neddicky and wing-snapping cisticola. In the same way, these maps also suggest potential, but not as striking, decreases in brown-throated martin, cape grassbird, red-capped lark, cape rock thrush, red-winged starling, pied starling, cape weaver, African quailfinch, common waxbill, pin-tailed whydah and cinnamon-breasted bunting.

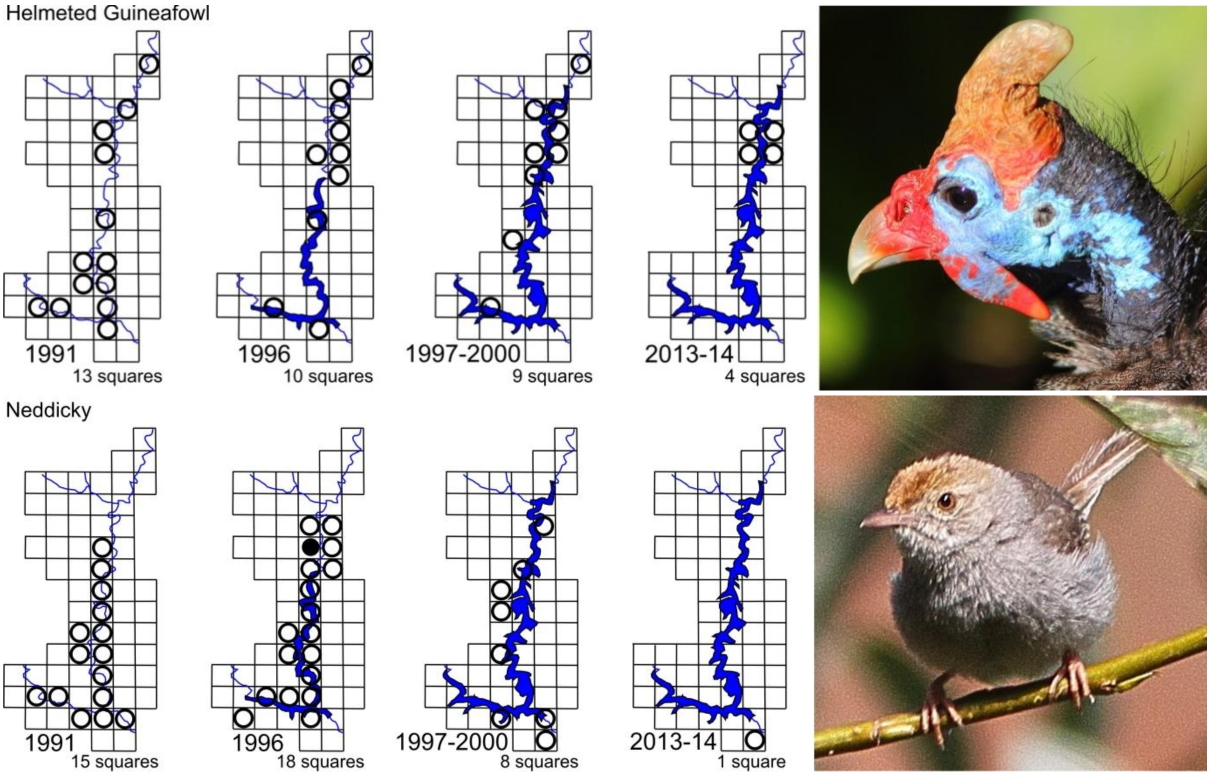

Figure 23. Distribution changes for the helmeted guineafowl (top) and neddicky (bottom) in the Katse Dam catchment 1991-2013/14.

10.4 Transects

Both the number of bird species counted per transect as well as the number of groups of birds has declined since the baseline study (Figure 24 & Figure 25). There were also higher numbers of bird as well as species found in the cultivated fields than in any of the grassland habitats.

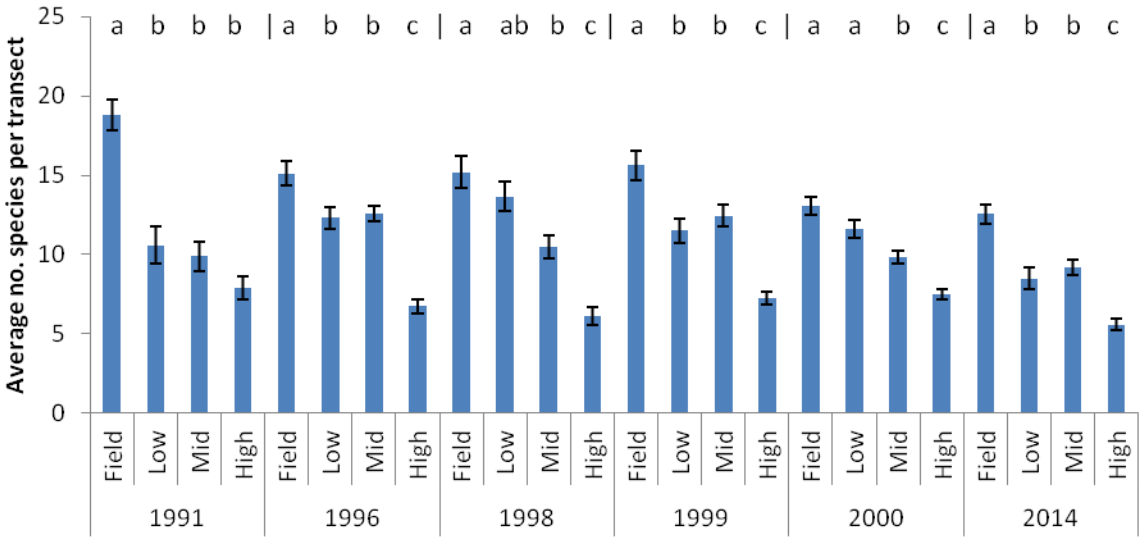

Figure 24. The average number of species seen per 20 min transect in each year surveys were conducted. Letters denote significant differences within years.

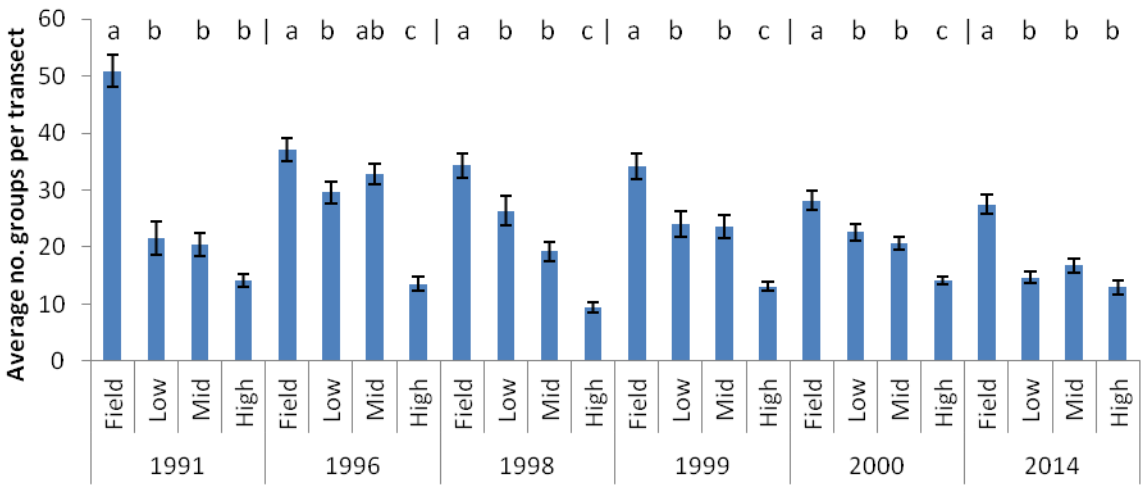

Figure 25. The average number of bird groups encountered per 20 min transect in each year surveys were conducted. Letters denote significant differences within years.

Data from transects revealed that significantly different communities of birds occupied each of the different habitats (cultivated fields, low altitude grasslands, mid altitude grasslands and high altitude grasslands). The three natural grassland habitats were more similar to each other in species composition than they were to the cultivated field habitats. Cultivated fields were more dominated by seed-eaters such as cape sparrows whereas the highest altitude grasslands had more mountain grassland specialist species such as jackal buzzards and mountain pipits. It should be noted that two of the three Lesotho highland endemics, Drakensberg rock-jumper and mountain pipit feature in this analysis, both being entirely restricted to natural vegetation.

The composition of bird communities in Katse has changed significantly between the baseline study in 1991 and the monitoring in 2000, then also between 2000 and 2014. Although a few species showed increases in abundance, most of these changes were decreases in abundance, particularly so between 2000 and 2014. The top five changes between 1991 and 2000 included both increases and decreases in species, whereas between 2000 and 2014, the top five changes were all negative (Table 6). Worryingly some of the most obvious decreases were in species that are endemic or near-endemic to the area such as Drakensberg siskin and rock-jumper.

Table 6. Top five species changes in relative abundance between 1991 -2000 and 2000-2014 in transects.

Main Species Different 1991-2000	% Change	Main Species Different 2000-2014	% Change
Mountain pipit	144%	Cape canary	-59%
African stonechat	-27%	Drakensberg siskin	-47%
Sentinel rock-thrush	-64%	Cape bunting	-7%
Drakensberg siskin	-16%	Sickle-winged chat	-47%
Cape canary	146%	Drakensberg rock-jumper	-39%

A significant finding of the bird-transects counts at the high-altitude study site in Bokong Nature Reserve at Mafika Lisiu was that the globally threatened yellow-breasted pipit has become common there since the monitoring survey, with breeding confirmed, likely due to the protection of this area from over-grazing.

10.5 Cliff-nesting birds

Of nine ‘non-waterbird’ cliff-nesting species at Katse (barn and cape eagle- owls, bearded vulture, jackal buzzard, lanner falcon, rock kestrel, southern bald ibis, cape crow and white-necked raven), only two show evidence for a change of status in the catchment (Figure 26 & Figure 27). The regionally ‘critically endangered’ bearded vulture supported 4-5 breeding pairs during the baseline and monitoring periods but the species no longer appears to breed in the catchment. The most abundant cliff-nesting raptor at Katse, the jackal buzzard, remains common but manifests a subtly negative impact in that the breeding territories in the lower part of the inundation zone, i.e. those with the highest level of habitat submerged, are disproportionately unoccupied or are occupied but inactive.

