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Original Research Paper

Indicators of Species Richness of the Raptor Guild of the Carnivore Community of Afro-Alpine Habitats in the Bale Mountains, Ethiopia

Anteneh Shimelis, Afework Bekele and Simon Thirgood*
Department of Zoological Sciences, College of Natural Sciences, Addis Ababa University, Addis Ababa, Ethiopia
*Macaulay Institute, Craigiebuckler, Aberdeen, AB15 8QH, United Kingdom
Corresponding Auother: Anteneh Shimelis

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ABSTRACT

Indicator species may provide useful substitute for large scale surveys to monitor biodiversity. We conducted surveys in the Afro-alpine habitats of the Bale Mountains National Park (BMNP) with the objective of identifying indicators for the species richness of the raptor guild. Raptors were counted by scan sampling technique from a suitable vintage point. Three classes of 18 sample units grouped according to the variability of the moorland ecosystem in the magnitude of process variables important for raptor species richness were used in determining the indicator value of species as a function of their abundance concentration and the percentage of species occurrence per sample group. This procedure determined indicator values for all species in the resident raptor community. Comparison with randomly expected values demonstrated that only *Aquila verreauxii* and *A. chrysaetos* have indicator values that were significantly larger than the randomly expected values. The species richness estimated using the abundances of these two species predicted the observed species richness of the whole community in a linear regression model that explained 66% of the deviance in the data set. Furthermore, the species richness of the community predicted by process variables had correlation of very high significance with that predicted by the indicator species. We have thus identified two indicator species to a raptor guild of the BMNP and demonstrated that these two species encapsulated most of the information regarding the species richness response of the guild to key process variables in the Afro-alpine moorland ecosystem. Our findings contribute significantly to current and future efforts of monitoring the biodiversity of the park providing a cheap and quick means of data generation relevant for making management decisions.

INTRODUCTION

Global biodiversity is being lost at an alarming rate. The number of species to monitor is much larger than the man power available to do the job in many corners of the world. This is mainly a result of the lack of financial resources in many countries and institutions to train and assign personnel regularly. Such an imbalance together with the severity of the loss demands devising quick and effective methods to monitor changes in the state of biodiversity (Meffe & Caroll 1994, Cincotta et al. 2000). One such method is the identification of indicator groups or species, some important attribute of which can be used to effectively predict and corroborate the diversity of the larger group to which they are members (Caro & O'Doherty 1999).

The indicator concept is one of the specialised developments in community ecology and the rationale behind its application is the concept that adheres a selection of a few species reflect effectively patterns in key attributes of a community to which they are part (Krebs 2000). One attribute that is prominently used to describe diversity and also to test the efficacy of the indicator concept is species richness (Meffe & Caroll 1994, Cincotta et al. 2000). The idea of biodiversity indicators has been applied at different ecological scales and various workers have reported positive relationships in species turnover across taxa and also at the scale of a single community (Pearson & Cassola 1992, Crisp et al. 1998, Pearson & Caroll 1998, Pahro et al. 1999). Once groups or a selection of species that effectively indicate the state of the biodiversity of a site, a system or a community are identified, it may not be necessary to undertake full diversity surveys for making good management decisions. Indicator groups, if selected carefully, incredibly ease the tasks of conservation biologists particularly in developing countries that are overwhelmed by thousands of 'unknown' species that need to be monitored. This could also be a long overdue remedy for the conservation practitioners who are unable to keep up with the rate of loss of biodiversity in these countries.

