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The value of the Black Harrier *Circus maurus* as a predictor of biodiversity in the plant-rich Cape Floral Kingdom, South Africa

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Summary

Determining the efficacy of using indicator species to predict the spatial location of biodiversity hotspots is one way of maximising the conservation of biodiversity in already threatened habitats. Recent evidence from Europe suggests raptors can play such an indicator role, so we tested this approach with a globally threatened southern hemisphere species, the Black Harrier *Circus maurus*. We asked if this species, found in South Africa's mega-diverse Cape Floral Kingdom, breeds in habitat fragments that were more diverse in terms of small mammals, birds and plants than unoccupied fragments of similar size. Renosterveld is a highly fragmented habitat that has lost > 90% of its original extent and remains only on privately-owned lands. Surveys of small mammals, birds and plants undertaken in 20 fragments in the Overberg region, South Africa, revealed nine with breeding harriers and 11 without harriers. Harrier-occupied fragments were associated with a 3.5 fold higher number of bird species and higher small mammal species richness than unoccupied ones. There was a lower abundance of most plants in occupied patches, except for red grass *Themeda triandra* which is an indicator of pristine renosterveld. Vegetation structure was significantly different, with harriers nesting on patches with taller, more open vegetation. While the diversity trends were not statistically significant, a positive trend between the presence of harriers and higher abundance of red grass – as an indicator of the more pristine state of the patch, suggests that harriers might allow biodiversity managers a heuristic approach for selecting the remaining patches of pristine renosterveld. The need for intensive sampling of several taxa leads to small samples and a lack of clear-cut trends for these top predators as indicators of plant diversity.

Introduction

Raptors are wide-ranging, top-level consumers, and are often proposed as potential indicator, umbrella and flagship species (Thiollay 1989, Primack 1993, Simberloff 1998, Mikusinski *et al.* 2001). Their position at the top of trophic food webs, large home ranges and their sensitivity to human disturbance (Newton 1979) makes them ideal candidates as biodiversity surrogates, but until recently this had not been formally tested. In a recent examination, however, Sergio *et al.* (2005, 2006) used the presence and absence of six species of diurnal and nocturnal raptors in Europe as indicator species and found these apex predators were consistently associated with higher species richness of three taxa selected as measures of biodiversity - trees, butterflies and other birds. Given the criticism that the use of indicator species has faced (e.g. Entwistle and Dunstone 2000) these are important findings that require testing in other areas as originally recommended by Sergio *et al.* (2005, 2006). We provide such a test here in an area where conservation planning is urgently required because of the high incidence of threatened and endemic flora and fauna – the Cape Floral Kingdom of South Africa (Cowling and Richardson 1995). Because our analysis was already underway at the time Sergio *et al.* (2005, 2006) published their findings, our measures of biodiversity differ from theirs and include small mammals, plants and birds. We set out to investigate if the presence of a globally vulnerable raptor the Black Harrier *Circus maurus* was associated with higher diversity indices of these three taxa in the Cape Floral Kingdom's most threatened habitat – renosterveld.

The Black Harrier is one of the few avian endemic species of the Cape Floral Kingdom (von Hase *et al.* 2003) and its core breeding area lies within this hugely plant-rich biome of south-western Africa (Curtis *et al.* 2004, Simmons *et al.* 2005). In the southern Overberg region, Black Harriers are found nesting almost exclusively in large renosterveld patches (Curtis 2005). Where nesting occurs outside these large (> 100 ha), relatively undisturbed patches, only smaller patches with high connectivity with other patches are used (Curtis 2005). We tested whether the presence of harriers indicated higher biodiversity value than similar sized patches unoccupied by harriers (controls).

Biodiversity value was measured in terms of (i) small mammal species richness and abundance, (ii) bird diversity and abundance and (iii) species richness of rare and endemic plants. This study adds data to the hotly debated topic (Kery *et al.* 2008, Roth and Weber 2008, Sergio *et al.* 2008a) of whether top predators can be used as indicators of biodiversity from more diverse regions of the world.