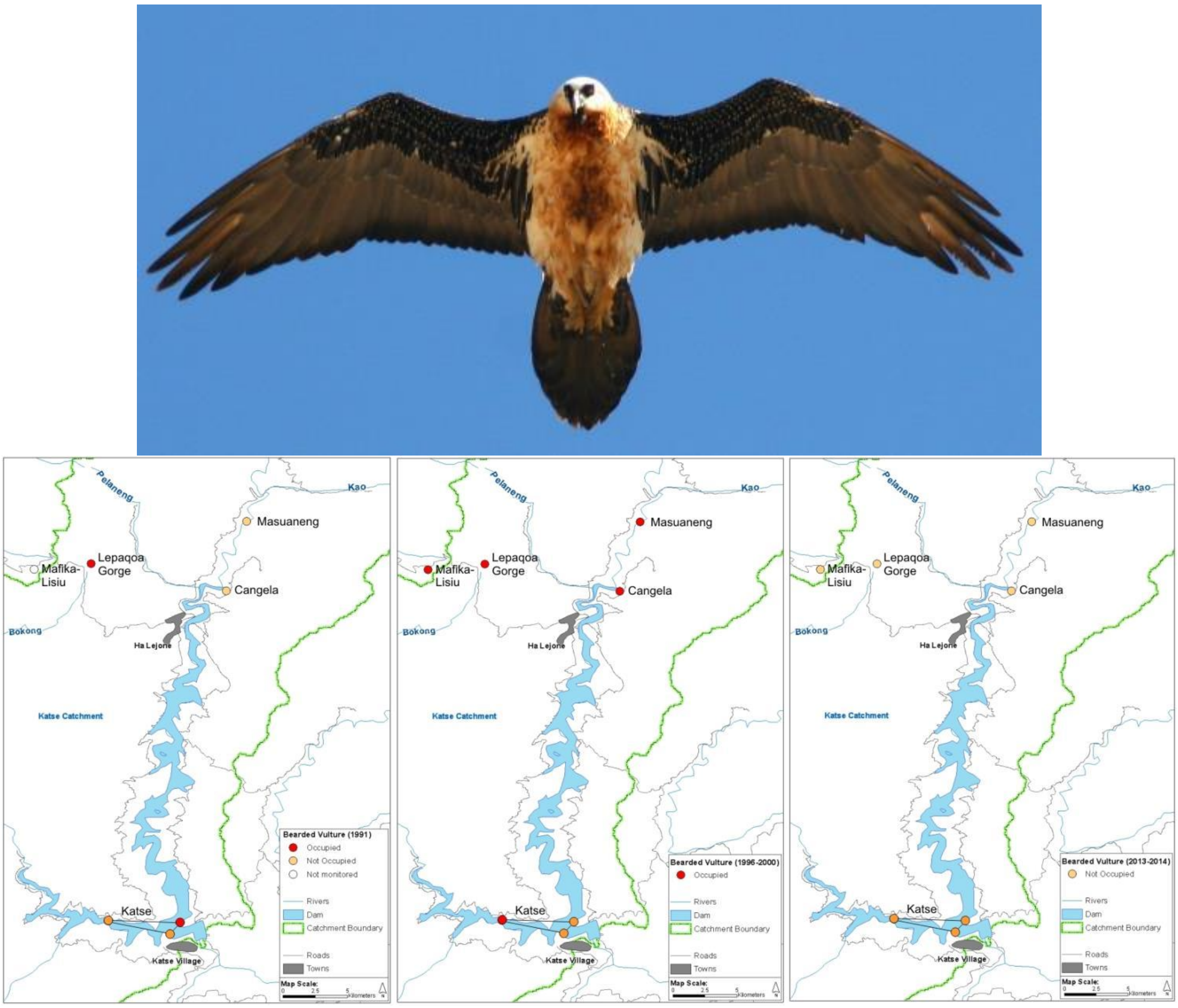

Figure 26. Cliff-nesting sites for bearded vulture in Katse dam in 1991, 1996-2000 and 2014.

Figure 27. Cliff-nesting sites for jackal buzzard in Katse dam in 1991, 1996-2000 and 2014.

10.6 Waterbirds

In the face of the inundation of Katse Dam, of the 18 non-vagrant waterbirds recorded from the original rivers or the subsequent inundation zone, one (black stork) has disappeared as a breeding species. Six species (African black duck, giant kingfisher, common sandpiper, three-banded plover, hamerkop and cape wagtail) have decreased in abundance, especially the African black duck. Three species (Egyptian goose, little grebe and red-knobbed coot) have colonized the dam, the first two as breeding species. Five species that were already present (yellow-billed duck, reed and white-breasted cormorants, and grey and black-headed herons) have increased in abundance. Of these, the reed cormorant and grey and black-headed herons did not breed previously at Katse but now do so. The yellow-billed duck possibly, and the white-breasted cormorant definitely, nested in small numbers along the original rivers but now breed in larger numbers on the dam, especially the white-breasted cormorant. Finally, three species (malachite Kingfisher, cattle Egret and hadeda ibis), the first two of which are uncommon visitors to the catchment, show little evidence for a change in status, although the number of breeding pairs of hadeda ibis may have increase concomitant with their increased use of cliffs for nesting.Of these changes to the waterbird community, the disappearance of the black stork - a red data species, the large-scale decrease in African black ducks, and the massive increase in white-breasted cormorants and the establishment of a major breeding colony by this species, were the most noteworthy (Figure 28).

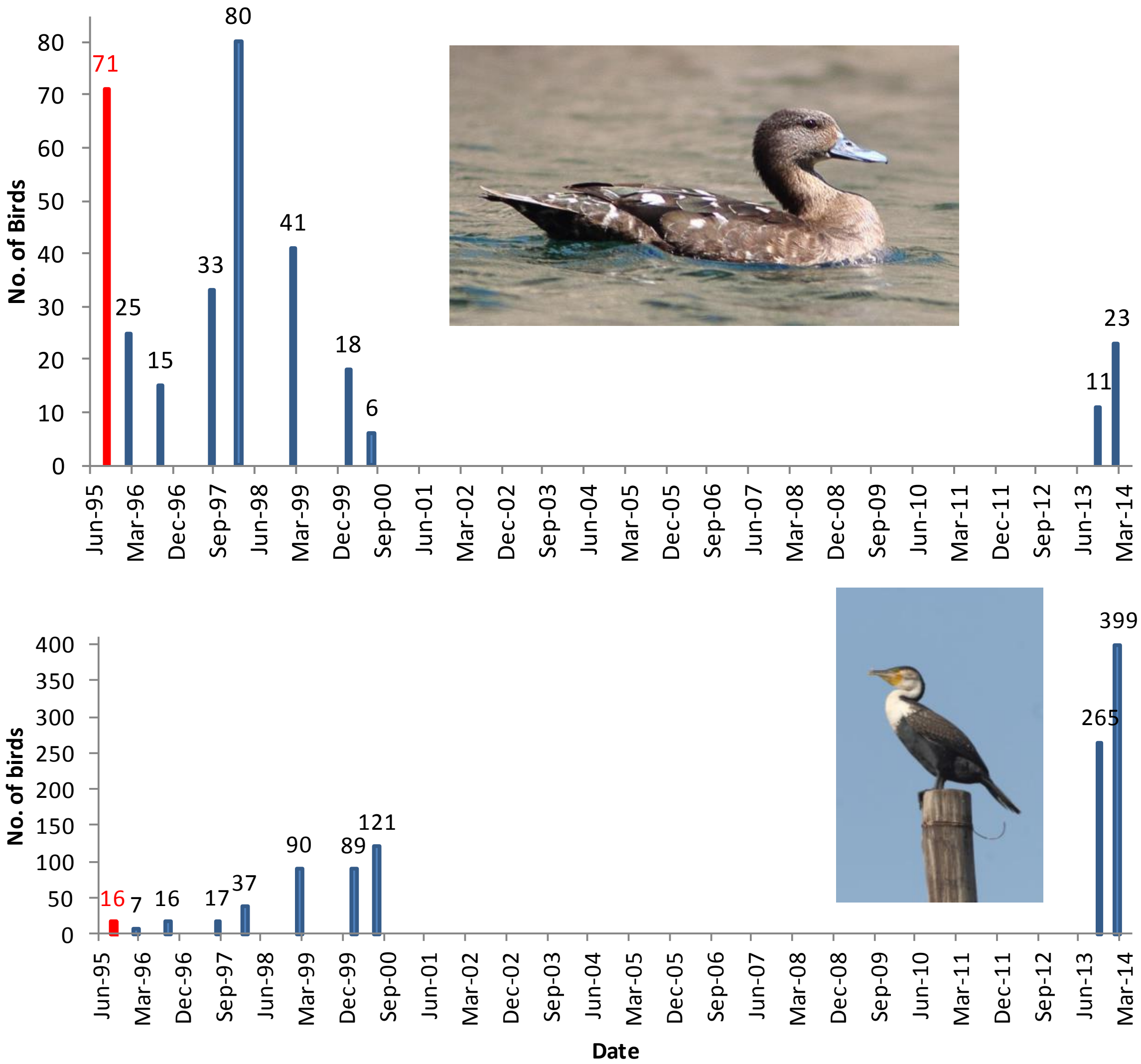

Figure 28. Change in abundance of two species, African black duck and white-breasted cormorant from before (red bar) and after (blue bars) dam inundation. Note that years without bars were not sampled.

10.7 Priority bird species

Three key indicator bird species were specified for investigation by LHDA in the Scope of Work (see Appendix 1): a gamebird (Swainson's spurfowl), a raptor (black-shouldered kite) and piscivorous waterbird (white-breasted cormorant). Of the gamebirds, both Swainson's spurfowl and helmeted guineafowl have apparently decreased in the face of inundation and the survival of the former in the catchment area requires confirmation. The grey-winged francolin and African quail remain relatively common, and the latter species was recorded for the first time at the high-altitude bird-transect count study site apparently due to the protection of this area from over-grazing. Of the raptors, the black-shouldered kite remains uncommon, although breeding was confirmed for the first time during the 2013/14 survey, and the jackal buzzard is suggested as a preferable indicator species in this regard. The third indicator, white-breasted cormorant, has increased massively at Katse with inundation and is now far-and-away the most common waterbird in the inundation area with a large breeding colony having become established.

