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Full Length Research Paper

Assessment of biodiversity, socio-economic status and sustainable development options at Mlawula, Swaziland

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An assessment of biodiversity across an environmental gradient in an African nature reserve is made. The Forest, with its structural layers and richer soil exhibits greatest botanical diversity, followed by the Savannah and Wetland, which are impacted by human activities and flood events, respectively. The Wetland had the highest zoological (insect) diversity, followed by the Forest and Savannah, as a result of adaptation forced by natural events. Although the study site exhibits high biodiversity, deterioration is likely due to alien encroachment along the river banks. Community participation in conservation is required for sustainable ecosystem management. This involvement may be informed by our socio-economic analysis, as eco-tourism management evolves from public to private, to spin-off greater benefits to the local community.

Key words: biodiversity assessment, socio-economic development, Swaziland.

INTRODUCTION AND BACKGROUND

Biodiversity includes genetic diversity, species richness and ecosystem diversity, and assumes that these are interdependent (Groombridge and Jenkins, 2002) and quantified through taxonomy inventories within specified areas (Fox and Rowntree, 2000). The number of different species within a geographical area depends on migration and adaptation to environmental conditions and how they in turn modify the environment (Barbour et al., 1998; Groves, 2002).

Biological conservation is concerned with the protection of living species (Stohlgren, 1994), including the sustainable use of soils and environmental resources. Biologists have long realized the value of biodiversity to humanity, but local communities also value biodiversity in their own terms for 'use' (Zobolo and Mkabela, 2006) and traditional conservation systems exist (Kunene and Nkosi, 1997). A range of species may have no direct value to people, but provide common ecological services to the wider community through tourism revenue and an ecosystem that is more sustainable.

Like many countries in Africa the culture of Swaziland is rooted in the environment, so a loss of biodiversity could adversely affect its perpetuation (Swaziland Biodiversity Action Plan, 1999). Government protected areas are a small percentage of the country's total land area, yet private reserves add considerably (Goudie and Price-Williams, 1983). The conservation of natural resources has been called for since 1951 (Compton, 1968), and it was in 1960 that the first national park was proclai-med. During the last four decades six nature reserves have been established in different vegetation types with associated unique fauna (Roux, 2003).

Conservation activities in the Lubombo Mountains have been conceived to promote environmentally sustainable development in rural areas based on the wise use of biodiversity resources and local participation in resource management, with emphasis on the country's regional tourism markets. Recently, the country has established the Swaziland Environmental Authority, a national body responsible for overseeing environmental protection. There are several legal instruments that cater for conservation issues residing in different government departments, but many of these legal structures are said to be outdated (Dlamini and Dlamini, 2002). Current regulations and enforcement may be far from reaching the requirements for sustainable ecosystem management. For instance legislation to control burning, crop cultivation and destruction of vegetation along rivers, and the collec ting of plant material is not strictly enforced. As a result, areas falling outside the reserves are regularly burnt, agricultural lands are established within metres of river-banks, and in some areas vegetation is severely altered

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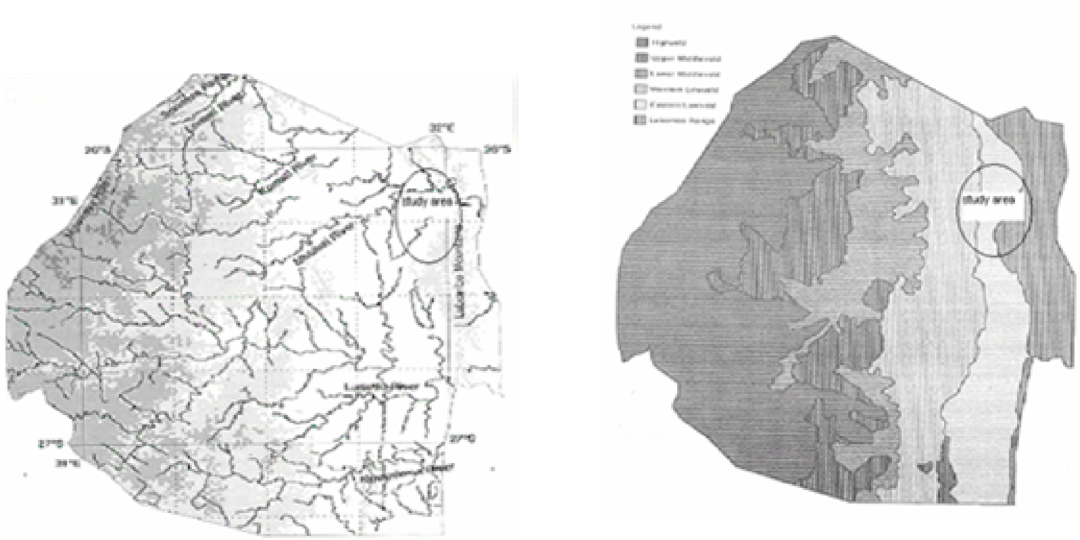

Figure 1. Map of Swaziland illustrating rivers, darker shading represents elevations (on left) and physiographic regions (right).

as a result of uncontrolled grazing (Roux, 2003). More species are said to be endangered by agricultural land use than by any other human activity (Jordan, 1986), mainly through sugar farming.