Materials and methods

Study area

Renosterveld is the most threatened habitat type in the Cape Floral Kingdom (Low and Robelo 1996), itself one of the world's richest and smallest floral hotspots (Myers *et al.* 2000). This biome lies completely within South Africa and supports at least 8,600 endemic, mainly flowering, plants (Cowling and Richardson 1995). Renosterveld is essentially a grassy shrubland, with an exceptionally high diversity of geophytes (bulbous plants), often dominated by the shrub renosterbos *Elytropappus rhinocerotis* Less., that occurs on moderately fertile, shale-derived soils along the west and south-west coastal lowlands (Kemper *et al.* 1999). Structurally it ranges from grassland to shrubland, depending on fire regime and/or grazing pressure, and was formerly considered to have a higher component of grasses (such as *Themeda* spp.) than shrubs (Newton and Knight 2004). Renosterveld has been reduced drastically by expanding agriculture, mainly cereal and pasture crop production, to < 10% of its original extent (von Hase *et al.* 2003).

All patches of renosterveld studied in the Overberg were located between Botriver (34°13′S 19°12′E) in the west, Bredasdorp (34°34′S 20°10′E) in the south and Heidelberg (34°06′S 20° 59′E) in the north-east (Figure 1).

Average rainfall ranges from 350 to 600 mm per annum (Kemper *et al.* 1999) and varies from west to east; winter (May–July) rainfall occurs in the west and a bimodal spring-autumn rainfall regime occurs in the east (Kemper *et al.* 1999, Low and Robelo 1996). Mean annual rainfall is 14% higher in the west than the east (436.4 mm versus 381.8 mm; South African Weather Service). The mean minimum annual temperature is 12°C and the mean maximum annual temperature is 24°C (SAWS 2007).

Habitat patch selection

Unlike Sergio *et al.* (2005) we compared the biodiversity of harrier-occupied patches with those of nearby unoccupied patches in the same habitat rather than randomly chosen areas of same habitat. We did so because of the rarity of renosterveld, and the wish for a matched-pair type design to reduce the influence of other variables. No occupied patches were so close to unoccupied ones that harriers, small mammals or passerines might regularly pass between them.

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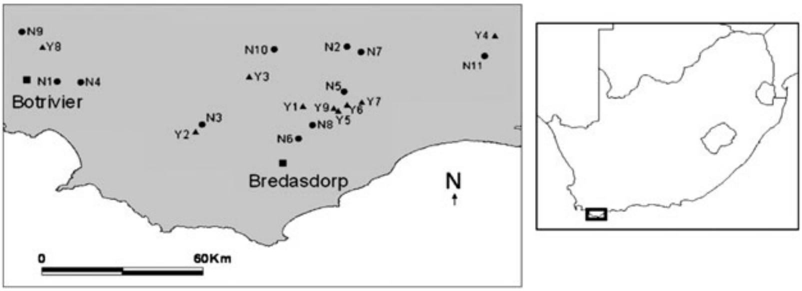

Figure 1. Sites within the Overberg region of South Africa, selected for this study. ▲ sites with breeding black harriers (Y1-9) and ● sites without breeding harriers N1-11)

Patches were selected using a GIS data layer from the South African National Biodiversity Institute's (SANBI) database on the basis of previous knowledge of patches where Black Harriers were known to breed (Curtis 2005). In that survey, patches had been randomly chosen (all sizes) and the larger ones found to contain breeding Black Harriers significantly more often than smaller patches (Curtis 2005). To increase sample size, new patches were identified in the same manner and these were observed for a minimum of three hours to determine the presence of breeding harriers (Curtis 2005). Nine years of monitoring Black Harriers has shown that three hours is sufficient to reveal the presence of a nest through food passing activities (R. E. Simmons unpubl. data). Where possible, patches of 100 ha or larger were surveyed but two patches smaller than 100 ha (one occupied and one unoccupied), were included due to their connectivity to other patches and the presence of breeding harriers. The data were collected over two harrier breeding seasons (2005 and 2006) and a site was classed as active if harriers bred in either of the two years. In total nine patches with Black Harriers (hereafter 'occupied patches') and 11 patches without Black Harriers ('unoccupied patches') were chosen for biodiversity assessment.