Relevant to red data species, the loss of the bearded vulture and black stork as breeding species in the catchment is of profound concern, especially as relates to the former species.

The potential for the two alien invasive species, common myna and common starling, which have colonised the catchment, to become significant crop pests is discussed. Both of these species are listed, along with the brown trout, in the 'World's 100 Worst Alien Invasive Species' (Lowe *et al*. 2000). The Egyptian goose, an indigenous waterbird which has also colonised the dam, also has potential as a crop pest.

10.8 Conclusions

The results of the current survey reveal that substantial changes have taken place in the bird community of the Katse Dam catchment. These changes include both increases and decreases in the distribution and abundance of bird species. Species that occupied low-lying habitats along the river have been displaced by the inundation of the dam. A small number of islands were also created by the inundation. These areas have created breeding habitats for species such as the white-breasted cormorant. On the whole however, the number of species as well as the abundance of birds seems to have declined since the inundation of the Katse Dam as well as a shift in composition of the bird communities in different habitats. Of particular concern is the cessation of breeding in the 'critically endangered' bearded vulture within the Katse catchment.

Changes in communities that live within each of the four habitats were apparent regardless of how the extent of the different habitats has changed over the same period. Because there have been increases in the extent of agricultural land over the period 1991-2014 within Katse Dam catchment, it means that the overall composition of birds species has changed even more than these results suggest.

Reasons for the changes seen could include changes to bird habitats and breeding sites, increased human disturbance (including hunting) as well as changes in food availability through the degradation of the grassland habitats as well as decreases in small mammal and insect prey for predatory birds.

11 DISCUSSION AND SYNTHESIS[2]

11.1 Impacts of increased human activity

Land use and land cover within the Katse Dam catchment area has changed significantly over the past two decades, with the analysis of satellite data suggesting that more than half of the catchment area has changed in some way. These changes have included a decrease in the biomass of grassland vegetation, increases in subsistence cultivation and increases in shrubby vegetation. These changes are associated with increased human activities in the area, notably livestock grazing and agriculture.

The decrease of grassland biomass has occurred throughout the catchment, but has occurred more in areas closer to the dam. The flora study found an almost 35% increase in bare ground within grasslands. Grassland habitats have not only decreased in biomass and the vegetation cover, but have also shown a shift in species composition from before the dam was built until now. There has been an increase in the relative proportions of unpalatable grass species at the expense of important palatable grass species. These responses are indicative of overgrazing by livestock. Although grasslands have evolved with grazing by herbivores, and in fact do not do well with zero grazing, too much grazing results in lower vegetation cover and the predominance of unpalatable species (SANBI 2014). The consequences are a decrease in the carrying capacity of the grasslands for livestock and/or other herbivores, loss of biodiversity and increased soil erosion.

Increases in shrubby vegetation were picked up from the satellite imagery as occurring in some areas, and was also detected in some of the vegetation plots closer to the dam (Figure 29). Shrub density as well as the prevalence of alien shrubs, appeared to be increasing, especially in the Pelang sub-catchment. This is also thought to be a consequence of overgrazing. Species like *Chrysocoma ciliata* and *Artemisia afra* occur naturally in the grassland system, however with overgrazing these species can proliferate without the usual competition from the grasses. Natural fires normally help to keep small shrub density low, but if fire is excluded or not sufficiently hot (as often the case when grassland is degraded and has low biomass) then shrubs can grow to a size where they become dominant and transform the ecosystem (Prof A.R. Palmer, Agricultural Research Centre, Grahamstown, pers. comm.).

[2] Many of the findings and issues were in common with both Phase I catchments. The discussions in the two reports are therefore identical apart from the text highlighted in grey, which pertains to this catchment only, for the benefit of those reading both synthesis reports.

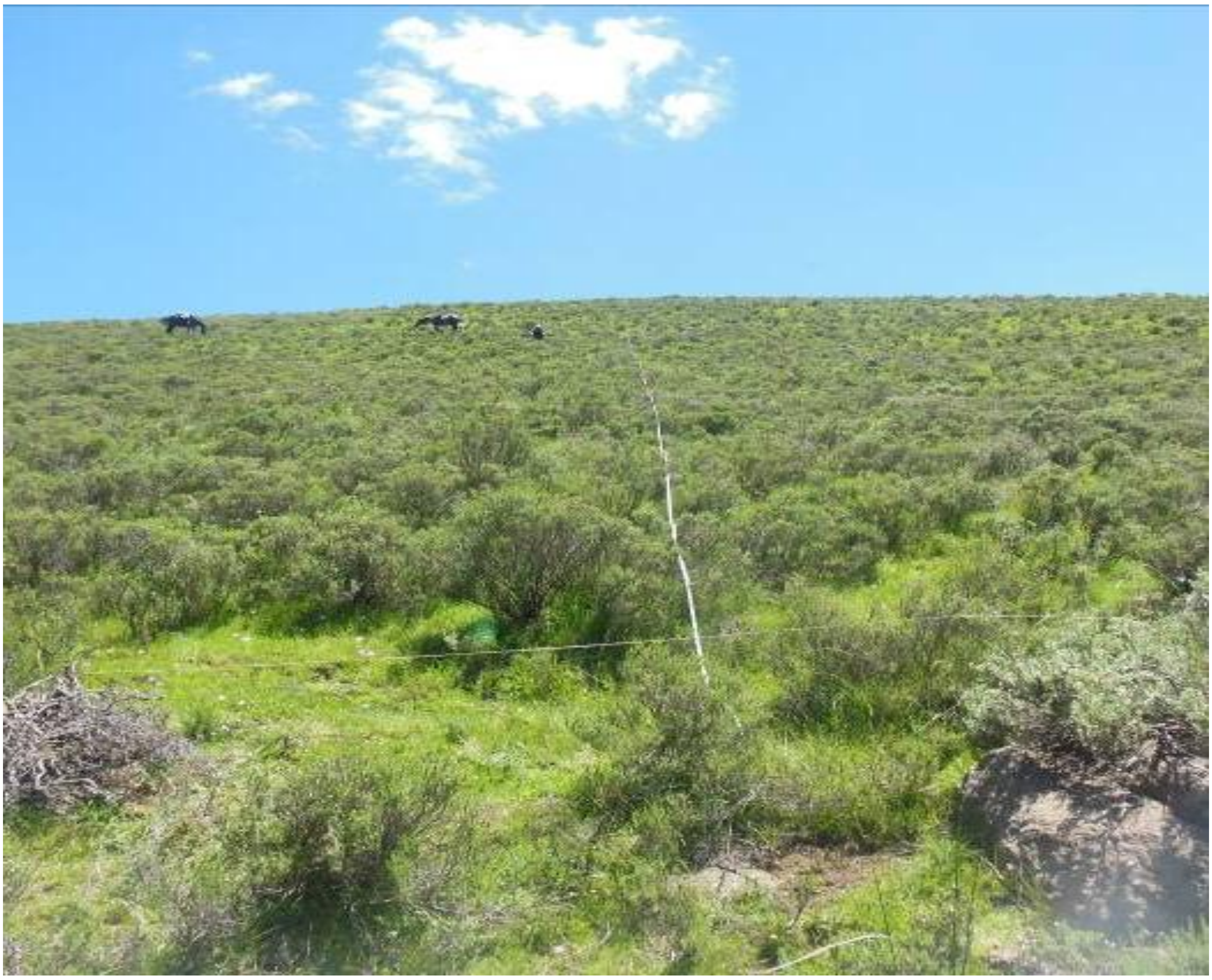

Figure 29. Grassland dominated by the shrub *Chrysocoma ciliata*.

The amount of subsistence cultivation has more than doubled in the area, with the increases being highest in areas close to the dam. This transformation from natural grassland to cultivated land leads to the loss of plant species and grazing area, and drastically changes the habitat for faunal species. Cultivation also increases the potential for erosion. Agricultural fields generally have erosion rates 1-2 times that of soil under natural vegetation (Montgomery 2007). The erodability of agricultural soils is also directly related to the steepness of the slopes cultivated. Anecdotal reports from the field studies were that cultivation on steep slopes was common.

The loss of biomass and vegetation cover within the grasslands habitats lowers the water infiltration rate when it rains and also exposes more bare ground to wind and water erosion. The combination of these factors leads to less water being transported sub-surface and more surface run-off on slopes, taking loose sediment and debris with it. This fast-flowing water causes gully erosion when it reaches the deeper soils at the base of the slopes. Sheet erosion on slopes was especially prevalent in the Katse catchment, this is where almost all the soil had been removed down to bedrock, aggravating gully erosion in the deeper soils at the base of these slopes (Figure 30).

Figure 30. Sheet erosion on mountain slopes in Katse catchment. This subtle form of erosion strips the thin soil down to bedrock.

Gullies that form in wetlands drain the water present, exposing and oxidising the peat below, and leading to further sediment losses. Peat acts to absorb and store surface and subsurface flows from the catchment areas. The water is then slowly released into the streams and rivers downstream. This helps to slow the flow of water into streams during high rainfall periods, reducing the impacts of flooding events and supplementing flows during dry months. This slowing of water also decreases erosion and flow of sediment downstream. Peat also acts as a major carbon store. When peat is exposed to air it oxidises and releases carbon to the atmosphere. Peat oxidisation was observed to be occurring in many of the wetlands in the study area. Peat formation is an extremely slow process, so once it has been dried out, oxidised and eroded, it is unlikely to recover.

The degradation of wetlands has been further exacerbated by heavy and continuous livestock grazing and associated trampling and creation of livestock paths. This has resulted in reduced wetland vegetation cover, making wetlands even more vulnerable to the erosive processes described above.

The degradation of grasslands and of wetlands in particular also affects the capacity of the landscape to trap sediments transported from eroded areas, and to assimilate nutrients that have entered the system from human settlements, agriculture and livestock. Wetlands are particularly efficient at the provision of these services, but only in situations where they retain their capacity to hold water. However, in the study area, most of the wetlands have become or are in the process of being transformed from perennial to ephemeral systems, and have lost their capacity to store water. The field studies noted that the gabions used to restore wetlands in some cases were able to restore some of the capacity for sediment retention, they were not efficient in restoring their water holding capacity (Figure 31).