It was with this in mind, and our knowledge of the potential invasion by alien plants such as *Chromolaena*, that our project, initially sponsored by UNESCO, has taken an interest in the area through environmental monitoring in support of sustainable development. The need for this type of long-term monitoring is important as African savannah comes under increasing pressure from human activities (Dlamini and Dlamini, 2002). Tourists are attracted to these nature reserves because of their environmental assets and location along the new transborder route between two major ports: Durban and Maputo.

One hypothesis we wish to test is that biodiversity is greatest in the wetlands, followed by forest, then savannah. Zoological diversity was expected to follow the botanical trends, and both were expected to be related to environmental conditions such as slope, aspect, rockiness, soil nutrients, distance from water, and elevation. The objectives included:

A determination of species diversity per 100 m^2 for three unique habitats in close proximity.
An analysis of relationships between flora, fauna and environmental data.
A baseline inventory of environmental and socio-economic conditions in close proximity.

We also want to determine whether the local comm.-unity is aware of its environmental assets, in addition to their 'direct use' value.

Study area

Swaziland lies land-locked in southeastern Africa and is surrounded by South Africa and Mozambique along the Lubombo Mountains (Braun and Dlamini, 1994). Mlawula Nature Reserve is located in north-eastern Swaziland, 26° 20′ S and 31° 56′ E covering an area of approximately 16 500 ha (Figure 1). The Swaziland National Trust Commission (government) manages Mlawula Nature Reserve in the eastern lowveld. It is sparsely populated and has been used for cattle grazing (Greyling and Huntley, 1984). Mlawula Nature Reserve has a community-based tourism component that is marginally successful.

The reserve lies within the transitional zone between two biogeographic regions, dry thorn savannah of the west, and the moister coastal thickets to the east. Farming had always been difficult in the semi-arid land of the Lubombo where annual evaporation is double the rainfall. Although small, the reserve is contiguous with other natural areas, but also borders on sugarcane fields. The reserve consists of three distinct topographic zones, the basaltic Ndzindza Plateau and Siphiso Valley, and the rhyolite ridges of the Lembombo Mountains. These formations evolved about 200 million years ago, when volcanic lava was extruded. Later, as the edge of the African continent began to form, volcanoes along a north-south orientated line from the Limpopo Province to Kwa-Zulu-Natal in South Africa pushed up keva that forms the the rhyolitic rocks of the Lubombos. Subsequent erosion lowered the resilient basalt, and left the harder rhyolites as an escarpment incised by rivers (Roux, 2003).

The soil types found within the Mlawula Nature Reserve vary greatly. Much of the area consists of stony ground (raw mineral soil) but on the Ndzindza Plateau, soils consist of either grey sand or sandy loam on hard rock. In contrast, the Siphiso Valley area holds mainly brown to black loams or clay. Grey, black and red clays as well as deep red, yellow and orange loams have also been recorded in the area. The larger watercourses are flanked by narrow strips of colloidal and alluvial soils. The Siphiso Valley contains areas that have been subject to sheet, rill and gully erosion.

Four major river systems, the Komati, Mbuluzi, Lusutfu and Ngwavuma rivers, drain Swaziland. These are perennial rivers originating from the highveld to the west of the country, which form deep valleys as they cut through the hilly terrain (Roux 2003). In Mlawula Nature Reserve, the Mlawula and Siphiso Rivers form tributaries to the Mbuluzi River, that together flow through the reserve. The Siphiso catchment is largely restricted to the reserve. The Mbuluzi and Mlawula rivers are perennial, but have reduced flow since the irrigation of the sugar cane fields begun in the 1970s and droughts more recently.

The climate may be classified as sub-humid to tropical with a mean minimum temperature of 15℃ and a mean maximum temperature of 29℃ (Roux 2003). The average annual rainfall for Mlawula is approximately 600 mm, and typical of dry African savannah. Temperatures exhibit a high diurnal variation.

The animal diversity of Mlawula Nature Reserve is documented through museum collections (Culverwell, 1990; Hyslop, 1991; Boycott and Culverwell, 1992; Mahlaba and Perrin, 2003). Recent ecological research has included a study of the population dynamics of small mammals (Mahlaba and Perrin, 2003). Plant diversity for the reserve has been estimated (Braun et al., 2004) and conservation status of selected plant species has been analyzed (Dlamini and Dlamini, 2001). Within southern Africa, Swaziland has less than 1% of the land area yet it contains almost 14% of taxa recorded in the region. Owing to steep gradients of climate, topography, and edaphic characteristics, the country's flora is rich (Dlamini and Dlamini, 2002). Most endemics are found in the Lubombo Mountains (Braun and Dlamini 1994) where our present study is situated.