Bird transects

Renosterveld is a low, relatively two-dimensional habitat, therefore the line transect technique (Bibby *et al.* 2000) was used to survey birds. Transects were walked over a variety of slope aspects and habitats. Each transect was 200 m long except where patch topography disallowed this. In total 4 km of transect per patch were carried out. The length of each transect was determined by recording the start and end points using a Garmin Global Positioning System (GPS) accurate to about 10 m. Transects were carried out during breeding seasons in November and December 2005 and 2006. All patches were surveyed once and all birds within 50 m of each side of the transect line were counted. Although noted, raptor species (including Black Harriers) were not used in the data analysis. Species were identified by sight and/or call. All transects were walked in the early morning or late afternoon, avoiding the middle of the day when birds are known to be less active (Bibby *et al.* 2000). These data were used to calculate relative abundance measures,

$$\text{Relative abundance} = \frac{\sum n_i}{N}$$

where n_i is the number of times the species occurred and N the total number of species along the transect.

Transects were carried out by three observers. We assessed inter-observer bias by comparing the species detected by each individual within the same two patches (one occupied and one unoccupied).

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Performing a Kendall Coefficient of Concordance on a Friedman ANOVA showed no significant difference between observers ($P = 0.08$). Therefore all bird transect data were compared for other variables.

Small mammal trapping

Six lines of 10 Sherman live traps each (8 cm wide by 9 cm high by 30 cm long) were set out for four consecutive nights in 14 patches from 4 October to 28 November 2005 and at 10 patches from 23 September to 15 November 2006. Transects were placed to take advantage of different slopes and were a minimum of 200 m apart. A trapping period was defined as the time between setting the trap and checking the trap. In this study there were 240 night trapping sessions and 240 day trapping sessions per 24 hours. Non-target captures and traps found closed but empty were counted as a half trap period (Sutherland 1997).

Traps were placed 20 m apart and baited with peanut butter, rolled oats and oil (Dippenaar 1974). Crushed maize was used to ground bait for trap-shy species (Sutherland 1997). Thermal insulation was provided inside the trap. Traps were checked at dawn and dusk. Captured animals were fur clipped, weighed, sexed and recorded as a new or recaptured animal and released at the point of capture. Non- target species (e.g. lizards) were recorded and released at point of capture. Captures were converted into trap success per 100 trap nights where:

Trapping success = (number of captures / No of traps x trapping period in days) x 100.

Because small mammal populations often fluctuate on a year to year basis (David and Jarvis 1985) we re-trapped four patches sampled in 2005 (two occupied and two unoccupied) again in 2006. There was no significant difference between species richness and trapping success on each patch over the two years (T = 3, 10, 3, 2; $P = 0.465, 0.917, 0.465, 0.593$), data were therefore pooled between years.

In 2005, day trapping was no longer possible after 25 October due to high temperatures and the increased risk of trap mortality (Atyeo 2006). A regression was developed to predict the day-time capture rate of striped mouse *Rhabdomys pumilio* from that date onwards. Using patches where both day and night captures had taken place we predicted the success rate per 100 trap periods during the day as a function of the trap success overnight. Predicted *R. pumilio* trap success during the day = 1.2823 (*R. pumilio* trapping success at night) -2.842 ($R^2 = 0.8797$, $P < 0.05$). Adjusted trapping success for *R. pumilio* was calculated for five patches. In 2006 the temperature remained below 30°C throughout the trapping period and trapping was done throughout the afternoon session.

Plant transect data

All plant data were collected by a professional botanist (B. A. Walton) by walking two 50 m transects in each patch. Transects were placed down slopes as opposed to across slopes and data were collected every 2 m. Due to the very high species richness, all plant species within a 10 cm radius of the point were recorded and the height of each plant measured to the nearest centimetre.

The number of species recorded for each site was converted to relative abundance using the expression

$$\text{Relative abundance} = \frac{\sum n_i}{N}$$

where n_i is the number of times the species occurred and N the total number of species along the transect.

The vegetation height along each transect was calculated by taking the average vegetation height every 2 m. Vegetation density was calculated by taking the number of plants occurring within the 10 cm radius at each point.