Figure 31. Rock gabions and concrete structures used in restoration efforts in Katse wetlands. Note the lack of water retention behind the rock gabion compared with the concrete structure.

Observations made of the rivers in the study area confirmed that erosion is a significant problem. The increased sediment loads derived from degraded grasslands and wetlands during rainfall events ends up in the riverine habitats before being transported into the dam. Alluvial mining activities along the Malibamatso River and especially its tributary the Kao River, as well as mining further upstream in the Kao the inundation zone, have had dramatic negative impacts on water quality and turbidity downstream of these mining activities. Due to the fast flowing nature of the rivers, the increases in turbidity are fortunately probably fairly brief. It is only when the rivers approach the dam that the flows are slowed sufficiently for the sediment loads to be dropped. This was evident from the sediment deltas that had accumulated at the points where the rivers entered the dam.

River habitats did, however, appear to have been impacted by increased human populations in the catchment area. This was evident in the changes in pH and nutrient levels indicative of human wastes as well washing activities in the rivers that were downstream of human settlements. Nevertheless, changes in water quality were moderate from a water quality perspective for human use (insofar as what was measured, which excluded *E. coli*).

11.2 Introduction and spread of invasive alien plant species

Invasive alien species have been found to be a significant problem in the Katse Dam catchment, both in terrestrial and aquatic habitats. These include species of plants, fish, mammals and birds that have arrived both before and since the construction of the Katse Dam. While some of the plants are believed to have been present before dam construction, with exception to the invasive trout, all other animal introductions are thought to have taken place since dam construction.

In addition to the proliferation of native weedy species described above, grassland areas have become invaded by alien species such as the wild rose. It is an aggressive invader, and if left unchecked it will spread rapidly, covering many of the slopes which are currently grassland and used for grazing. This species has spread along pathways and roadsides, and is probably associated with human use. They may also be dispersed by frugivorous birds as is often the case in other parts of the world where this species is also invasive. Indeed people harvest and use the berries in various ways. In the Katse area it has become the dominant plant on many South-facing slopes, displacing indigenous species, and rendering it useless for grazing. These South-facing slopes and cliff-lines are the most vulnerable for invasion, and are also habitats for the most palatable grasses and have the highest diversity of montane species (many of which are endemic to the Drakensberg-Maluti mountains). These invasions are likely to be an indirect result of dam construction, resulting from the increased access to the area, and the increased human activity in the area.

The river habitats have been impacted by the invasion of alien trees. Invasive willows and poplar trees are often found along the stream and river courses in the Mohale Dam catchment (Figure 32). In addition, another invasive alien species, *Robinia pseudo-acacia* (Black Locust tree) is locally dominant in some drainage lines. These trees have replaced native bank vegetation, changing the habitats available for aquatic fauna, including birds. This lack of bank vegetation has also made the rivers more vulnerable to erosion as a result of livestock trampling. These impacts are not related to the dam. The trees were introduced for firewood, before the establishment of the dams, and have spread on their own. The trees are in fact valued for their supply of fuel wood.

Figure 32. Streams from Tiping village have all been completely over-run by *Salix fragilis*.

11.3 Impacts of human pressures on faunal populations

Changes in terrestrial and aquatic habitats brought about by increased grazing pressure and invasive alien plants is likely to have had an impact on fauna. In addition, the increased human activity was also expected to result in direct disturbance of fauna, such as hunting and disturbance of resting or breeding areas.

There were noticeable changes in the diversity and abundance of **mammals**. Generally, lower densities and numbers of small mammal species have been found in the current survey as a result of lowered carrying capacity of the grasslands as well as other forms of disturbance. Among the small mammals, the absence of certain more specialised species was consistent with a reduction in the quality of grasslands. Species associated with riverine habitats such as water mongoose and clawless otter were absent from areas where they had previously been sighted. These species have potentially been impacted by the inundation of riverine habitats as well as hunting by people and dogs. Efforts to protect the Upper Bokong Valley have proved worthwhile: the highest small mammal species richness, diversity and trap success were found here, as well as a diversity of larger mammals threatened by human activities in other parts of the Lesotho Highlands. A relatively large number of larger mammal species were also observed in the partially fenced off area around Katse dam wall and lodge. This is likely due to the fact that within these areas mammals are less vulnerable to human disturbances such as cultivation, grazing and hunting.

There was no detectable change in **reptiles** in the catchment area. This group was expected to be the most resilient, in that their habitats are least vulnerable to change as a result of from human activities. Reptiles feed on small terrestrial invertebrates, amphibians, other reptiles and on small mammals. Though some rodent species appear to have remained common, evidence suggests that the mammal abundance is declining in the study area, which may be expected to have an impact on reptile abundance. The presence/absence type of sampling used in this study would not have been sufficient to pick up anything other than major trends.

The community composition of **birds** in the study area has been demonstrably modified as a result of the environmental changes that have taken place related to the dam and its associated developments. Some species have benefited from the changes and others have decreased or even disappearing entirely in the face of these modifications. As expected, the inundation of the dam has had a major impact on waterbird populations. The most significant changes in this regard have been the disappearance of the black stork, a red data species, as a breeding bird, the large-scale decrease in the African black duck (both the stork and duck being river specialists), and a massive increase in the piscivorous white-breasted cormorant. Changes to the terrestrial landscape and associated human pressures have also driven significant changes in the terrestrial bird populations. For example, significantly different bird communities occur on agricultural lands than on natural grasslands, and in the grassland areas, the degradation of these habitats has been accompanied by a decrease in overall bird species richness and abundance. Some decreases may also have been due to hunting, for example relevant to some of the gamebirds. The loss of the iconic and 'critically endangered' bearded vulture as a breeding bird in the catchment is particularly distressing. The precise reasons for its retreat are unknown but are likely related to a combination of disturbance, direct persecution and enhanced mortality through indirect threats such as power-line collisions, all associated with the increased levels of human presence and pressure in the catchment.

This study picked up significant degradation of wetlands and some changes in water quality and sedimentation of rivers. While the changes in water quality were moderate from a human use perspective, they had had a noticeable impact on **aquatic macro-invertebrates**. There was no evidence that these habitat and food changes had any effect on **amphibians**. Despite extensive degradation to wetland systems, the current survey confirmed the presence of a large proportion of amphibian species recorded during the baseline and previous monitoring studies. Breeding activity was recorded for six of the nine species detected and many species were recorded widely throughout the catchment. Habitats for all recorded species remain available, despite increased vegetation degradation and loss within portions of the catchment. Species that were not recorded during this survey are thought likely to still occur within the catchment. However, as for the reptile component, the presence/absence type of sampling used in this study would not have been sufficient to pick up anything other than major trends.

River habitat changes and other human pressures (fishing) are unlikely to have been a significant factor in the changes of the **fish** communities observed in the rivers. The main habitat impact has been the loss of parts of the river system due to the construction of the dam, as well as the new habitat created by the dam. The rivers upstream of the Katse dam are occupied by alien fish species causing the main impacts on fish in the system. One of these species definitely existed in the catchment prior to the construction of the dam. This is discussed in Section 11.4.

11.4 Impacts of faunal invasions

Although rainbow trout was present before the Katse dam construction, it has subsequently increased in abundance, and has had a negative impact upon the native fish species living in the catchment. This impact would likely have occurred regardless and is not related to the building of the dam. These native species have almost been entirely excluded from rivers and are now in fact only persisting by being able to inhabit the dam and lower reaches of the rivers where the trout cannot survive. The second invasive fish, the brown trout is still at low densities, although it is expected that this species may further negatively impact native fish species as it is an aggressive predator.

Two invasive bird species, the common starling and the common myna were recorded near human settlements at Katse Lodge and Ha Lejone village during the current survey. Both these species are aggressive and territorial and may displace native species, as well as being potential crop pests. The presence of these two alien species, likely as breeding residents, at isolated villages deep in the Lesotho highlands emphasises the invasive capability of these birds.

The greater cane rat *Thryonomys swinderianus* was recorded for the first time during this study and is the first invasive mammal species recorded in the Katse dam and catchment area. This exotic species competes with the natural fauna and can cause significant ecological problems, especially in areas where their natural predators have become limited (such as in the study area). Similar to parts of the Free State, cane rats may have been intentionally brought to the Katse area as a sought after and easy-to-breed protein source.

11.5 Overall health of the catchments and biota

Taking into account the overall picture of the catchment presented by each of the specialist reports, each component was assigned a health class from A - Unimpaired to F - Critically Modified (Table 7). These assessments can help to prioritise the areas in which the most serious degradation has taken place, and so where urgent remediation action is required.

The most serious degradation and modification appears to have happened at the habitat level and is only beginning to be seen in the faunal species. The exception being the fish, which have been severely impacted by invasive trout. The interconnected nature of all these components makes the need to improve the health of the most degraded components even more critical. If not addressed, the degradation that has already occurred will likely continue to affect even the components that are now seemingly minimally impacted.

Table 7. Summary assessment of qualitative health class (A-F) for each component examined for Katse catchment.

Component		Health Class
Land cover	☹	D – Largely Impaired
Vegetation	☹	D – Largely Impaired
Wetlands	☹ ☹	E – Seriously Impaired
Rivers	😐	C – Moderately Impaired
Fish	☹ ☹	E - Seriously Impaired
Amphibians	☺	B – Minimally Impaired
Reptiles	☺	B – Minimally Impaired
Mammals	😐	C – Moderately Impaired
Birds	😐	C – Moderately Impaired

It should also be borne in mind that, even in groups considered not severely affected overall at this stage, particular species within those groups have been extremely hard-hit, to the extent of local extinction (as breeding species) or at least subject to major reductions in the catchment. Telling examples from the avifauna include the bearded vulture, black stork, red-collared widowbird and African reed-warbler in terms of local extinctions, and helmeted guineafowl, African black duck, neddicky and wing-snapping cisticola in terms of major decreases.

11.6 Overview of the probable causes

The probable linkages between human pressures and the state of the catchment observed in this study are summarised in Figure 33. This is similar to that for the Mohale Dam catchment, with the exception that there is an additional pressure from mining in the Katse Dam.