The vegetation of Swaziland ranges from open grassland to forest and from semi-arid savannah to wetlands (Braun and Dlamini, 1994). Mlawula Nature Reserve has diverse habitat types and vegetation. These include Bush Grassland and Open Grassland (with *termitaria* based bush clumps on the mountains), Moist Broadleaved Savannah (dominated by deciduous species), Savannah / woodland and Pioneer Acacia Wood-land, Mixed Combretaceous Woodland (the boundary being ill-defined and impacted by rock sheets and loose rocks); Forest / Thicket (including riparian forests, *Androstachys johnsonii*, dry *Spirostachys africana* thickets and open thicket mosaics) and Wetlands. Many alien plants, mainly of South American origin, are dispersed into the reserve by the Mbuluzi and Mlawula rivers. The most problematic aliens are *Chromolaena odorata*, *Lantana camara* and *Melia* herbaceous species, especially *Parthenium hysterophorus*, as a consequence of grazing pressure.

Here we evaluate biodiversity as an indicator of ecosystem health using rapid assessment techniques. We consider the soil chemistry and other physical attributes, relating to the botanical diversity. The zoological diversity is difficult to capture in rapid assessment, so we use indicator species to study changes across a sharp gradient in the landscape. Because we want to study the potential for community involvement in ecosystem management, socio-economic surveys were conducted in the adjacent town. The following section outlines data and methods, results are divided into a comprehensive analysis of botanical diversity, a more cursory analysis of zoological diversity, and a qualitative snapshot of community opinions, followed by recommendations for sustainable development.

DATA AND METHODS

In order to obtain representative floristic data in diverse habitats, sampling was done in 3 homogeneous units (forest, dry savannah and wetland) each with 3 replicates, consisting of 10 x 10 m quadrants, following the procedures of Mueller-Dombois and Ellenberg (1974). Within each quadrant, floristic composition was recorded and environmental factors were documented: aspect, slope, altitude, soil nutrients, terrain type, rock cover, rock size, soil composition and structure (see photos in Appendix 1).

Vegetation was classified according to physiognomy (Edwards, 1983). Species names and growth forms followed the plant checklist of Swaziland (Braun et al., 2004) (Table 1).

Because rapid assessment is done in winter season, it is necessary to target abundant orders that are habitat-specific. Thus insects are used as indicators of diversity, but other zoological families were also assessed. For the collection of insects, pitfall traps and net sweeping was employed in each of the 3 habitats. Ten sites were randomly chosen within the 10 x 10 m quadrant where the traps were set over the period of 6 h from 9h00 to 15h00. For crawling and flying insects pits were dug into the ground with a garden trowel. Water-filled plastic bowls were buried into the pits so that the insects could enter easily. After 6 h, the insects in the water were collected. To capture flying and jumping insects, a sweep net was used to dislodge the insects (Table 3) in each quadrant. The area was walked in 1 m transects up and down until the entire area was covered, numerous times during morning and afternoon.

The same procedure was followed in all three sites, sampling for crawling, jumping and flying insects. All the insects that had either fallen into the traps after 6 h or those that had been caught in the net were put into a labeled ziplock bags, and preserved until identification in the laboratory. In the following year, we returned to the same sites with a zoological taxonomist, to identify the higher order zoological diversity. These results are given in section 3.2 and Table 4.

Botanical data were captured on field forms and entered into spreadsheets as sample sites (columns) versus species presence and environmental factors (rows). Species were identified by expert taxonomists according to Germishuizen and Meyer (2003). Data sets were subjected to both Two-Way Indicator Species Analysis (TWINSPAN) (Hill, 1979) to obtain a classification of plant communities and Canonical Correspondence Analysis (Braak and Smilauer, 2002) for vegetation ordination with environmental variables. This constrained ordination approach helps to determine alien herbaceous species, especially *Parthenium* savannah areas have been colonized by a number of *azederach* (Macdonald and Jarman

Table 1. Results of the TWINSPAN classification, numbers = % cover.