Samples of unknown species were collected and identified using herbaria or by consultation with other specialists. Species were identified as rare using the Interim Red Data Lists of South

Africa Plant Species (SANBI 2009). Species were identified as endemic to the Cape Floristic Region (CFR) and endemic to the Overberg from plant lists supplied by CREW (Custodians of Rare and Endangered Wildflowers, SANBI). Species endemic to the Overberg were defined as species occurring between Elgin and the Breede River but excluding Elim Fynbos (SANBI 2007). Plant data were not collected at two of the 20 patches; one occupied patch burnt after the 2005 field season and we were unable to contact the owner of an unoccupied patch to gain access.

Data analysis

Species richness and Shannon-Wiener and Brillouin diversity indices were calculated for small mammal, bird and plant species assemblages at each site. Both indices are sensitive to the number of rare species in the sample, and both will increase as the number of rare samples increases (Krebs 1999). The Shannon-Wiener index has been widely used in other studies of small mammal assemblages in South Africa (e.g. Joubert and Ryan 1999). The measure of evenness based on the Shannon-Wiener Index was also calculated (Stiling 1999). Dominance was calculated using Simpson's D statistic.

Data were tested for normality (Kolmogorov-Smirnov test d-statistic). When data were not normally distributed, transformations were attempted to induce normality (Zar 1999). Where this was not possible non-parametric tests were used. Data were analysed using Statistica 7.0 (Statsoft 2004).

To determine if Black Harriers are biodiversity indicators, each taxon was compared for higher species richness and biodiversity indices compared between occupied and unoccupied sites. Within birds, species were further separated into feeding guilds and their relative abundances compared. Within small mammals overall abundances were compared between sites. These were compared using Student's t-tests or Mann-Whitney U tests. We tested if more rare and endemic plant species were present on sites occupied by harriers.

To examine if patches occupied by Black Harriers were similar to each other and significantly different from patches not occupied by Black Harriers, multivariate analyses of bird, small mammal and plant data were undertaken using cluster analysis (CLUSTER) and non-metric multi-dimensional scaling programmes (MDS) in the software package PRIMER 6.0 (Plymouth Marine Laboratory UK). Between-site similarity was assessed using the Bray-Curtis similarity co-efficient. Cluster analysis dendrograms reflecting the hierarchical relationship of patches were produced using group-average linking. SIMPER (Similarity percentages) analysis was also carried out to determine which species contributed most to dissimilarity between patches.

Average plant height and overall vegetation density were compared between patches using t-tests.

Abundance data from birds, small mammals and plants were combined and used to calculate overall diversity indices. These were compared and a multi-dimensional scaling plot of all data produced.

Results

Bird diversity

Across all patches, 67 different species of bird were recorded. The most commonly occurring species on both sites were Grey-backed Cisticola *Cisticola subruficapillus* (21.8 % of all birds recorded across 20 patches), Karoo Prinia *Prinia maculosa* (10%), Cape Bunting *Emberiza capensis* (9.1 %) and Karoo Scrub-robin *Cercotrichas coryphaeus* (4.8 %). Overall, the relative abundance of birds was 3.5 times higher on occupied patches (4.4 $\pm$ 4.7 birds ha^{-1}) than on unoccupied control patches (1.3 $\pm$ 3.9 birds ha^{-1}). This difference was not, however, statistically significant ($U = 31$, $P = 0.160$) due to high variance.

There was a higher relative abundance of all feeding guilds except nectarivores on Black Harrier patches. These differences were not statistically significant (Table 1). There was a significant

Table 1. Relative abundance and species richness of bird guilds on occupied vs unoccupied patches. Significant differences are shown in bold.

Relative Abundance				Species Richness		
Guild	occupied	unoccupied	*P*-level	occupied	Unoccupied	*P*-level
Carnivore	0.25	0.071	0.195	2	1	**0.046**
Frugivore	0.164	0	0.189	1	1	0.892
Generalist	0.859	0.166	0.342	3	3	0.803
Granivore	0.797	0.542	0.271	5	5	0.876
Insectivore	3.176	1.205	0.21	7	9	0.397
Nectarivore	0.022	0.06	0.376	1	2	0.944

difference between species richness of avian carnivores between occupied and unoccupied patches, but other feeding guilds had similar species richness.