It is likely that the development of the dam and improved access to the area have led to a higher rate of population increase in this area than in other rural areas. While this study did not have access to sufficiently detailed population data to test this hypothesis, there has certainly been significant population growth. For example, in Thaba-Tseka which is mainly in the highlands, the population increased by 2.7% from 126 353 in 1996 to 129 881 in 2006, which suggests that the increase over the time period analysed in this study would have been in the order of 5%. However, satellite data suggest that agricultural land in the study area has more than tripled from 2% to 7% of the area. This strongly suggests a rapid influx of people into the study well above the levels one would have expected based on general population growth. While opportunities for work are likely to have been a big pull factor, land pressure in other areas may have been part of the reason that people have rapidly colonised the area after it became more accessible.

With improved access and movement of people, there is inevitably increased opportunity for the introduction and spread of alien species.

These developments have resulted in increased pressure from human activities in the catchment. More people has meant more land being transformed for agriculture, more livestock in the catchment, and increased land under settlements, roads and paths. Increased agriculture and livestock lead to the loss and degradation of terrestrial and wetland habitats. Grazing pressure, agricultural fields, roads and paths all contribute to the increased movement of sediment in the landscape, as described above. This in turn affects riparian habitats. Human activities also lead to increased inputs of organic and inorganic pollutants into the landscape, which is washed down by rains and ends up in aquatic habitats. Mining activities in and near the rivers, as it the case in the Kao and Malibamatso rivers, also add a considerable amount of sediment into streams, which also affects both aquatic and riparian habitats.

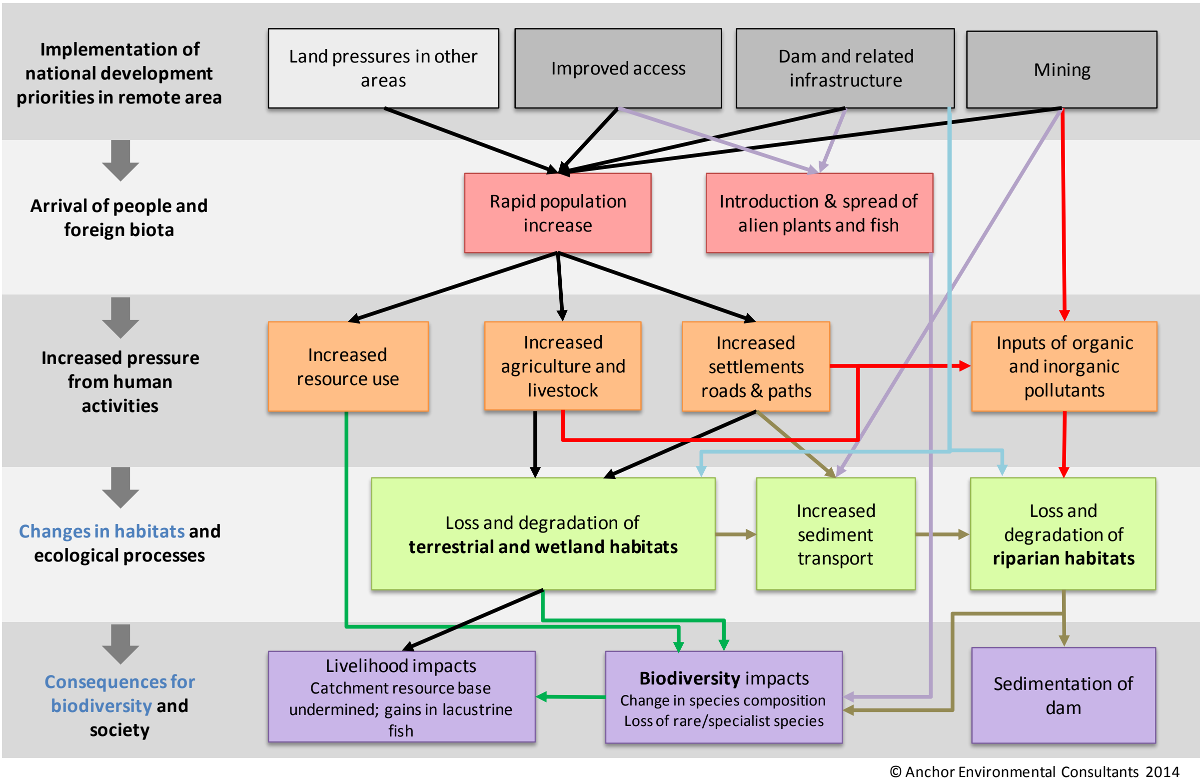

Figure 33. Schematic diagram of the chain of impacts of the dam development and other contributing factors.

The habitat changes have been described in detail in this study. The degradation of habitats brought about by overgrazing, invasion of alien invasive plants and to a lesser extent, pollution, have led to changes in habitat for biota. The more rare, specialised elements of biodiversity are giving way to widespread, common species. The introduction and spread of alien invasive fish have had a marked impact on river fauna. The degradation of habitats will also have led to reduced primary production and therefore an overall reduction in carrying capacity of the area for fauna, as is evident in the mammal and bird fauna of the terrestrial areas. In addition, the presence of more people in the area means that there will inevitably be increased utilisation of flora and fauna, with potentially significant impacts on biodiversity, as has been seen with the almost complete loss in the spiral aloe in the Mohale Dam catchment, and the reduction in certain mammal and bird fauna in both catchments. The impacts on faunal biomass are to some extent reversed in the dam, which contains a high biomass of fish and birds. However, from a biodiversity perspective, these are not viewed as "gains".

11.7 Other implications

Apart from biodiversity, the subject of this study, these developments also have important implications for water supply and for the livelihoods of people living in the area. The concern that decreases in vegetation cover and increases in erosion within the dam catchments could result in silting up of the dams is not new (Quinlan 1995). Sedimentation undermines the performance of dams and can severely limit the lifespan of large dams (WCD 2000). Changes in land use within dam catchments have been directly implicated in being a cause of increased sedimentation of dams (Harden 1993). Erosion rates are much higher under cultivation than natural vegetation (Montgomery 2007) especially on steep cropland (Pimentel et al. 1995). Loss of natural vegetation cover also contributes heavily to increased erosion (Pimentel et al. 1995). This report documents increases in the extent of cultivated fields as well as decreases in vegetation cover, which have likely accelerated erosion rates. The loss of peat in wetlands, severe gully formation and sheet erosion on hill slopes are all evidence that sediment is being lost from the catchment. The severe degradation of many of the wetlands also reflect a reduced ability of wetlands to trap sediment before it reaches the rivers and dams. Turbidity and sediment were not detected in the river surveys, although these measurements were only taken during the late dry-season low-flows. Observations of specialists during field surveys did however notice sediment deltas close to the river-dam interface. Measuring sediment deposition within the dam was beyond the scope of this study, but the degradation grasslands and especially the rapid erosion of the wetlands, should be of serious concern to the LHDA.

Degradation of the grasslands negatively impacts the long-term grazing capacity and hence the ability for livestock rearing to provide a sustainable livelihood for the rural Basotho people. Decreases in overall grass cover as well as invasion by shrubby species result in less food available for livestock. Simultaneous increases in the proportion of unpalatable vs. palatable grass also further decrease the grazing capacity of the area. These impacts will result in the inability of the catchments grasslands to support the number of livestock. What this means in practice is that livestock health would be adversely affected, production levels would decline and a drought would lead to more mortality than has been seen in the past.

Erosion and increased water run-off results in loss of organic matter content in the soils due to the drier soil conditions and shorter vegetation (Du Preez & Brown 2011). This will impact upon the productivity and fertility of the area, affecting grasslands, but also making fewer areas viable for any further cultivation. In addition, and drying out wetlands and adjacent areas may also negatively impact upon cultivation on the edges of these wetlands. These factors combined indicate that the long-term sustainability of the currently cultivated fields is limited, and areas suitable for replacement of these fields are becoming fewer. This further limits the sustainable livelihood options for people living within the dam catchment.

The degradation of the grasslands and wetlands will likely have a negative effect on tourism in the area. Currently tourism ventures such as Katse, Mohale and Likaleng Lodge rely on the beautiful scenery and environment of the catchments to draw tourists to the area and activities are based around exploring the outdoors such as hiking, birding, 4x4 driving and pony rides. If the vegetation cover continues to decline and the bare ground, livestock paths, erosion and gully formation increase, the appeal of the area to tourists will be severely diminished. The LHDA has invested substantially in tourism as a means to support rural livelihoods in the area. The continuation and future success of this programme, and the livelihoods of many people, are threatened by the degradation of the catchment's environment.

The decreasing health of the river systems is of concern not only biodiversity, but also directly to people's health. Although the water quality parameters measured in this study were all within allowable limits, they did show decreasing quality downstream.

Invasive alien species are one aspect where people have benefited at the expense of biodiversity. The invasive alien trees and invasive shrubs provide a source of fuel, and increased fish biomass in the dam, though currently underutilised for cultural reasons, holds potential as a food source. Nevertheless, these benefits are rather small in comparison to what is at stake in the catchment as a whole. Invasive alien species like the cane rat, one the other hand, have been known to become agricultural pests which could have detrimental effects on people's livelihoods if they were allowed to become widespread.

12 RECOMMENDATIONS

12.1 Addressing the problems observed

In order to address the problems observed and documented during this survey, a number of actions need to be taken. In order to sustain productive ecosystems that will continue to support rural livelihoods into the future, as well as limit erosion and sediment run-off into the dam, the pressure currently placed upon these ecosystems needs to be reduced. In some cases, reduction of pressure will not be sufficient to restore productivity and ecosystem function and services to habitats, in which case active restoration efforts need to be conducted.

12.1.1 Reduce grazing pressure on rangelands

In the early stages of degradation, changes are mainly seen in vegetation cover and demography of the plant species (Milton *et al*. 1994). This type of degradation, as is the case in most of the dam catchments (especially within 1.5 km of the dam) can be controlled and repaired through strict rangeland management. As grasslands continue to degrade, as species are lost from the system and function is impaired, the cost and effort require to restore productivity and biodiversity escalates dramatically (Milton *et al.* 2003).