Replicates	Description	1	2	3	7	8	9	4	5	6
Total number = 160		Savannah			Forest			Wetland		
Grewia hexamita	shrub	30	10	10	.	.	.	.	.	.
Acacia nigrescens	large tree	5	30	5	.	.	.	.	.	.
Emilia transvaalensis	herb	10	10	10	.	.	.	.	.	.
Ziziphus mucronata	large tree	5	10	10	.	5	.	.	.	.
Achyranthes aspera	herb	10	5	5	.	.	.	.	.	.
Euclea divinorum	shrub	10	5	5	.	.	.	.	.	.
Schkuhria pinnata	herb	20	10	.	.	.	.	.	.	.
Achyropsis leptostachya	herb	5	10	5	.	.	.	.	.	.
Barleria prionitis	herb	5	10	5	.	.	.	.	.	.
Bidens bipinnata	herb	5	5	5	.	.	.	.	.	.
Heteropogon contortus	grass	10	.	30	.	.	.	.	.	.
Cenchrus ciliaris	grass	30	.	20	.	.	.	.	.	.
Themeda triandra	grass	10	.	10	.	.	.	5	.	.
Combretum apiculatum	small tree	10	.	5	.	.	.	.	.	.
Waltheria indica	herb	.	10	10	.	.	.	.	.	.
Suregada africana	small tree	.	.	.	10	30	10	.	.	.
Artabotrys monteiroae	shrub	.	.	.	10	5	20	.	.	.
Isoglossa grantii	herb	.	.	.	10	10	5	.	.	.
Acacia brevispica	shrub	.	.	.	10	5	5	.	.	.
Erythroxylum emarginatum	large tree	.	.	.	5	5	10	.	.	.
Sansevieria hyacinthoides	herb	.	.	.	5	5	10	.	.	.
Asparagus virgatus	herb	5	.	.	5	5	5	.	.	.
Commicarpus pentandrus	shrub	.	.	.	5	5	5	.	.	.
Philonoptera violacea	large tree	.	.	5	5	5	5	.	.	.
Ziziphus rivularis	small tree	5	.	.	5	5	5	.	.	.
Hypoestes aristata	herb	.	.	.	.	20	5	.	.	.
Berchemia zeyheri	large tree	.	.	5	10	.	5	.	.	.
Rhoicissus tridentata	shrub	.	.	.	10	.	5	.	.	.
Pleurostylia capensis	large tree	.	.	.	5	.	10	.	.	.
Acacia robusta	large tree	.	.	.	.	5	10	.	.	.
Euclea natalensis	shrub	10	5	5	5	5	5	.	.	.
Panicum maximum	grass	10	5	20	30	5	.	.	.	5
Karomia speciosa	shrub	5	.	5	.	10	.	.	.	.
Schotia brachypetala	large tree	10	5	.	20	5	5	.	.	.
Cissus rotundifolia	shrub	10	5	.	.	5	5	.	.	.
Typha capensis	herb	.	.	.	.	.	.	30	10	30
Cyperus sexangularis	herb	.	.	.	.	.	.	20	30	5
Panicum deustum	grass	.	.	.	.	.	5	20	20	5
Bothriochloa insculpta	grass	.	.	.	.	.	.	20	5	30
Phragmites australis	grass	.	.	.	.	.	.	10	30	10
Eriochloa meyeriana	grass	.	.	.	.	.	.	10	10	5
Schoenoplect articulatus	herb	.	.	.	.	.	.	10	5	5
Sium repandum	herb	.	.	.	.	.	.	10	5	5
Litogyne gariepina	herb	.	.	.	.	.	.	5	5	10
Ficus sycomorus	large tree	.	.	.	.	.	.	5	5	5
Gymnosporia senegalensis	small tree	.	.	.	.	.	.	10	.	20
Phyllanthus reticulatus	shrub	.	.	.	.	.	5	5	.	10

Table 1. Contd.

Acacia xanthophloea	large tree	.	.	.	.	.	.	10	5	.
Merremia palmata	shrub	.	.	.	.	.	.	10	5	.
Macrotyloma axillare	shrub	.	.	.	.	.	.	.	5	10
Phoenix reclinata	small tree	.	.	.	5	.	5	10	.	5
Bridelia micrantha	large tree	.	.	.	10	.	5	.	5	.
Ageratum conyzoides	herb	.	.	.	5	.	.	5	10	.
Commelina eckloniana	herb	.	.	.	.	5	.	.	.	5
Acacia grandicornuta	large tree	.	.	.	.	5	10	.	.	5

Table 2. Sampled plant taxa per vegetation type according to order and family

ORDER	FAMILY	SAVANNAH	FOREST	WETLAND
ARECALES	Arecaceae	0	1	1
ASPARAGALES	Asparagaceae	2	1	0
	Dracaenaceae	0	1	0
ASTERALES	Apiaceae	0	0	1
	Asteraceae	4	1	8
	Lobeliaceae	0	0	1
CAPPARIDALES	Capparaceae	1	1	0
CARYOPHYLLALES	Amaranthaceae	3	0	0
	Molluginaceae	1	0	0
	Nyctaginaceae	0	1	0
CELASTRALES	Celastraceae	2	3	1
COMMELINALES	Commelinaceae	1	1	2
CYPERALES	Cyperaceae	0	0	10
	Poaceae	14	2	11
FABALES	Fabaceae	6	5	9
GENTIANALES	Apocynaceae	4	2	0
	Strychnaceae	1	0	0
LAMIALES	Boraginaceae	0	1	0
	Lamiaceae	2	1	0
	Verbenaceae	2	2	0
LINALES	Erythroxylaceae	0	1	0
MAGNOLIALES	Annonaceae	1	2	0
MALPIGHIALES	Euphorbiaceae	2	4	3
MALVALES	Malvaceae	6	2	1
	Sterculiaceae	3	0	0
	Tiliaceae	3	1	0
MYRTALES	Combretaceae	2	0	0
	Onagraceae	0	0	1
POLYGALALES	Polygalaceae	1	0	0
POLYGONALES	Polygonaceae	0	0	1

1985). The alien the influence of environmental variables in the distribution of plant communities along the landscape gradient.