One example of a developing country, rich in biodiversity, but poor in financial resources and conservation infrastructure, is Ethiopia. The avifauna of the country is one of the richest in Africa with 860 species (EWNHS 1996). But the local skill amounts to no more than four field ornithologists and only one institution that consistently pursues avian conservation. Such imbalance in conservation input and the tasks that are undone and waiting to be accomplished emphasize the importance of development of a mechanism of selection of indicator species as tools of monitoring the overall status of avian and other biodiversity at the community scale. In addition to the sheer number of species that make up the diversity of a given set of species, some communities constitute species that are very difficult for field identification and census, hence require specialised human skill at the very highest level. A very good example is a guild of raptors that is generally made of species that are frequently difficult to distinguish one from another without a good deal of field experience which is very expensive to come by even at the scale of a single ornithologist. This study was conducted on one such guild that constituted diurnal raptors that are resident in the Afro-alpine moorlands of the BMNP. The country has only one proper raptor ecologist and the National Park does not have the expertise in raptor monitoring although there exists a biologist with good general bird identification skills. The raptors of the afro-alpine moorlands of the NP do have significant regulatory role that may be key for the maintenance of highland ecosystems in south-eastern Ethiopia (Shimelis 2008). Furthermore, some of the member species are internationally considered as being at some level of extinction risk. For these very important reasons, raptor conservation is one of the key factors that will ensure the effective maintenance of the Afro-alpine moorland ecosystem of many values. At this stage monitoring the state of the community is one of the essential tasks of ecosystem conservation in the BMNP and accomplishing it full-scale with the existing resource and man power shortage may be unrealistic. In this paper we analyse community and species specific data to determine a few indicator species of the raptor guild that we studied in the BMNP. The objective was selecting a set of a few species with ecological attributes that effectively predict the species richness of the whole guild.

MATERIALS AND METHODS

Study area: Bale Mountains National Park (BMNP) is situated on the southeast plateau of Ethiopia. BMNP is located between 6°29' to 7°10'N and 39°28' to 39° 58'E. The area of BMNP is 2200 km sq varying in altitude from 1500 to 4377 m above sea level (Hillman 1992, EWNHS 1996). BMNP is the largest extent of protected Afro-alpine habitat on the African continent.

BMNP contains a notably diverse community of diurnal raptors of 25 resident and migrant species. In addition to the only breeding population of the Golden Eagle *Aquila chrysaetos* in sub-Sharan Africa, residents such as the Black Eagle *A. verreauxii,* Tawny Eagle *A. rapax,* Augur Buzzard *Buteo augur*, Lammergeyer *Gypaetus barbatus* and Red-chested Sparrow-hawk *Accipter rifiventris* and migrants such as Steppe Eagle *A. nipalensis,* Greater-spotted Eagle *A. clanga,* Lesser-spotted Eagle A. pomarina, and Pallid Harrier Circus macrourus (Clouet et al. 2000, Shimelis 2008). BMNP is the only known site where seven species of Aquila eagles coexist (Clouet et al. 2000, Shimelis 2008).

In this paper we have only analysed data on species that have resident populations in the Afro-alpine moorlands of the BMNP.

Raptor census: Fieldwork focused on three 100 km^2 areas of BMNP: The Lower Web Valley (B), the Upper Web Valley (A), and the Senetti Plateau (C) (Fig. 1). In each of the three study sites six random circular sampling sites with 1 km radius were established and counts were conducted from a suitable vintage point. Raptors were counted in the morning for three hours per scanning plot. The full three hour scan was divided into successive three minute bouts that helped to determine frequencies of intensities of forager aggregations per patch. Samples were also separated by a minimum distance of 2.5 km. Data were collected for 54 scanning hours.

Data analysis: To identify a set of species that indicate the

Table 1: Percent indication of species richness computed using the relative abundance of species in each of the three groups of the sample units.

Species	Low (n = 4)	Medium (n = 12)	High (n = 2)	Average
Gypaetus barbatus	0	25	75	33
Accipter rufiventris	0	14	86	33
Buteo augur	26	41	33	33
Aquila verreauxii	0	14	86	33
A. chrysaetos	0	38	62	33
A. rapax	11	66	23	33
F. biarmicus	38	31	30	33

Table 2: IV values expressed as percentage of samples in a given group where a species occurred.