To ensure the long-term productivity of rangelands and conservation of the important biodiversity, both fire and grazing should be properly managed within the dam catchments. Mesic high-altitude grasslands such as these generally recover slowly from damage which kills adult plants, but can recover quickly after burning (dependent on the rainfall and season). These grasslands can be sensitive to woody shrub encroachment. If not burnt or sufficiently grazed, dead plant material can build up reducing the vigour of the system. Burning too frequently, e.g. to get a green flush for sheep, or high grazing pressure can also cause shifts in species composition and lower vegetation cover. The South African National Biodiversity Institute (SANBI) produced general guidelines for using grazing and burning to manage grasslands for biodiversity and livestock production (SANBI 2014). The main principles relevant to high-altitude mesic grasslands such as those in Lesotho are outlined below. It is important to understand, however, that this is not a prescriptive list of rules, and any action should be informed by continued research and conditions on the ground.

- **Grazing** - Most importantly, the number of livestock on the range should be determined by the carrying capacity of the land in order to prevent overgrazing. Current indicators suggest the stocking rate within the catchments is too high and should be decreased. In addition, grazing should be rotated so that each area gets a full year's rest every 4-5 years. Grazing on steep slopes during wet periods should be avoided to limit erosion. The current grazing strategy of the wetlands in the catchment needs to be addressed urgently. Some form of rest period needs to be implemented.
- **Burning** - Burning carried out too frequently or in summer/autumn can be detrimental to the grassland. Autumn burns leave soil exposed for long periods, which will likely further increase erosion. Generally the best timing for fires is during late winter or early spring in order to get rid of residual material and promote high quality graze in the following season. Burning during this time of year, prior to the start of the growing season, does not damage

the growth points of the plants. Depending on the condition of the grassland, grazing regime as well as current conditions, burning should be conducted in any one area every 2-5 years. Burns should aim to create a mosaic of burnt and unburnt land rather than burning large continuous areas.

- **Variability** - Different components of the ecosystem will respond to grazing and burning management differently, also depending on current conditions. For these reasons it is very important to include variability into the design of the rangeland management scheme. This variability should not only be in the timing of grazing and burning, but also in the geographical location and extent.
- **Adaptive management** - Different components of the biodiversity can respond differently to management actions. The effect of burning is dependent upon the exact timing of the fire, the fuel load and moisture content of the plants as well as weather (recent rainfall, wind, temperature and humidity). As such, any form of management of the grasslands in the catchment needs to be adapted to current conditions and informed by changes in grassland condition.

Reducing stock numbers within the catchments is the first and most vital step required to reduce the pressure on the rangelands. Livestock serve multiple functions to the rural Basotho such as for milk, meat, cash sales, transport, manure for fires and fertilisers as well as cultural traditions (Turpie & Scovronick 2007). Thus, to decrease the numbers of livestock, solutions will need to be social in nature and are beyond the mandate of this contract. A brief overview of a number of potential options to address the situation is however provided here.

In order to reduce the number of livestock on the rangeland, alternatives need to be found for the functions that livestock play to the occupants within the catchment. An example is providing micro financing options which will discourage people from keeping excess livestock as storage of wealth/insurance policy (Anderson *et al*. 2002). In South Africa's Eastern Cape, the increase in welfare pensions and access to jobs had the effect of shifting people's reliance away from livestock rearing as the main livelihood strategy (Hajdu 2006).

Another option is to use incentives (either positive or negative) to encourage people to lower the number of livestock they keep. Negative incentives such as taxes or levies can be applied to the number of livestock grazing on the communal rangeland in an attempt to discourage people from keeping extra livestock. Alternatively, subsidies could be given to people in return for grazing fewer animals, or by guaranteeing a price for sales of livestock to reduce the need to increase livestock numbers.

None of these options should be undertaken without an in-depth socio-economic study of the dam catchments to determine the reliance on natural resources for local livelihoods. Such a study would also need to assess the willingness of the different stakeholders to participate in any intervention and would be able to more accurately assess which management option would most likely be successful. The current responsibilities for range management are spread across different sectors within the government of Lesotho nationally, as well as some responsibility falling to LHDA within the dam catchments. As such, considerable co-ordination and co-operation between these sectors will need to be facilitated. Any decisions should be made in the light of thorough evaluation of previous attempts already made to try and manage rangeland resources Lesotho highlands (see Table 8).

Table 8. National regulations and programme aimed at reducing the land degradation caused by overstocking of livestock on communal rangelands in Lesotho. Adapted from Chapeyama 2004.

Management body	Period	Responsibilities
National Rangeland Management and Grazing Control Regulations	1979-1992	• Gave Principal Chiefs authorities over grazing land and institutionalise traditional rotations grazing system by setting aside closed areas and issue grazing permits
	1992-93	• Development Councils took the place of the Chief in range resource administration and control • Grazing fees were introduced
	1993-1999	• Grazing fees removed
	1996-onwards	• Grazing control now responsibility of urban, rural or community councils depending on location
Land Conservation and Range Development Project	1980-1987	• Strengthen institutional capacity within the ministry of Agriculture • Staff training • Prototype range management area (RMA) established • First grazing association of 11 villages established
Lesotho Agricultural Policy Support Programme	1988-1993	• Introduced policies and regulation to introduce grazing fees to regulate livestock numbers • Rangeland adjudication, training and organising Village Development councils to collect and manage fees

The issue of overgrazing and overstocking, especially on common land is complex that has been battled with worldwide. Addressing the current rangeland management system is going to require input from multiple sectors, including government but more importantly must include all relevant stakeholders and be carried out in conjunction with ongoing scientific socio-economic as well as environmental research.

12.1.2 Restoration and conservation action

Urgent interventions are required in the catchment to prevent the further deterioration and ultimately the loss of the catchment's unique wetland systems. It must be noted that the wetlands surveyed in this study were only a subset of the wetlands within the Katse catchment. It is of critical importance that any strategy would also need to include the prioritisation of all the wetlands and associated catchments for intervention. For wetlands Ka 26 and Ka 27, in the catchment of the Afriski Resort, it is recommended that a Wetland Management Plan (WMP) be drawn up for the catchment, particularly to try to protect the remaining parts of wetland Ka 27 as well as wetland Ka 26, to help inform planning and further development going forward, and to ensure the long term viability of water supply in this catchment, an aspect that both the wetlands and resort are dependent upon. Also of significant importance is the utilisation of the rehabilitation structures in prioritised peatlands to successfully rewet these systems by raising the water table. It must however be emphasised that the success of any rehabilitation effort will also depend on addressing the rangeland management issue, without which rehabilitation is unlikely to succeed.

It is recommended that protection efforts in the Bokong Nature Reserve are continued, but with increased control of human activities and grazing by domestic stock. LHDA should also maintain controlled access to the current security zones around the Katse dam wall and lodge. Such informal conservation areas may ensure the protection of species that do not occur in the higher altitude areas of the Upper Bokong Valley. For example, areas that are known to and likely to support the frog *Amietia vertebralis* (the upper valleys in the Bokong and Pelaneng River catchments) have conservation significance and continued and increased protection and appropriate management of these areas would be of biodiversity-conservation value.

Additional conservation areas, with regulated grazing areas, can provide refuge areas for mammals (and other fauna) that can protect representative populations of animals and thus provide an important contribution to conservation of Lesotho’s biodiversity. Extending the protection from over-grazing currently being implemented at Bokong Nature Reserve to a wider area in the catchment, to the benefit of species such as yellow-breasted pipit and African quail. Remaining intact riparian habitat should also be conserved and protected from stream bank scouring and trampling by livestock. These riparian zones, when naturally vegetated, serve as important faunal habitats. In addition, granting formal protection status to ‘bird island’ the large colonial waterbird locality in the dam, could help protect breeding waterbird populations.

The establishment of an artificial vulture feeding site in the catchment area could entice the endangered bearded vulture back into the catchment to breed as well as benefit the cape vulture. This could also function as a tourist attraction within the Katse catchment.

12.1.3 Control invasive species

Urgent measures need to be taken to control the spread of alien invasive species, although this needs to be linked with appropriate research on these invasive species. Programmes similar to the Ministry of Forestry and Land Reclamation’s Sustainable Land Management Project, whereby voluntary community groups are encouraged to remove invasive shrubs such as *Chrysocoma* could be initiated to help improve range condition as well as control invasive shrubs.

In addition to controlling plant invasive species, invasive and domestic animals also need to be controlled. Dogs are considered one of the major factors threatening small and large mammals in the study area. Stricter control of them, such as a ban or limit on the number of dogs, even if only in some areas, are expected to have a marked beneficial influence on mammal species diversity and ecosystem health in the Katse Dam and catchment areas. Enforcement of a seasonal grazing/vegetational rest regime would benefit mammal abundance and diversity if herders and their dogs can routinely be kept out of specific areas for a period of time.

Brown trout are listed among the World’s 100 Worst Alien Invasive Species (Lowe *et al*. 2000). They are more aggressive predators than rainbow trout, consuming a diet largely of large prey items like fish, amphibians and crabs, and can have a severe impact on indigenous fish populations. The appearance of brown trout in the Bokong River and Katse Dam is therefore a major concern for biodiversity. Specific recommendations on how to eradicate this predator from Katse Dam catchment are made in the specialist report.

12.1.4 Plan infrastructure carefully

Future infrastructure, including roads and other developments, need to be properly planned to take into account the impact they will have, especially on water run-off and subsequent erosion. Road network densities in these catchments should be kept as low as practically possible and any new roads or developments need to be constructed to high standards with proper drainage. Maintenance of roads and structure drainage, stream crossings, surface conditions and more should be undertaken on a regular basis, and incorporated into catchment management plans. Considering that the sensitive nature of the areas biodiversity, we recommend that environmental impact assessments have a strong biodiversity components including appropriate specialist studies.

12.2 Future research and monitoring

12.2.1 Continue regular monitoring with improved protocols

The current protocols and methodology used for monitoring could be improved in future surveys to allow a better understanding of the effects the dam is having on biodiversity within the catchment. Firstly, monitoring needs to be conducted more frequently. The last monitoring in Katse was conducted in 2000, leaving a 14 year gap until this current survey. Monitoring of all components should be conducted, at an absolute minimum, every 5 years. Having data on a finer time-scale will provide more confidence that trends seen are due to actual changes in biodiversity rather than fluctuations caused by climatic differences between years.