Of the 67 bird species recorded, only the Yellow Bishop *Euplectus capensis* had a significantly higher relative abundance on occupied patches (0.22 occupied vs 0.02 unoccupied, $P < 0.05$).

We found no overall significant difference between occupied and unoccupied patches for bird species richness, diversity, dominance and evenness (Table 2).

Overall, there was no pattern for higher relative abundance of birds on patches occupied by breeding harriers. Avian species richness across the occupied and unoccupied patches was similar.

Small mammal diversity

Across all patches, 10 different species of small mammal were caught. Seven species occurred on both occupied and unoccupied patches. One species occurred exclusively on occupied patches and two exclusively on unoccupied patches. Overall the most commonly caught species was the striped mouse *R. pumilio*, comprising over 70% of all small mammal captures. Abundance of all species (small mammals per 100 trap days) was lower on occupied patches but these differences were not significant (Table 3). There was a higher trapping success for three species on occupied patches and four on unoccupied patches. Surprisingly, diurnal species (prey items, *R. pumilio* and *Otomys irroratus*) were slightly more abundant on unoccupied patches (Table 3).

Relatively high values of dominance, and low values for evenness were apparent across most patches. This was due to the high abundance of *R. pumilio*. There were higher diversity values on occupied patches but these differences were not statistically significant because of the low number of species involved (Table 4).

Black Harriers breed on patches that have a lower abundance (in terms of captures per 100 trap sessions) of small mammals than unoccupied patches. In this study, vegetation density (measured as the number of plants per point along a transect) was significantly lower on patches occupied by Black Harriers. This suggests that small mammals are more available to Black Harriers on these patches despite the lower small mammal density. However, as a measure of the biodiversity value

Table 2. Avian species richness and diversity indices for occupied versus unoccupied and east versus west patches. Results in bold are significant.

	occupied	unoccupied	*P*-level
Richness	17	19	0.396[1]
Evenness	0.88	0.86	0.470[1]
Dominance	0.098	0.108	0.702
Brillioun	1.058	1.023	0.790[1]
Shannon-Wiener	1.097	1.058	0.587

[1]Indicates Mann-Whitney U test was carried out, all other tests were t-tests.

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Table 3. Median abundance (small mammals per 100 trap days) by species and overall trapping success for occupied versus unoccupied patches.

Common name	Scientific name	Occupied	Unoccupied	*P*-level[1]
Grant's Rock Mouse	*Aethomys granti*	0.23	0.02	-
Namaqua Rock Rat	*Aethomys namaquensis*	1.91	1.41	0.462
Greater Musk Shrew	*Crocidura flavescens*	0.79	0.32	0.643
Pygmy Mouse	*Mus minutoides*	0.26	0.75	0.248
Forest Shrew	*Myosorex varius*	0.15	0.24	0.355
White-tailed Rat	*Mystromys albicaudatus*	0.36	-	-
Vlei Rat[2]	*Otomys irroratus*	0.21	0.24	0.886
Striped Field Mouse[2]	*Rhabdomys pumilio*	9.42	15.53	0.382
Kreb's Fat Mouse	*Steatomys krebsii*	-	0.12	-
Cape Gerbil	*Tatera afra*	-	0.22	-
Diurnal species[2]		3.25	8.25	0.612
Overall trap success		12.51	15.13	0.424

[1]Mann-Whitney U test. Where tests are not reported species occurred at too few patches. [2]Diurnal species preyed on by Black Harriers.

of patches occupied by Black Harriers, small mammal species richness was not significantly higher on harrier-occupied patches.

For red-listed species there was no trend – the only such species, the white-tailed rat *Mystromys albicaudatus* occurred at one occupied site.

Plant diversity

Transects for plants recorded 308 species in 60 families over 18 patches. There was no significant difference between the number of species endemic to the Overberg ($P = 0.391$), and species on the IUCN Red List ($P = 0.409$) present on occupied and unoccupied patches. All occupied patches contained at least one Red List or endemic plant species (Table 5). *Themeda trianda* Forssk. was more abundant on occupied versus unoccupied sites (3.36 versus 0.88). This difference however, was not significant ($t = -1.179$, df = 8, $P = 0.272$).