Species	Low (n = 4)	Medium (n = 12)	High (n = 8)	Average
Gypaetus barbatus	0	17	50	22
Accipter rufiventris	0	8	50	19
Buteo augur	75	100	100	92
Aquila verreauxii	0	17	100	39
A. chrysaetos	0	75	100	58
A. rapax	25	67	50	47
F. biarmicus	100	75	100	92

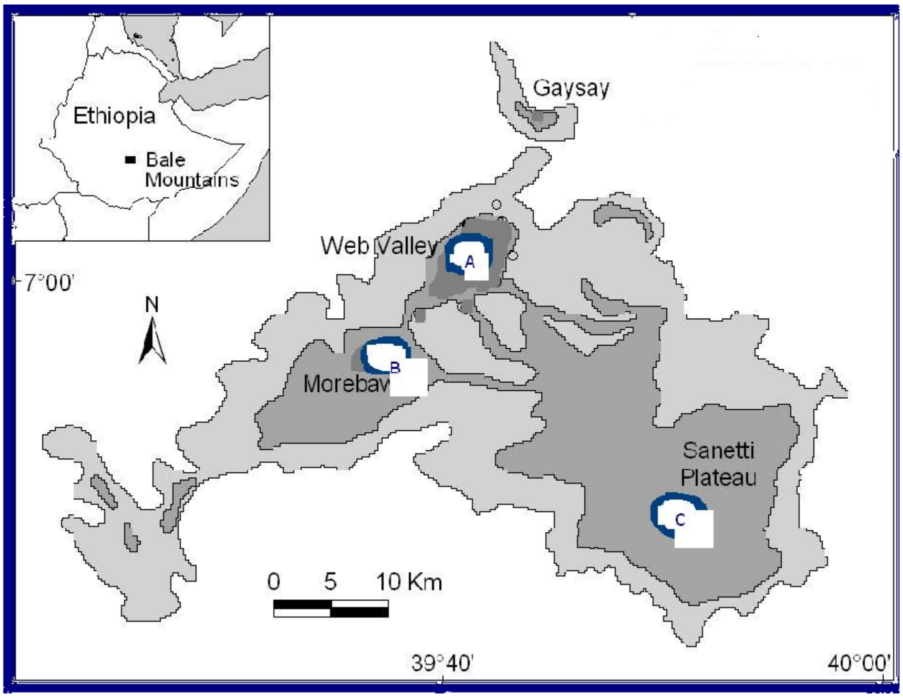

Fig. 1: The study areas where censuses were carried out in the Afro-alpine moorlands of the BMNP.

species richness of the raptor community in the BMNP a method developed by Dufêne & Legendre (1997) was used to compute indicator values (IV) of each species in the guild. As the method requires apriori classification of sample units, three groups spatial samples, determined using ecological factors, described as important for raptors of the BMNP in a species-specific manner (Shimelis 2008), and more importantly for species richness as a community, were used to evaluate the contribution of species members as indicators of diversity of avian predators (Dufêne & Legendre 1997, McCune et al. 1999). This IV computation involved determination of the information related to the abundance of a specific species, which was essential for determining the stability of a species membership in a spatial group (McCune et al. 1999). This determined the proportional abundance of a particular species in a particular group relative to its abundance in all groups and also the percentage of sample units in each group that contained the species. Multiplication of these two values resulted in an overall indicator value expressed as a percentage for all sample groups but the highest value (*IVmax*) was the ultimate measure of a species total contribution as an indicator. The significance of this as a measure of the value of contribution of a species a stable indicator of the species richness of the community was evaluated using the Monte Carlo method that randomly reassigned sample unit group membership a 1000 times calculating each time an *IVmax* to a species to compare the means with the observed values (McCune et al. 1999). This tested the null hypothesis that the observed *IVmax* is no larger than what would be expected by chance (i.e. that the species has no indicator value).

