PREDICTED EFFECT OF BLACK WATTLE REMOVAL ON REPTILIAN SPECIES DIVERSITY IN WILDCLIFF NATURE RESERVE, WESTERN CAPE, SOUTH AFRICA

Technical Report Submitted to Wildcliff Nature Reserve

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Summary

Black Wattle (*Acacia mearnsii*) is an invasive tree species in Southern Africa; it tends to grow rapidly forming dense forest stands, and these stands are generally associated with a lower diversity of plant an animal species, compared to natural areas. However, the relationship between reptilian species diversity and Black Wattle stands has not been quantified, and there are a number of reasons to suspect that the preferred habitat of some reptile species includes Black Wattle stands. Such an investigation is warranted because both government and private interest groups are moving to eradicate Black Wattle stands from much of the South African countryside. I tested for associations between Black Wattle and reptilian species diversity on Wildcliff Nature Reserve, South Africa. Between April 18th and May 14th, 2008, I quantified reptilian diversity in 11 different areas of the reserve, and subsequently related species diversity in these areas to 14 different measures of vegetation composition using Principal Components Analysis. Twelve species of reptile were identified in my surveys (5 snake species, 4 lizard species, 3 gecko species), and on a macro-scale, I found a negative relationship between areas forested by Black Wattle and/or Pine (*Pinus* sp.) and reptilian diversity. Further analysis indicated that diversity was highest in non-forested areas featuring a moderate amount of low brush cover (i.e. small shrubs and bushes). Notwithstanding, 66% (2 of 3) of Gecko species were found exclusively in forested areas, and this suggests the eradication of Black Wattle could have detrimental effects on Gecko diversity, even though reptilian diversity in general would likely not be adversely affected by wattle eradication.

Introduction

The reptile fauna in southern Africa is among the most diverse on earth. There are currently 498 species described, and present rates of discovery in some taxa are similar to those in the early 19th century (SARCA 2007). Of particular interest is that reptile fauna in southern Africa has a high level of endemism; that is, many of these species are found nowhere else on earth. For example, of the 498 described reptile species, 391 are endemic (78.5%) to southern Africa, while in birds and mammals, endemism is less than 25%. It will be particularly important to describe the factors contributing to the observed levels of reptilian diversity, as well as any threats that current farming practices or invasive species pose to reptilian habitat.

Wildcliff Nature Reserve (Western Cape, South Africa) was founded in 2007. It was previously farmed, and it currently consists of 955 hectares of mountainous fynbos, meadows and mixed Black Wattle (*Acacia mearnsii*) and Pine (*Pinus*) forests, which are invasive tree species. In order to preserve and restore the natural fynbos ecosystems on the reserve, an aggressive eradication program is underway to remove the existing wattle and pine stands. Indeed, Black Wattle has been described as "the number one threat to biodiversity in the Cape Floral Kingdom" (de Bakker 2003), and it is clear that Black Wattle stands and pine stands are generally associated with a decrease animal diversity (Breytenbach 1986; Samways and Moore 1991).

However, it is not clear how such stands impact species diversity of reptiles. For example, wattle stands may host a variety of microhabitats which provide favourable conditions for reptilian thermoregulation (e.g. Blouin-Demers and Weatherhead 2001). Moreover, arthropod diversity, abundance, and species assemblages are affected by Black Wattle (Breytenbach 1986; Samways et al. 1996), so wattle stands might host preferred prey items of some reptiles (e.g. Donnelly and Giliomee 1985). This may lead to a greater abundance of some reptile species, which may even encourage an abundance of larger reptilian or non-reptilian predators. Removal of Wattle from an area may therefore have a negative impact on reptilian diversity, and an investigation is warranted before large-scale removal of wattle occurs. In this study, I compare species diversity of reptiles in Black Wattle stands of varying density to diversity in areas where Black Wattle is absent. If Black Wattle encourages reptilian diversity, then we would expect diversity to be highest in Black Wattle stands, and lower in areas where wattle is absent. Additionally, I assess the level of species endemism in forested and non-forested areas.

Methods

Surveys

In late April, 2008, I identified 11 survey areas that differed in vegetative composition on Wildcliff Reserve (Table 1, Figure 1). Between April 18th and May 14th, I surveyed these areas between the hours of 8:00 am and 4:00pm; usually no more than 3 areas could be surveyed in a given day. Sites were visited between 3 and 8 times for an absolute minimum of 20 minutes, but usually lasting around an hour. In all survey areas, the primary survey method was flipping cover objects, primarily rocks, though I also inspected bushes and trees (albeit to a much lesser extent). When an animal was found it was captured (if possible) and identified on site or subsequently identified from pictures taken on site. A GPS position was recorded, along with the time, date, and any notes pertaining to the observation. Finally, at each site I performed four trials in which I started at a random location and recorded the number of cover objects I flipped in 10 minutes (a total of 40 minutes per site). These data allowed me to estimate the total number of rocks flipped at a site given my entire survey time. Surveys were discontinued on May 14th because the possibility of a temporal sampling bias due to lower reptilian activity with the approaching winter.

Vegetation Sampling

In order to quantitatively assess reptilian diversity in relation to habitat (at a macro-scale), I quantified 14 specific habitat parameters within each study area (Table 2). A 2m x 2m plot was created at five random locations within each site; the random locations were determined using a random number generator in Microsoft Excel, and these values were converted to GPS point then plotted within each study area using Google Earth. The vegetation measures (Table 2) were then averaged across all five plots for each of the 11 sites.