Sampled insects were stored in ziplock bags and sorted in trays. The sorting trays were each in turn, observed under a dissecting binocular microscope. For identification to family level, the guide-book "Insects of Southern Africa" by Scholtz and Holm (1985) was consulted. A trained zoologist helped confirm species identifications in the university laboratory (Table 2).

Shannon-Wiener diversity indices were used to combine species richness and relative abundance among species (Whittaker, 1977; Barbour et al., 1998). The Shannon-Wiener Diversity Index measures the rarity/commonness of species in a community. In the vegetation study the Braun- Blanquet scale was converted to percentage cover, and the mean cover per species in each plant communi-

Table 2. Contd.

POLYPODIALES	Thelypteridaceae	0	1	0
RHAMNALES	Rhamnaceae	3	3	0
	Vitaceae	3	2	0
RUBIALES	Rubiaceae	1	0	0
SANTALALES	Olacaceae	1	0	0
SAPINDALES	Anacardiaceae	2	0	0
	Rutaceae	0	1	0
	Sapindaceae	1	0	0
SCROPHULARIALES	Acanthaceae	4	4	0
	Lentibulariaceae	0	0	1
	Oleaceae	2	1	0
SELAGINELLALES	Selaginellaceae	1	0	0
SOLANALES	Convolvulaceae	0	0	2
THEALES	Ebenaceae	3	2	0
	Ochnaceae	1	0	0
TYPHALES	Typhaceae	0	0	1
URTICALES	Moraceae	0	0	1
VIOLALES	Flacourtiaceae	0	1	0

Table 3. Sampled insect taxa per habitat according to order and family, number = morphospecies per site.

ORDER	FAMILY	SAVANNAH	FOREST	WETLAND
ORTHOPTEA	Acridiidae	5	0	0
	Grylidae	1	1	1
	Tetridae	4	0	1
	Tettigonidae	1	1	2
ODONATA	Lestidae	1	0	0
	Libellulidae	3	2	8
LEPIDOPTRA	Lasiocampidae	2	0	4
	Saturniidae	0	6	0
	Sphingidae	5	0	0
HYMENOPA	Apoidae	1	2	0
	Chalcidoidae	2	7	5
	Eurytomidae	0	5	0
	Formicoidae	24	14	4
NEUROPTEA	Chrysopidae	0	1	11
	Crocinae	0	0	4
	Mymeleontidae	1	1	1
COLEOPTEA	Cerambycidae	0	1	0
	Chrysomelidae	0	0	1
	Dytiscidae	0	1	2
	Hydraenidae	0	0	1
	Mycetophagidae	0	0	1
PLECOPTEA	Nemouridae	0	0	1
ISOPTERA	Hodotermidae	0	14	2
HETEROPTRA	Coreidae	0	0	1
	Lygaeidae	0	1	2
	Nabidae	2	1	2

Table 3. Contd.

	Pyrrhocoridae	0	1	0
	Reduviiae	0	0	1
DICTOPTEA	Blaetidae	1	3	0
DIPTERA	Bombyliidae	3	3	2
	Muscidae	5	1	4
HOMOPTEA	Cercopidae	3	0	7

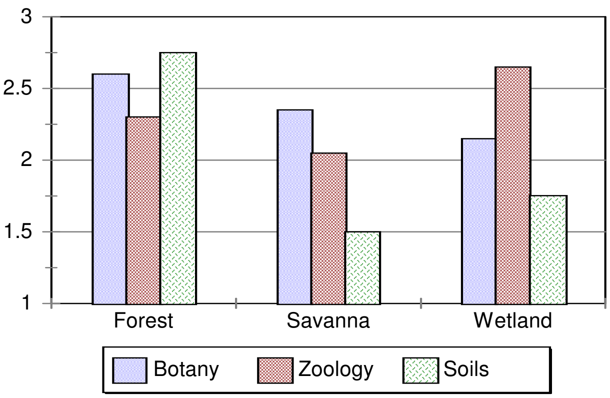

Figure 2. Graph comparing species diversityand soil nutrient 'value' across the habitats using the Shannon-Wiener Diversity index

nity was taken as its abundance value (Siebert and Siebert, 2005). To determine the dominant tree species in each physiognomic unit, a transect method was employed and the rarity of species was considered. The richness and diversity of insect species was calculated. Comparisons were also made with soil nutrient data, based on a chemical analysis of 200 g soil samples taken in each habitat.

The first analysis was of similarity between species at the order level of classification, and then at the family level using the Bray-Curtis similarity measure. The values were transformed to the 4^{th} root to normalize the data for species count. A cluster analysis (similarity matrix) was produced using hierarchical agglomeration. The key measurement from our analysis of the data is the species diversity (d), calculated with equation: $d = [S – 1]/ \text{Log}\ (N)$, where S = total number of species and N = total number of individuals. From this we can compare zoological and botanical species diversity and environmental factors.

A discussion of socio-economic data collection and analysis is provided.