For some components recommendations were made regarding to improving the sampling protocol:

- **Land cover** – considering this component doesn't require intensive on-the-ground sampling, monitoring land cover change remotely could be conducted at a finer time-scale than other components.
- **Vegetation** – (i) monitoring should be continued, and preferably at more frequent intervals, even if only at selected sites. A set of sites prioritised for regular monitoring is provided based on accessibility, sites which have shown a decline in rangeland condition, as well as other that are currently regarded as representing healthy rangeland. However, long term monitoring of all sites is still crucial; (ii) monitoring teams distinguish between bare soil and rock when recording what the vertical pointer is placed on. The use of a specific code for rocks (>10 cm in size) will enable the more accurate assessment of not only bare soil, but also degree of rock cover.
- **Wetlands** - Monitoring should continue on a 5-yearly basis, repeating the same methods as this study, but with more detailed peat sampling of selected sites. Monitoring should continue on a more frequent basis at the MCA rehabilitation sites Ka 09 and Ka 10, where the interventions implemented seem to have produced varying results. These sites provide

an ideal opportunity to learn and apply adaptive management when it comes to rehabilitation intervention. Monitoring should include peat transects for a more comprehensive dataset to document any changes in the peat profiles over time.

- **Rivers** - All data should be entered into the existing River Health Database (RHDB). This database was created to provide a central area to which all biomonitoring data collected in southern Africa could be submitted. Additionally all future reports should include the raw data collected during monitoring.
- **Fish** - understanding of the dynamics of non-native fish invasions, and interactions with native species in the Mohale catchment area would be greatly improved by (i) conducting fish surveys during other seasons (especially during summer high flows) and (ii) installing data loggers at strategic sites to monitor key environmental variables (such as temperature and flow) on a continuous basis.
- **Amphibians and reptiles** – (i) monitoring should take into account seasonality of amphibians and reptiles and so sampling should take place earlier in the rainy season (Sep-Dec) to improve detection and (ii) further inclusion of fish-survey bycatch results.
- **Mammals** – (i) it is strongly recommended that small mammals are sampled according to a standardised protocol, for at least three nights (preferentially four), and during the period mid to late-autumn; (ii) trapping on trap lines rather than on grids (as trap lines cover a larger area per number of traps used - Pearson and Ruggiero 2003); (iii) removal trapping with snap traps should be considered (due to its greater effectiveness compared with live traps and the fact that more traps can be carried; they are also less obtrusive and have a greater chance to not be tampered with); (iv) the number and spacing of traps (trapline length should be at least 200m, and 5m spacing between traps is recommended; Ferreira & Avenant 2003); (v) sampling should best take place at the end of the breeding season (March-April; Avenant 2011); (vi) trapping for at least three nights and days (Avenant 2000, 2011; Avenant & Cavallini 2007); (vii) to use the same kind of bait throughout (a mixture of peanut butter, rolled oats, sunflower oil and marmite is widely used and effective to sample both rodents and shrews); and (viii) to standardise how often traps will be checked and rebaited (e.g. early morning and at sunset).
- **Birds** – monitoring should be continued in a similar fashion, covering all species to at least a cursory level (bird lists), most species at some level of detail (transect counts), and several species in comprehensive detail (cliff-nesting species and waterbirds), and the value of this broad-based approach has been demonstrated throughout this monitoring effort where significant but unexpected changes occurred in some species. Days spent monitoring in the catchment however should be increased to allow adequate coverage of all grid cells in the entire catchment. In addition, particular attention should be paid to monitoring populations of terrestrial gamebirds.

12.2.2 Modify list of key indicator species

A more thorough list of key species should be compiled before the next round of monitoring, including reasons for choice as well as previous locations they were detected.

Two plant species were suggested for addition to the list of key species in the Katse region (i) *Kniphofia northiae*, which was encountered in the upland grasslands near Tiping. This species occurs infrequently in the area and is mainly found in the Drakensberg, with outlier populations know from places like the Hogsback in the Eastern Cape. (ii) *Euryop inops* which was located in a ravine below Ha Lejone (next to the gravel road before it crosses the narrow bridge), and on the island of Thabana-li-Male (at Plot 88). This species if of considerable rarity, and these two populations represent a substantial number of the known plants. Unfortunately, both populations are in imminent danger of being overrun by the invasive *Rosa rubiginosa*.

The key species listed for the amphibian monitoring included frogs were *Rana spp*., *Heleophryne* sp and *Xenopus laevis.* These were suggested as possible sensitive indicators of water quality (LVAb). It must be noted that these species have undergone name changes and are currently named *Amietia quecketti*, *Xenopus laevis*, *Amietia umbraculata*, and *Hadromophryne natalensis.* The first two are in fact fairly tolerant of a variety of conditions and some degree of degradation and may not be the best choice of indicators. *Amietia umbraculata*, although also not particularly sensitive to all impacts, it is a riverine-specialist species and should be considered a sensitive species and possibly an indicator of ecological health, whose continued presence should be monitored. *Hadromophryne natalensis* can be considered sensitive, given its need of rocky rivers with perennial flows for the tadpoles that often take over a year to develop, and its requirement of relatively clear, unsilted, rocky streams. To these two species, *Amietia vertebralis* should also be added as it is reliant on upper headwaters of streams, is largely aquatic and it may also suffer from degradation of these habitats from changes in land use.

Mammal key species listed included small mammal species forest shrew *Myosorex varius*, vlei rat *Otomys irroratus*, ice rat *Otomys sloggetti* as well as large mammal species jackal, caracal, African wildcat, grey rhebok, porcupine & rock hares. Both small and large mammals have been described as good indicators of ecosystem integrity (see Avenant 2011, Avenant & Schulze 2012). Where small mammals react relatively fast to natural and human-induced environmental changes, larger mammals are good indicators for habitat changes over a longer period and or larger area. The number and diversity of shrews (insectivores) are also an indication of habitat integrity. Additionally, the specialist species such as the grey-climbing mouse *Dendromus melanotis* may give a good indication of ecological integrity as they are generally only associated with pristine grassland habitats. The numbers and diversity of carnivores are in general good indicators of biodiversity and general ecosystem health as they are directly dependent on consumers (and not plants). In addition to the carnivores listed, small/medium sized carnivores like mongooses may act as good indicators or ecosystem health as well.

Relevant to birds, the previously identified key indicator species were Swainson's spurfowl, black-shouldered kite and the white-breasted cormorant. Gamebird species such as Swainson's spurfowl are likely to attract attention from hunters, so it could be useful indicators of increases in human disturbance. However, it should be borne in mind that Katse supports three other terrestrial gamebird species (grey-winged francolin, common quail and helmeted guineafowl), all of which are more abundant and widespread in the catchment than Swainson's spurfowl and so should be considered as equally or more suitable for monitoring as priority terrestrial gamebird species. Diurnal raptors such as the black-shouldered kite are good indicators of rodent populations; however this species is also too infrequently encountered in Katse to be able to infer impacts. The jackal buzzard is more common, breeds within the catchment and is less specialised making it a better indicator relevant to indirectly monitoring rodent populations at Katse. The white-breasted cormorant remains a valuable indicator species relevant to fish populations in the dam and should continue to be monitored. In addition to these three groups, it is suggested that all eight of the red data species which occur at Katse on a regular basis should be regarded as priority species for monitoring and management consideration. These species are: bearded and cape vultures, black harrier, lanner falcon, southern bald ibis, black stork, and African rock and mountain pipits. The recent colonising Egyptian Goose should also be closely watched as a potential crop pest in the future.

12.2.3 Undertake continuous monitoring of drivers of habitat change

Long term, continuous data are needed on several parameters in order to better interpret the results of sporadic monitoring studies on biodiversity:

- **Rainfall** – Range gauges should be installedand measurements recorded daily.
- **Water flows and quality** - Data loggers should be installed at strategic sites in rivers to collect data on temperature, flow and other key environmental variables over appropriate temporal scales. This will allow better understanding of hydrology and of the interplay between non-native fish, environmental conditions and native fish populations.
- **Population and livestock** - Population, herder and livestock numbers should be recorded annually within the catchment areas, preferably at the village scale.
- **Grazing and burning patterns** - Grazing and burning patterns should be recorded systematically on a continuous basis. Grazing patterns should record which areas have been set aside from grazing and for how long. And well as which areas are grazed at different times throughout the year. Burning monitoring should record both the season and extent of fires.

12.2.4 Further research

The specialist studies came up with a range of areas for which future research should address in order to fully understand the dynamics of change within the Katse dam catchment and the drivers causing it.

The spread and impact of alien invasive species must be monitored and researched (including native species which increase under degradation like *Chrysocoma ciliata* and *Artemisia afra*). Control measures to limit the spread of alien invasive species must be linked with appropriate research to understand these invasive species. This may be somewhat problematic, as the villagers use these as either domestic resources (e.g. fuel and construction material in the case of *Salix fragilis*) or for financial gain (harvesting fruit for sale to the food industry in the case of *Rosa rubiginosa*). The role of frugivorous birds in the dispersal of the seeds of *Rosa rubiginosa* calls for investigation.

There is a need to initiate, facilitate and fund ongoing scientific studies to obtain a better understanding of ecosystem function, threats and conservation. The removal of the livestock by means of relatively small exclosures (20 x 20 m), and the subsequent monitoring of vegetation changes within these plots would be informative in terms of developing a rangeland management strategy. This would need to be done in collaboration with the Lesotho Department of Range Resources Management.

A dedicated specialist should be appointed to source and clean the existing macro-invertebrate data. For example, the aquatic invertebrate data exists in different formats, with some misidentification due to limited taxonomic guidelines. In some cases, voucher specimens are still available, and need to be checked against new techniques. The cost associated with such an exercise will be minimal compared to the time required to access scattered data in different and user unfriendly formats.

It is recommended that a hydrological monitoring programme is developed in conjunction with a more frequent wetland monitoring programme (at least every 5 years), not only to monitor these observed changes, but also to determine the extent of the change and trends and to understand the consequences of such changes in terms of water supply in the long term. This would also test the hypothesis that the runoff patterns are changing, with a reduction in perennial baseflow and increased prevalence of seasonal elevated high flows of shorter duration, an aspect that is contributing to the further degradation of the wetlands and the catchment itself. Such a programme should include the monitoring of the shallow groundwater (interflow component) which is expected to be the main 'loser' as infiltration decreases and surface runoff becomes more prevalent. Certain wetland types, namely those driven by interflow such as the peatlands, together with their catchments, provide ideal sites for monitoring surface and subsurface flow interactions.