Once the indicator species were identified, their abundances were used to estimate the number of species expected in the modal octave via the equation $Y_o = I/0.5\sqrt{2\pi}\sigma$; where Y_o was the expected number of species in the modal octave; I was the total number of individuals of the indicator species; σ was the standard deviation of I (Preston 1962). To avoid the effect of zero truncation, data on the abundance of the indicator species were subjected to transformation referred to as Beals smoothing that generated quantitative values that represented "favourability" index of each sample for each species (McCune et al. 1999). The estimated Y_o values were used to compute the total number of species using the equation $N = Y_o\sigma\sqrt{2\pi}$; where N was the total estimated number of species in each sample. Once this was done, the estimated species richness values of the guild were evaluated using the incidences of the indicator species in multiple linear regression (Mac Nally & Fleishman 2004). A variable, estimated using this linear model, was regressed against the observed species richness to evaluate the efficacy of the indicator species in predicting the guild's species

Table 3: Monte Carlo test of significance of observed maximum indicator value of species that resulted form the combination of IVs generated using abundance concentrations and frequencies in specific groups.

Species	Maxgrp	Observed Indicator Value (IV)	Mean IV ± s.d from randomised groups	P
Gypaetus barbatus	High	37.5	27.1 ± 13.47	0.262
Accipter rufiventris	High	42.9	23.3 ± 12.36	0.174
Buteo augur	Medium	41.2	38.8± 3.360	0.236
Aquila verreauxii	High	85.7	29.5 ± 14.30	0.015
A. chrysaetos	High	61.5	40.0 ± 10.63	0.024
A. rapax	Medium	44.1	39.1 ± 13.28	0.346
F. biarmicus	Low	38.1	40.3 ± 5.280	0.700

Table 4: Univariate ANOVA test results that measured the significance of variation in the abundance of individual species across the three groups of sample units.

Species	Low	Medium	High	Significance	
				$F_{(15)}$	P
Gypaetus barbatus	0.00±0.00	0.01±0.12	0.15±0.21	1.12	0.340
Accipter rufiventris	0.00±0.00	0.003±0.01	0.15±0.21	0.19	0.120
Buteo augur	0.30±0.25	0.48±0.13	0.39±0.12	2.01	0.170
Aquila verreauxii	0.00±0.00	0.31±0.21	0.39±0.12	5.80	0.010
A. rapax	0.01±0.15	0.44±0.37	0.15±0.21	2.20	0.150
A. chrysaetos	0.00±0.00	0.29±0.19	0.48±0.00	6.71	0.008
F. biarmicus	0.38±0.15	0.31±0.21	0.30±0.00	0.19	0.824

richness. Using process variables that successfully predicted the species richness of a raptor guild of a larger species set in were regressed against the diversity of the species set targeted in this study and the resulting model estimates were compared with what was estimated using the incidences of the indicator species using simple correlation analysis. All analysis were carried out using PC-ORD and SPSS.

RESULTS

Seven resident species were intercepted at varying degrees of abundance in the Afro-alpine sections of the BMNP. Along the grouping of spatial samples, the intergroup relative proportional abundance of each species was determined as a measure of its indicator value (Table 1). Four species had IV values that consistently increased along an ascending gradient of species richness. *Aquila vereauxii* and *Accipter rufiventris* changed their species specific abundance proportions across samples in the same way maintaining a substantial gap between the medium and high species richness groups. Furthermore, these two species attained IVmax values in samples of highest species richness. *Gypaetus barbatus* and *Aquila chrysaetos* showed patterns of in formation concentration abundance that changed positively with the species richness gradient. Two species had their IVmaxs in the group of samples with intermediate species richness and their lowest values as indicators were observed in the collection of samples with the smallest number of species of the community. Only *Falco biarmicus* had IVs that changed inversely relative to the spatial gradient of species richness.

IVs by relative frequency in a group: Here also the same four species had increasing IVs that positively ascended with species richness (Table 2). Although the IV of *Accipter rufiventris* changed positively with species richness, it attained the smallest of the IVmaxs observed in the group with the highest species diversity. The two remaining species, although the highest level of their frequency per group was at sites of intermediate species richness, their indicator values across groups were not substantially different.