There was a significant difference in vegetation height (49.31 cm) on occupied patches compared to unoccupied patches (38.87 cm: $t = -4.87897$, df =934, $P < 0.001$).

We also found a significant difference in plant density between occupied and unoccupied patches. Unoccupied patches had an average of 3.28 plants per point while occupied patches had an average of 2.88 plants per point ($t = 4.152$, df = 934, $P < 0.001$).

We found no other specific difference in occupied versus unoccupied patches in terms of plant species richness, evenness, dominance, or diversity indices. Diversity indices were higher for unoccupied patches suggesting higher species richness (Table 6).

To our surprise, plant species richness was lower on occupied patches than on unoccupied patches. This may be a function of lower plant density on the occupied patches. Themeda grass

Table 4. Species richness and diversity indices for small mammals in occupied versus unoccupied patches.

	occupied	unoccupied	*P*-level
Richness	4	3	0.44
Evenness	0.302	0.307	0.689
Dominance	0.729	0.811	0.425[1]
Brillioun	0.271	0.197	0.436
Shannon-Wiener	0.197	0.149	0.456[1]

[1]indicates Mann-Whitney U test was carried out; all other tests were t-tests

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Table 5. Number of plant species endemic to the Overberg, endemic to the Cape Floristic Region (CFR) or on the IUCN Red Data List found on occupied versus unoccupied patches

	Patch	Endemic	CR	EN	VU	NT	LC[1]
Occupied	Y1	1				1	
	Y3					1	
	Y4	1			2		
	Y5	1				2	
	Y6	4	1		1		
	Y7	Overberg		1	1		
	Y8	2			1		
	Y9	2			1		
Unoccupied	N1						1
	N2	1			1		
	N3	2					1
	N4	1		1			
	N5	3			3		
	N6					1	
	N8	2			1	2	
	N9						
	N10						1
	N11	3		1	3		

[1]Has national Rare status

T. triandra abundance, however, was higher on the occupied patches. It is thought that renosterveld was once dominated by *Themeda* grasses and overgrazing has led to present-day domination by bushes such as renosterbos *E. rhinocerotis* (Cowling *et al.* 1986). As such, high abundance of *Themeda* is considered by botanists to be a sign of good quality renosterveld which has not been overgrazed or degraded (Cowling *et al.* 1986). A grassy layer is also associated with high small mammal abundance in montane areas of western South Africa (Bond *et al.* 1980). In effect harriers may be indicative of pristine renosterveld patches rather than of highly diverse patches.

Vegetation height was significantly higher on occupied patches compared to unoccupied patches. Because nest site selection is very important for ground nesting harriers this result is expected given that they face higher predation rates than tree-nesting species (Simmons 2000). Black Harriers also select nesting patches in thick vegetation to conceal the nest (Chadwick 1997, Simmons *et al.* 1998, Simmons 2000, Curtis *et al.* 2004).

Rare and endemic plants

This study showed little evidence of a link between Black Harrier presence and a higher abundance of rare and endemic plants. This was contrary to initial analyses (Stanway and Raimondo 2006)

Table 6. Plant species richness and diversity indices for occupied versus unoccupied and east versus west patches.

	occupied	unoccupied	*P*-level
Richness	33	44	0.082
Evenness	0.808	0.84	0.146
Dominance	0.085	0.061	0.091[1]
Brillioun	2.436	2.653	0.065
Shannon-Weiner	4.036	4.528	0.069

[1]Mann-Whitney U test was carried out, all other tests were t-tests

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using previous plant data from the Overberg. Six Black Harrier patches and six unoccupied patches had been sampled to varying degrees. Their data showed Black Harriers occurred on patches with double the number of rare and double the number of endemic plant species. However, there was a significant sampling bias towards harrier-occupied patches, with 36 sampling records compared to 17 for unoccupied patches (Stanway and Raimondo 2006). This is unlikely to be patch-size related because Kemper *et al.* (1999) showed that fragments less than 1 ha are very similar in plant species composition and diversity relative to large fragments (> 30 ha). Instead we suggest that different methods used in this study (two 50-m transects per patch within the same season) relative to the CREW methods (sampling over a wide area focussing on the rare and endemic plants, year after year), can explain why our methods did not yield the harrier association with rare and endemic plants found by CREW.