The disappearance of the 'critically endangered' bearded vulture from the Katse catchment as a breeding species may be symptomatic of a wider decline in the fortunes of the species and begs for a broader survey of its current status in the Lesotho highlands, its last remaining southern African stronghold.

Finally, in order to understand the changes seen in habitats and biodiversity within the dam catchments, it is vital that the human component also be studied. In order to make informed choices about future management of the catchment, a sociological study to determine the reliance on natural resources (including livestock grazing, fishing, hunting, as well as harvesting grass and products from alien invasive) for local people living within the catchment must be conducted.

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14 APPENDIX 1: SCOPE OF WORK

1.0. BACKGROUND

The Lesotho Highlands Water Project (LHWP) is implemented pursuant to the Treaty between the Government of Lesotho and the Republic of South Africa. The Lesotho Highlands Development Authority (LHDA) is the implementing Authority reporting to the LHDA Board and the Lesotho Highlands Water Commission (LHWC).

Project implementation within Phase I involved construction of dams, tunnels, access roads and bridges. During construction it was necessary to have ancillary developments such as extensive infrastructure including construction camps, villages & implementation of the Environmental Action Plan (EAP) made up of four key plans which include Public Health plan, Compensation & Resettlement plan, Rural Development plan and Natural Environment & Heritage (NEH) plan. An essential component of the NEH action plan is a long term monitoring program which should collect and analyze data on the impacts of the LHWP on the biophysical & socio-economic environment of the Project area.

2.0. RATIONALE

Biological Resources Monitoring of the impacts of the LHWP activities on the biophysical environment has to be carried out in order to provide a basis for impact identification, quantification, and mitigation. The biological monitoring is an essential component of the long-term monitoring program, and has to follow and build on the data collected during the Baseline Biological surveys of both Phase 1A and 1B of 1983, 1990 and 1995.

Routine biological resources monitoring was carried out in 2000 lo 2002 for Phase 1A and 1B under LHDA Contracts 615 and 1053 respectively as a follow up to the Baseline studies alluded to above. These studies recommended key components to be monitored as vegetation, birds, terrestrial invertebrates, mammals, aquatic fauna and wetlands. The studies further recommended that monitoring should be repeated after every five (5) years. lt is against this background that this scope of services is drawn.

3.0. OVERALL AIM AND OBJECTIVES

The main aim of the Biological Resources Monitoring Project (LHDA Contract 1273) is to provide a long term base of data and information on the status of the taking into consideration the Key floral and faunal species. The LHDA is seeking the services of a Professional Service Provider to:

i. Use GIS and remote sensing as primary tools to collect floral data from Phase 1 catchments of the LHWP and to validate information using the existing fixed vegetation transects in the sub-catchments;
ii. Determine the seasonal changes in cover, species composition and extent of eroded surfaces using specific transects within the sub-catchments;
iii. Assess the impacts of land-use, grazing and project related activities on vegetation cover, composition and associated fauna varieties and their distribution;

iv. Using relevant indicators, determine the impacts of the project developments and associated factors on vegetation, animal and insects species;
v. Identify mitigation measures to enhance vegetation cover and animal species and determine their optimal composition in the area. These measures should be provided as recommendations within each specialist report; and
vi. Provide long term database, information and complementary data on the key terrestrial fauna, vegetation cover, and aquatic fauna, taking into consideration occurrence, distribution and abundance of rare species.

3.1. Monitoring of Flora

It was anticipated that implementation of Phase 1 of the LHWP would reduce available land through inundation and development may impact on the remaining biological resources. Biological monitoring and surveillance of flora is necessary to assess the changes caused by these constraints on the existing indigenous vegetation. The baseline studies identified 137 vegetation transects (plots) within the Phase 1 catchments (87 in Phase lA and 50 in Phase 1B). Monitoring and analysing changes on the flora will take place in these catchments using remote sensing and GlS. There were a number of key indicator species that were identified by the baseline studies that have to be given priority during monitoring. These include both rare and endangered plant species as follows: (*Aloe polypgylla, Delosperma ashtonii, Kniphofia thodei*) and species of *Rhodohypoxis* and endangered habitats (*Leucosidea* woodland, *Thamnocalamus tessellates*).

3.2. Monitoring of Terrestrial Fauna and Birds

It was thought that Phase 1 would cause changes in food webs as a result of habitat alterations and loss, and changes in land use patterns. Changes in food webs may adversely affect rare or endangered species including the 10 Red Data-listed species already identified as occurring in the Mohale Catchment by previous studies. Using appropriate methods, which might include, but not to be restricted to trapping, netting catching and. observation on terrestrial invertebrates, mammals, birds, amphibians and reptiles should be deployed at the wide catchments of Phase 1 and Phase 2. The key indicator terrestrial and birds' species to be closely monitored are:

i. The faunal species include Myosorex varius, Otomys irroratus & Otomys sloggetti, locally endangered species such as jackal, caracal, African wildcat, grey rhibuck, porcupine & rock hares;
ii. The birds species are White-breasted Cormorant, B lack-should ered Kite and the Swainson's Francolin; and
iii. The Amphibia species are the two species of Rana, one species of Heleophryne plus the Xenopus laevis.

3.3. Monitoring of Aquatic Fauna

It was anticipated that implementation of Phase 1 would cause physico-chemical changes and increase in levels of pollution and toxicity of the aquatic environment. The benthic macro invertebrates' distribution is considered a reflection of the surface water quality and therefore the aquatic eco-system's health. There is a need to undertake habitat integrity assessment, river classification and sediment analysis, water quality sampling, aquatic macroinvertebrates sampling and fish population studies. Monitoring and analysis of aquatic fauna should employ methods at sites established in the baseline study and subsequent monitoring, or equivalent. The key aquatic indicator species to be monitored include indigenous fish species such as smallmouth yellow fish (*Barbus aeneus*), *Labeo capensis, Austroglanis sclateri* and the Maloti Minnow - *Pseudobarbus quathlambae*.

4.0. APPROACH

The Approach to the Scope of Services should address at least the following key Tasks as listed below:

a) Task 1
Review existing data and information, and establish continuity with previous LHDA studies and other studies carried out regionally that have relevance to the monitoring of biological resources, particularly in the LHWP;

b) Task 2
Undertake qualitative and quantitative biological resources surveys of the key indicator species of biota and habitats;

c) Task 3
Collecl biological specimens and recommend storage methods and facilities Threatened and/or endangered birds, animal and plant species should not be collected. At the conclusion of the study, all specimens to be correctly identified, labelled and preserved and then presented to the recommended facility which shall be a National Biological Bank, such as the NUL herbarium, as museum voucher species;

d) Task 4
Produce spatial and seasonal vegetation and animal distribution maps of key indicator species using a remote sensing and/or Geographical lnformation System (GlS) or equivalent;

e) Task 5
Assess the ecological inter-relationships between the main biological components, identify, compare and explain any changes with baseline data, time and space;

f) Task 6
A biological resources inventory shall be established as a computer database comprising all archival and information gathered in this study. Data management issues such as data handling, archiving and interpretation shall be provided to LHDA to sustain the biological resources inventory.

g) Task 7
Reporting should be of the highest international standards in terms of, format and quality based on the outputs as detailed in Section 5 (a) below.

5.0. DELIVERABLES AND PAYMENT SCHEDULE

a) Deliverables

All deliverables shall be submitted to the LHDA in fifteen (15) hard copies and in electronic form Microsoft Word format. The reports shall be considered as "drafts" upon initial receipt until accepted by the LHDA. Any concerns and comments on the reports will be provided within three (3) weeks of receipt.

No.	Deliverable	Time Frame (weeks)
1	Draft Inception Report with Analysis Framework, detailed Work-plan and timelines	4
2	Final Inception Report as in 1. above	6
3	Summer field survey and report	16
4	Winter field survey and report	36
5	Final technical Specialists reports	40
6	Draft copies of Main report & executive summary	45
7	Final copies of Main report & executive summary	48
8	Fully functional database & contract closure	52

b) Cost Proposal and Payment Schedule

The Consultant shall provide a fixed price cost proposal for each task assuming a level of effort of specialists involved. Payment shall be made in accordance with the schedule below.

No.	Deliverable	Payment proportion (%)
1	Draft Inception Report with Analysis & reporting Framework, detailed Work-plan and timelines	0%
2	Final Inception Report as in 1. above	10%
3	Final Specialists reports – Summer survey results	10%
4	Final specialists reports – Winter survey results	10%
5	Draft copies of Main report & executive summary	20%
6	Final copies of Main report & executive summary	40%
7	Fully functional database & contract closure	10%

6.0. TIMEFRAME

The study will be carried out over a period of '12 months by the preferred service provider.

7.0 REFERENCE DOCUMENTS

The consultant will be allowed to access, review and make reference to some of the technical documents that bear relevance to Biological Resources Conservation/monitoring. Apart from the reference materials listed below, the consultant may decide to include other relevant literature that would help to successfully complete this study.

List of selected documents to serve as Reference include the following

1. The 1986 Treaty on Lesotho Highlands Water Project,
2. Environmental Action Plan on Phase 1 of 2002).
3. Baseline Biological Surveys for Phase 1A & Phase IB of 1983, 1990 and 1995.
4. Volume 1:Executive Summary of the Baseline Biological Survey,

5. Volume 2: Specialist report on Flora - Baseline Biological Survey,
6. Volume 3: Amphibians and Fish specialist Report - Baseline biological Survey
7. Volume 4: Mammals - Baseline Biological Survey,
8. Volume 5: Reptiles - Baseline Biological Survey,
9. Volume 6: lnvertebrates - Baseline Biological Survey
10. Volume 7: Birds - Baseline Biological Survey
11. Volume 8: Synopsis and monitoring - Baseline Biological Survey
12. Biological Resources Monitoring Reports for phase 1A & phase 1B of 2002,
13. Specialist reports associated with phase 1A (LHDA Contract 615) & 1B (LHDA Contract 1053) 2002 Biological Monitoring reports.
14. EIAs for Phase 1A & Phase 1B of 1990 and 1997 respectively,
15. National Environment Act 2008,
16. Any other reports that may be found suitable while executing this contract.