RESULTS AND DISCUSSION

Biodiversity and environmental relationships

A total of 160 plant species were recorded. TWINSPAN analysis (Appendix) confirmed that the floristic data could be grouped into three distinct plant communities, namely Savannah, Forest and Wetland. This result is supported by the structural composition of the vegetation.

The Forest sites were dominated by a woody layer, whilst the wetlands by the herbaceous layer. The Savannah has the highest number of plant species per unit area; the Forest has the least, in keeping with past studies on savannah systems (Augustine, 2003).

The Shannon Wiener Diversity Index indicates the relative prevalence of many species. Here the Forest has the highest botanical diversity, followed by the Savannah, then the Wetland (Figure 2). The insect diversity (as an indicator of zoology), either family or order level, was highest in the Wetland, followed by the Forest then the Savannah.

The Forest soils are high in nutrients: Ca, Mg, and K, fol-\lowed by the Savannah, then the Wetland. The Forest is also high in P, organic matter and cations, but low in N. Govender et al. (2005) found that biodiversity in a coastal forest-savannah environment was related to Mg, Ca, P and pH. Evaluating the cumulative effects of the soil attributes, and assigning a relative 'value' throu-gh 2.75 multi-variate regression, we find a standardized value of for the Forest, 1.75 for the Wetland, and 1.5 for the Savannah. Comparison with diversity indices (Figure 2) illustrates that the plant diversity corresponds better with the 'soil richness' than the insect diversity. However, the tree canopy that contains a rich diversity of insects (Tangmitcharoen et al., 2006), was not sampled and future studies on the invertebrates of tree canopies might show similar diversity patterns to plant diversity.

Life/growth forms provide evidence of the structure and composition of the vegetation. The Wetland has the highest numbers of aliens, forbs, grasses and annuals. The dry Savannah is characterized by mainly shrubs, climbers and grasses. A high number of tree species and low number of annuals and grasses are indicative of the Forest.

The PCA for habitat types and environmental data is shown in Figure 3. Sample plots 1, 2 and 3 (Savannah) respond to rock cover and slope; sample plots 4, 5 and 6 (Wetland) to soil texture and soil depth; and sample plots 7, 8 and 9 (Forest) are characterized by soil depth, slope and open patches. Statistically, rock cover, slope, soil depth and soil texture are important environmental factors which have a direct influence on groundwater flow and subsequently species richness (Zinko et al., 2005). A CCA was run on these few environmental factors and it was found that 67% of the variation in the vegetation is explained (Figure 4).

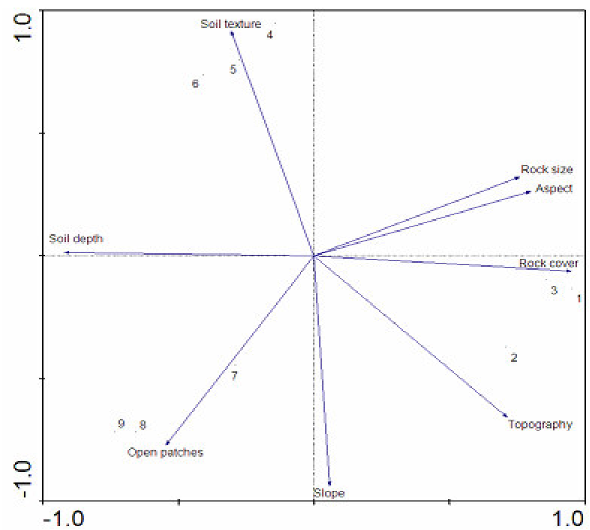

Figure 3. PCA graph showing environmental impacts on botanical diversity.

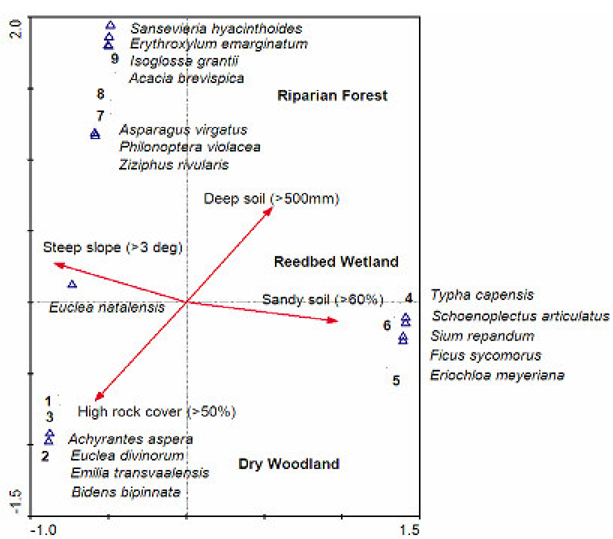

Figure 4. CCA graph showing environmental factors with sample sites.

Higher order zoological diversity

In 2006 we returned to the same sites to make a rapid assessment of the higher order zoological diversity to family level. We found the alien *Chromolaena* had invaded the sites and disturbed the botanical biodiversity.