Overall indicator value of species: IVs that resulted from the combination of values from the relative abundance concentrations and frequency proportions generated IVmaxs in same groups as were determined by the two partial valuations (Table 3). But there were changes in magnitude compared to either one or both of the partial values. *Falco biarmicus's* conclusive IV was very similar to the results that made use of proportion of its abundance while a more than two-fold difference was detected with its maximum value that resulted from the proportion of sample units in the least diverse group where it had its IVmax. Despite the difference regarding the IVmax group, the same relationship between the overall and the partial abundance values was documented for *Buteo augur, A. verreauxii* and *A. chrysaetos.* The final indicator values of *Gypaetus barbatus, Accipter rufiventris*

Table 5: The canonical variate correlation coefficients that represent the relative contribution of each species for group separation.

Species	Variate 1	Variate 2
Gypaetus barbatus	0.13	0.15
Accipter rufiventris	0.14	0.32
Buteo augur	0.12	-0.40
Aquila verreauxii	0.25	0.60
A. rapax	0.10	-0.46
A. chrysaetos	0.34	-0.07
F. biarmicus	-0.05	0.06

and *Aquila rapax* were smaller than results from both of the partial evaluation of their indicator importance and particularly the contribution of the latter species was smaller than the value of both *A. verreauxii* and *A. chrysaetos* as opposed to the results from the partial valuations. Comparison of the conclusive indicator values of species with randomized Monte Carlo trials demonstrated only *Aquila verreauxii* and *A. chrysaetos* had values that were significantly larger than the maximum limit of the range of values expected randomly (Table 3). This showed only these two species had meaningful values as indicators of the species richness of their community.

Merit of indicators in predicting species richness: The number of species estimated using the incidences of the indicator species was linearly regressed against the observed abundance of *Aquila verreauxii* and *A. chrysaetos*. The resulting model significantly explained ($F_2 = 36.5$, $P < 0.001$) more than 82% of the variation in the estimated species richness via the equation $\log ES = 0.122 \log AV + 0.113 \log AC + 0.436$; where ES was estimated species richness, AV was abundance of *Aquila verreauxii* and AG was abundance of *A. chrysaetos*. The species richness predicted through this equation was regressed against the total observed species richness. The resulting model significantly explained ($F_1 = 31.4$, $P < 0.001$) more than 66% of the variation in the observed data set. Plotting the observed species richness of the community with what was predicted demonstrated there was substantial spatial overlap between the two (Fig. 2). Furthermore, there was significant correlation between species richness estimated using key ecological factors important for raptors with that predicted by the abundance of the two indicator species (Fig. 3).

DISCUSSION

A good understanding of the state of communities and ecosystems is vital for devising effective regimes for their conservation (Sutherland 1996, 2000, Gaston 2000, Margules & Pressey 2000, Krebs 2000). This mainly involves an assessment of the state of collective attributes of species in communities and appraising the manner by which environmental changes may affect their future. The commonest approach is an assessment of species richness of a given community. But many around the world found this to be a difficult task to undertake. The main impediment is a result of the ecological and socioeconomic complexities of conservation planning that are further pronounced by the financial hurdles associated with data collection. To overcome such problems scientists are often forced to seek shortcuts (Krebs 2000, Mac Nally & Fleishman 2004). One popular approach has been the determination and use of indicator species as cheap and quick alternatives for conducting exhaustive species inventories of organisms (Pearson 1994, Scott 1998, Gutaffson 2000, Mac Nally & Fleshman 2004). Because of its applied value in reducing the cost of biodiversity monitoring, this approach is being seen as an appealing practical tool particularly for financially impoverished but biodiversity rich corners of the world. Many conservation biologists that searched for species richness patterns in ecological communities have reported findings that supported the theory that advocates the ability of a few select species in predicting significantly the diversity of a larger group of organisms to which they are related (Heywood et al. 1995, Chapin et al. 2000, Terborgh & Mooney 2000, ECC 2000, Krebs 2000, Pimm et al. 2001, Roberts et al. 2002). Mac Nally & Fleishmann (2004) built predictive model of species richness of 56 species of butterflies based on the incidence of a set of five species. In Ethiopia and the rest of Africa, Important Bird Areas (IBAs) were identified using a set of species, the status of which believed to reflect the state of avian species assemblages at the scale of a biome, although its efficacy in clearly reflecting species diversity at such a large scale has not been tested yet.