We suggest that the lack of association found between harriers and rare and endemic plants may have been masked by inappropriate sampling and our wish to keep transect-sampling for birds, mammals and plants similar. This will be explored in future years.

Cluster analysis

Analysis of bird, rodent and plant data showed no grouping of occupied and unoccupied sites, suggesting all sites were similar.

Combined diversity

The diversity indices and species richness for birds, plants and small mammals combined showed that although species richness (and dominance) may be lower on occupied patches the diversity and evenness indices were higher. This suggests that occupied patches are more diverse and less dominated by commonly occurring species.

Discussion

Given that raptors are top predators, sensitive to changes in prey base and disturbance and have recently been shown to be indicative of high biodiversity value in Western Europe, this analysis assessed whether Black Harriers might also be used as an indicator of biodiversity value in South Africa. We assessed this within renosterveld patches in the highly fragmented Overberg in terms of the abundance and species richness of (i) birds and (ii) small mammals and (iii) the presence of rare or endemic plant species.

Biodiversity vs naturalness in a fragmented habitat

This study did not assess Black Harrier presence in an area of unbroken habitat, unlike the other studies of raptor as indicators of biodiversity (Sergio *et al.* 2005, 2006, Ozaki *et al.* 2006). Instead we looked at discrete patches of natural vegetation in an agriculturally transformed matrix. Our results may be confounded by the fact that diversity *per se* is a poor measure of the effect of fragmentation (Kemper *et al.* 1999). More important differences may be found in changes within community structure as shown by the frequency of individuals and species with different biological attributes (Saunders *et al.* 1991, Holt *et al.* 1995, Kemper *et al.* 1999). The higher abundance of *Themeda trianda* on patches used by breeding harriers may also suggest that these occupied patches contain more pristine and intact natural renosterveld, independent of overall diversity values.

Black Harriers as biodiversity indicators

Indicators of biodiversity have been proposed as a potential tool for selecting areas for conservation when information about species distributions is scarce (Flather *et al.* 1997, Lawler *et al.* 2003). The use of raptors as indicators of biodiversity has shown mixed results. Ozaki *et al.*

(2006) found no relationship between the diversity of bird, butterfly, carabid and native forest-floor plant species and the presence or absence of Northern Goshawks *Accipiter gentilis*. Roth and Weber (2008) found that while raptors in Switzerland were reasonable surrogates for biodiversity measures there, *Parus* tits were better indicators of insect biodiversity. Sergio *et al.* (2005, 2006) however, found a significant relationship between abundance and diversity of birds and butterflies and the presence or absence of a raptor.

Our results do not show any significant correlation between the presence of Black Harriers and higher levels of biodiversity in similar sized patches. We may have been disadvantaged by the small sample size (nine occupied patches and 11 unoccupied patches), which was limited by the number of similar-sized and nearby patches that were used as controls. Under-sampling of multiple taxa may be a common problem for revealing associations between top predators and indices of diversity (Sergio *et al.* 2008a). We also chose a bird that is naturally rare, in need of conservation attention and does not occur at the same levels of abundance enjoyed by the six species assessed by Sergio *et al.* (2006) or the Northern Goshawk assessed by Ozaki *et al.* (2006).

Given our results, it may be that harriers are sentinel species linked to the lack of disturbance in the patch rather than the overall biodiversity. Apex predators at the top of the food chain are more vulnerable to alterations of their supporting ecosystem (Sergio *et al.* 2008b). Therefore conservation managers could use the presence of Black Harriers as a heuristic indicator of 'pristineness' or naturalness in this mega- diverse region. They can also use the future presence of Black Harriers to monitor the progress of the restoration of any patches that are protected in future. Therefore Black Harriers are not indicators of biodiversity of renosterveld patches. However their vulnerable status means their presence on a patch should not be ignored by conservation managers.

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