The terrestrial biodiversity was again limited by the winter weather, but a giant monitor lizard was discovered, whose presence signified adequate forage.

At the beginning of our surveys, some time was spent looking over the three inventory sites of forest, grassland and wetland. We saw a fish eagle, F. Accipitridae, a skink, F. Scincidae, and we found mammal and turtle bones. The Swaziland sites lie in close proximity (hund-reds of meters). Because of the limited samples found, a detailed statistical analysis could not be accomplished.

Forest site

At this site we saw a *woodhoopoe*, *Phoeniculidae*, two *Hadeda ibis* flying overhead, *Plataleidae*, and two cape white-eyes, *Zosteropidae*. The dung of duiker, *Bovidae*, and another herbivorous mammal was seen, some old termite trails, and a clamshell. Walking back along the eastern side of the river we saw a serrated hinged terrapin (*Pelusios sinuatus*), *Pelomedusidae* with a lot of algae on its carapace. Animal noises were heard along the Rocky River bank, but we could not see the cause.

Wetland site

We found skinks including the rainbow rock skink (*Trachylepis margaritifer*), *Scincidae*, fast black lizards, which were most likely Lebombo flat lizards (*Platysaurus lebomboensis*), *Cordylidae*, and an unidentified frog. Birds seen included the blackeyed bulbul, *Pycnontidae*, two black eagles, *Accipitridae*, a flock of yelloweyed canaries, *Fringillidae*, and two African pied wagtails, *Motacillidae*. Unlike other years, there were many ticks in the grass around the wetland.

Grassland site

A white-throated monitor (*Varanus exanthematicus albigularis*), *Varanidae* was photographed and a southern boubou shrike *Laniidae* was seen. A list of vertebrate families is given in Table 4 of the appendix. This indicates seven orders in the wetlands, four in the forest and two in the savannah, although some animals were ‘in transit’ and may not be assigned to one or the other habitat.

Socio-economic analysis

With the new border crossing to Maputo, increased ecotourism traffic to the park, and the presence of a modern village within Mlawula Nature Reserve, it is useful to understand perceptions and services in the local community. Questionnaires were administered to 20 households in the town and responses were recorded by two university students of the local culture. Interviews were also conducted with three key Mlawula staff memb-ers, one neighboring eco-tourism business manager and one field researcher. These results may be considered a ‘snapshot’ of community opinions and activities. We summarize these qualitatively below.

Half of the respondents were male, and slightly more than half were under 30 years. All respondents were employed except two. About a third of respondents had resi

Table 4. Sampled vertebrate taxa per habitat according to order.

SAVANNAH	FOREST	WETLAND
Varanidae (monitor	Phoeniculidae (wood-hoopoes)	Scincidae (skinks)
Laniidae (shrike)	Plataleidae (ibises and spoonbills)	Cordylidae (spinytail or girdled lizards)
	Zosteropidae (white-eye birds)	Pycnonotidae (bulbuls)
	Bovidae (cattle, antelope, sheep, goats)	Accipitridae (hawks, eagles, and related)
		Fringillidae (finches and allies)
		Motacillidae (pipits and wagtails)
		Pelomedusidae (Afro-American side-necked turtles)

ded in the area less than two years; another third had resided there over 8 years. Households were comprised of the employee joined, in half of cases, by their partner; unlike most traditional villages where the household would include the extended family. Many older children were at boarding school, whilst many retirees had return-ed to their traditional homestead. Only 4 of 20 house-holds had a family member working in the Reserve. The remainder worked for the sugar estate or railway. More than half of respondents engage in small scale farming and the making of crafts, in addition to the salaried workers who provide services. Of the social activities, the majority of respondents said ‘there is not much to do’. Shopping, playing soccer and listening to music, TV watching were prevailing social activities. Only one respondent visited the Nature Reserve for recreation.

Only one respondent out of 20 was willing to report the extraction of natural resources from the Reserve. Of the 3 Reserve staff interviewed, it was estimated that 20 to 30% of the 100-strong community visit the Reserve once a week, mainly to collect fuel wood and for fishing (by permit), however poaching for game meat consumption was acknowledged. Most respondents agreed that resources had diminished in recent years due to drought and other factors.

On the development issues, transport was overwhelmingly cited as ‘poor’, however roads in the area are fine. Similarly electricity was ‘good’ whilst water was supplied by the municipality free of charge, but occasionally ‘it cuts out’. Water from the river is known to cause Bilharzia (Chaine, 1985). Only 5 of 20 respondents said the water did not meet their needs. Water consumption was estimated at 100 - 150 litres / day / person. There is no clinic or school in the community, so travel is necessary for these services. Of the prosperity issues, the householder’s opinion of their houses was split between good and poor. Only one respondent owned a car, but all owned cattle, goats or chickens either locally or in their home village. Many rated their development as neutral and were similarly split in their opinions about how the Reserve was being managed. Some suggested the Reserve should privatize and upgrade its facilities, including a swimming pool and clubhouse. This would create more jobs, tourism flows and interaction with the local community. All respondents agreed that crime was low; hence there was optimism in the village towards its development goals.