Censusing raptors requires a highly specialised skill and very good knowledge of their natural history. Such a skill is quite scarce in Ethiopia and building it from scratch is quite expensive. Raptors as top predators do have strong functional role in the BMNP affecting strongly the regulatory functions of the Afro-alpine moorland ecosystem of the BMNP which is a very important catchment (Shimelis 2008). As very important ecosystem components, their regular monitoring contributes significantly for the conservation initiatives in the BMNP. To be able to do this a cheap and effective alternative monitoring mechanism makes the existing conservation process in the NP a lot easier than what its is now. It is with this premise that we did set out to find indicator species for a raptor community that is found in the BMNP. The search for indicator species generally is justified by theory that postulates presence and changes in number of the indicator species reflect changes in other members of the community (Krebs 2000). This is so because,

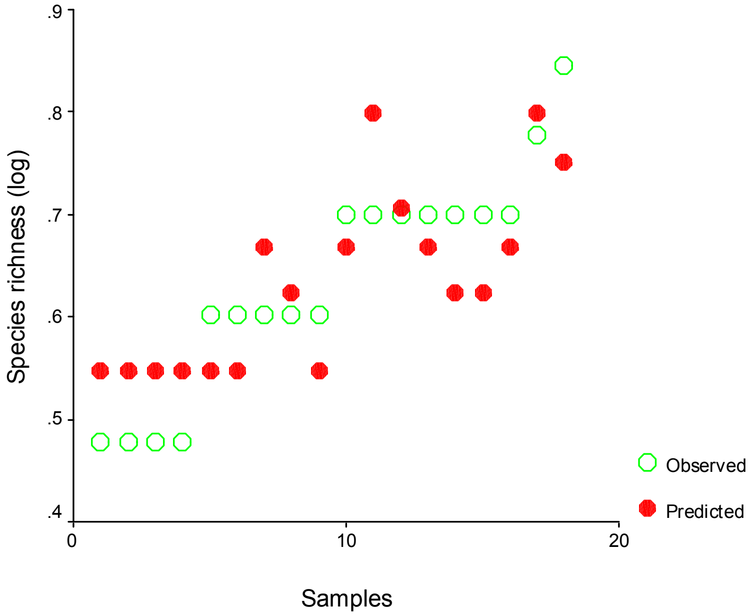

Fig. 2: Relationship of species richness predicted using the abundances of *Aquila verreauxii* and *A. chrysaetos* with values observed across sample units.

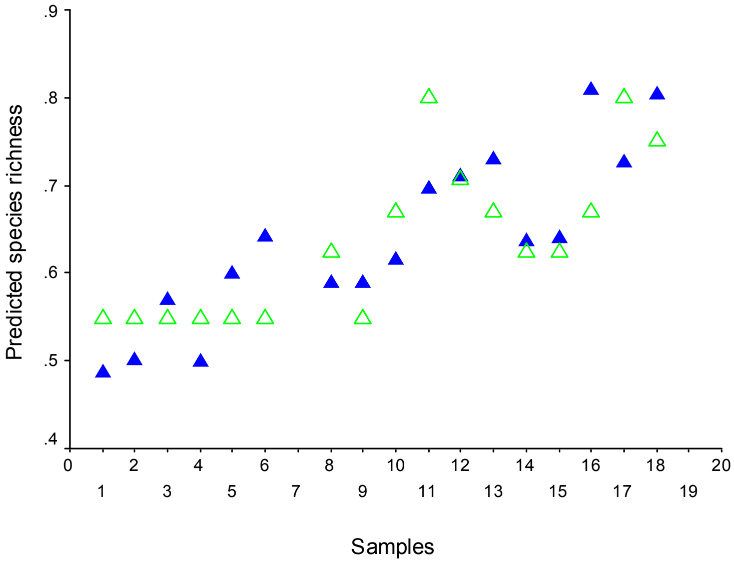

Fig. 3: Overlap in species richness (r = 0.77, P < 0.001) estimated by resource variables (solid triangles) and abundance of indicator species (open triangles).