During interviews with a local eco-tourism businessman and a community conservation researcher the following points emerged: the adjacent Reserve, Mbuluzi, is privately run as a timeshare resort. One problem with ‘combining’ the 5 Reserves is that Shewula Reserve on the perimeter is run by the local community, and has no fences and no control over cattle grazing and poaching. It was pointed out that the commercialization of Swaziland’s public conservation agency is necessary, but that there is ‘conflict’ between the government conservation agency and Big Game Parks, the main private agency involved in conservation management.

A researcher studying Shewula Nature Reserve indicated that the tribal authority lacked management skills, and there was a shortage of goal-setting. Shewula has a real-life cultural village, but is under-marketed and has an unviable 5% occupancy rate. The researcher mentioned that many ecological studies had been completed in the area, but that management-oriented studies were equally important. It was felt that Swaziland had a low tourism potential compared with Mozambique, hence identifying a constraint to conservation development.

The interviewers (students representative of the local culture) mentioned that they enjoyed camping in the wilderness. They noted that many workers living near the Reserve feel temporary, ‘they go home (elsewhere) to socialize once a month’. ‘The community does not have a feeling of belonging’ hence they seem unconcerned about the environment and do not seem to care whether it benefits themselves, their family or friends.

The ‘migrant worker town’ is common in Swaziland with its large sugar estates. However with the relative decline of sugar and other commodity prices, changes could be expected. Privatizing home ownership (with subsidized loans for improvements) would help bring a ‘sense of purpose’ to individuals and their community. It is recognized that amenities such as clinics, schools and regular transport require a certain volume of demand that this small town does not support. The Nature Reserve is not the only driver of development in the community, the sugar estate, railway and other employers share this responsibility. An employer–employee forum could discuss how to transform this migrant worker town to a viable community, thus gaining cooperation between these role players to improve the 'social calendar' and create events to attract tourists. There isn't much enthusiasm within the Reserve staff due to national and local structural problems. This is felt by the community whose attitude toward the Reserve is slightly antagonistic. Regular meetings of a 'Mlawula development forum' would improve relations, in addition to the self-help projects being undertaken at the Environmental Education Centre to promote sustain-able small scale farming, the making of crafts, etc.

At present the Mlawula Nature Reserve receives about 2 000 visitors per year, yielding occupancy rate of 5% for the campsite and 15% for the lodges. This is unviable, and would need to increase to about 10 000 visitors per year to reach 30% occupancy rates. Tourism activity peaks in the winter months, with international, South African (overnight) and domestic (day) visitors. However during the warmer seasons visitors are few, possibly because there are no recreational amenities other than hiking and game viewing, and the threat of malaria.

From the perspective of a tourist, the Mlawula Nature Reserve is quite similar to Kruger Park, but much quieter. Should the five adjacent parks 'down their fences' and become a 'southern Kruger Park' with appropriate branding and marketing, and privatization of the tourism interface as done in South Africa, visitor numbers should increase. Although Swaziland may be considered a 'transit stop' between Durban, Maputo and the beautiful beaches of Mozambique (in summer), the Lubombo Mountain scenery and biodiversity is rich and varied. A new lodge complex at the southern edge of the park could absorb many of those in transit, once its water supplies are in place.

Conclusions

In this multi-disciplinary study, fluctuations of biodiversity across a landscape gradient have been related to environmental factors that are largely controlled by elevation above the water table. The Forest, with its three structural layers, richer soil and micro-climate, exhibited greatest botanical species diversity, followed by the Savannah and Wetland (Figure 2). The forest is least disturbed and close to equilibrium. The Wetland had the highest zoological diversity (as represented by insects), followed by the Forest and Savannah, due to adaptation to natural events like flooding.

Efforts have been expended on the conservation of biodiversity in Mlawula, but some deterioration seems likely unless alien encroachment is reversed particularly along the river bank. Community participation in the enforcement of laws is required for sustainable ecosystem management. Whilst previous scientific research in support of conservation has focused on specific isues, "here we have sought to establish an environmental baseline in habitats nearest the community that can be assessed for changes over time". Although Swaziland's monarchial form of government is a cultural asset, some rules of fairplay need to be considered as governance slowly democratizes. To extend the usefulness of our research, it is recommended that the flora and fauna of Mlawula be monitored on a regular basis in various seasons; employing multivariate statistics and GIS analysis.

Mlawula is expected to join with the surrounding nature reserves to form a larger conservancy that will see conservation and eco-tourism management slowly evolve from public to private. This could spin-off greater benefits to the local community, making them more aware of the environmental assets at their doorstep.

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Appendix 1

Photos of quadrats

Plot 2. Savannah

Plot 2. Savannah

Plot 4. Wetland.

Plot 4. Wetland.

Plot 7. Forest. .

Plot 7. *Andr. john.* species

Plot 8. Forest

Plot 9. Forest with river in foreground.

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