indicator species if selected carefully represent a segment of a community where most of the variation in attributes of concern, is concentrated (Dufrêne & Legendre 1997, Krebs 2000). The species richness of the raptor guild in the Afro-alpine moorlands of the BMNP was studied and it was compared with the predictive value of process variables that were determined as having significant value in explaining the spatial variation in species richness. Our analysis of the seven species large community of resident raptors of the BMNP selected *A. verreauxii* and *A. chrysaetos* as indicators of the spatial variation in species richness of their community. The two species that were selected as indicators reflected the majority portion of the guild's spatial grouping encapsulating variations in species richness. The significance of the difference of the IVmaxs of these two species with what was expected randomly indicated the spatial variability in species co-occurrence was a result of their relationship with key process variables that were determined as having significant value in predicting the species richness of the guild spatially. In addition to the significant correlation of the predicted species richness with what was observed, the guild's observed species diversity was successfully explained by the combined raw abundances of these two species. Evaluation of the model parameters indicated that the two species contributed fairly similarly to the predictive power of the linear model. To asses the accuracy of predictions made by the model at a scale larger than this study, a cross-validation procedure was undertaken by computing an adjusted r^2 (Field 2000). This value was 0.64 indicating that there would only be a slight loss/decay of predictive power as more or less the same amount of variability would have been accounted for if the model has been derived from a larger set of species. This clearly demonstrated prediction made using the abundance of the two indicator species accurately generalized the observed species richness pattern expected in the raptor guild throughout the Afro-alpine habitats of the BMNP.

The results confirmed theoretical assertions of the indicator concept generating evidence that supported the expectation that the value of indicator species in representing the overall group attribute of their community is due to their relatively better response to the variations in attributes of underlying factors that determine the pattern of species richness and species composition (Begon et al. 1996, Krebs 2000). The most important factors driving variations in species richness of the raptor guild in the Afro-alpine sections of the BMNP include environmental features such as elevation and topography of patches together with spatial heterogeneity in habitat and prey diversity. The significant relationship of the species richness estimate made using the indicator species with what was predicted using these key ecological processes underlined the fact that variations in the spatial structuring of the raptor guild was chiefly a result of response of the two indicator species to these ecological processes that caused group organization patterns amongst raptors in space. The most important prey groups that have a higher value of predicting raptor species richness in the Afro-alpine moorlands of the BMNP included relatively large-sized mammals (hyrax, hare) and large-sized birds such as francolins. It was also determined that the species with the strongest functional relationship with such prey were *A. verreauxii* and *A.* chrysaetos (Shimelis 2008). This fact supported the results of this study emphasising the generalizations underlined by the significant similarity in species richness predictions made by the abundance of the indicators and the process variables. The significant contribution of the ultimate two indicator species in the clustering of assemblages along a gradient of species richness indicated, their presence/absence is key for understanding the variation in the turnover of species across assemblages of the raptor community. The fact that they are members of a genus with the largest species representation in the total species composition of the raptor guild in the Afro-alpine moorlands of the BMNP suggests that the indicator species were the ones to be most affected by processes that cause variations in the group organization patterns (Krebs 2000). By virtue of their taxonomic alignments they tend to have closer functional roles with the majority of the species in the guild and their localized magnitude of niche occupancy determines the degree of co-occurrence of species that have similar resource requirements. Such similarity may have imposed higher distributional limitations on them than other species in the community most of which were sole representatives of their respective genera (Mac Arthur 1971, Keddy & Weiher 1999, Kelt & Brown 1999).

On the basis of the findings of this study it can be concluded that a monitoring scheme that focuses on these two species generates information that can safely be generalised for the whole raptor community and it may serve as a very useful and cheap approach to design a comprehensive conservation plan that maintains the biodiversity attributes of the community along with its underlying factors.

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