Table 1: A description of each of the 11 study sites. "Area" of each site was estimated in Google Earth by dividing the search area into a series of right-angle triangles and/or rectangles then using the equations L x W [rectangles] and (L x W)/2 [triangles]. "Search Time" reflects the amount of time spent on site searching for reptiles. "Number of species" is the number of different reptile species found at each site during my surveys. "Number of rocks sampled" is the estimated number of rocks (based on my rock-flipping trials) overturned at each site during the entire sampling period. "Per cent of rocks sampled" is the estimated per cent of all rocks overturned in the entire site during my surveys, whereby the total number of rocks in at a given site was estimated by multiplying the average number of rocks per m^2 (see Methods, Table 3) by the total surface area of the site in m^2. "Number of rocks sampled" was then divided by the latter value to estimate "per cent or rocks sampled" (note that "per cent of rocks sampled" should be considered an educated guess at best, as 95% confidence intervals [not shown] on the number of rocks sampled at a given site and on the total number of rocks at a given site were often extremely large).

Site	Description	Dominant Plant	Area (m^2)	Search Time (mins)	# of Species	# of rocks sampled	% of rocks sampled
HHM	Moist meadow	Grasses	94285	240	2	618	100%
THF	Older wattle	Black Wattle	20844	170	0	438	100%
MM	Dry meadow	Grasses, Shrubs	51567	205	5	984	5.5%
RW	Thick, younger wattle	Black Wattle	4944	105	2	683	25.1%
P	Power line	Shrubs	3287	165	3	1592	60.6%
LW	Sparse wattle	Black Wattle	5659	120	2	1137	12.2%
UW	Sparse wattle	Black Wattle	2749	105	3	1273	30.0%
NM	Shrub-dominated meadow	Shrubs, few grasses	25011	175	2	1544	6.9%
PI	Older pine	Pine trees	105542	270	1	1465	2.5%
UF	Meadow with dense underbrush	Low brush, *Rhododendrum*, some fynbos	58279	210	0	741	3.6%
LF	Fynbos meadow	Fynbos, Grasses, *Rhododendrum*	81842	380	4	3439	3.6%

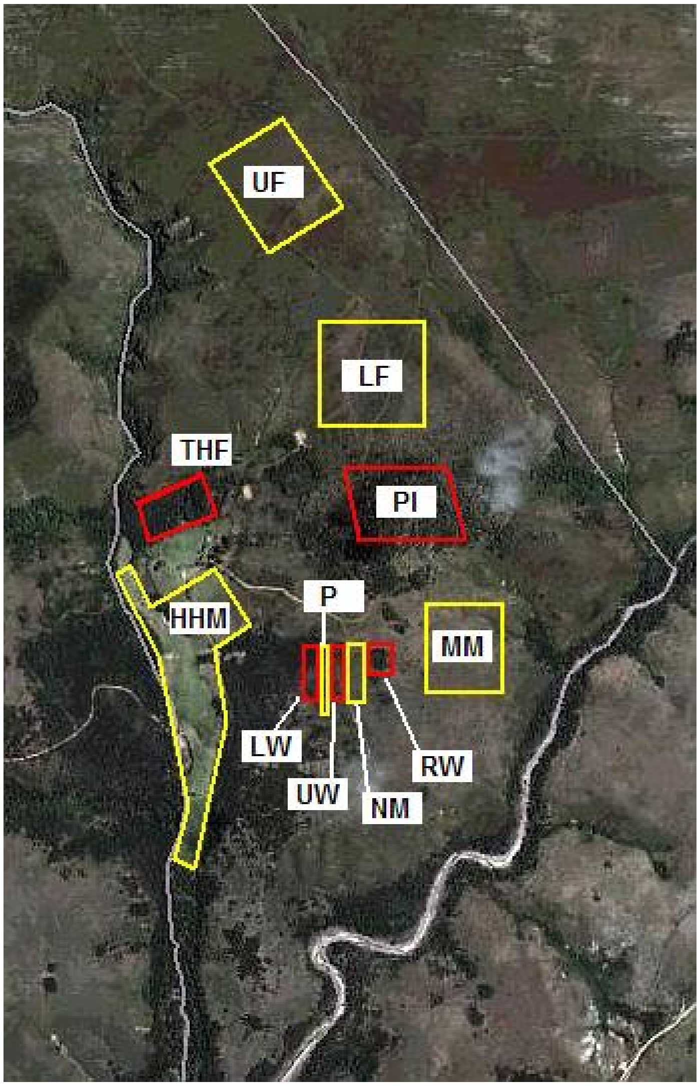

Figure 1: Approximate size and location of the 11 reptile sampling areas within Wildcliff Nature Reserve. The reserve is outlined in white (only the lower half of the reserve is shown); open sampling areas are in yellow, and forested sampling areas are in red. The scale is approximately 2.5cm = 500m.

Table 2: At each of the 11 sites, five 2x2m plots were created, and the following parameters were measured. Data Transformation is the type of transformation performed on the data after it was collected (so that it could be analyzed properly).

Vegetation Measure	Description	Data Transformation
Number of rocks	Number of rocks > 40cm surface area	None
Mean size of rocks	The length, width, and/or diameter of the rock was measured; surface area was approximated using the equations L x W [rectangular rocks]; (L x W)/2 [triangular rocks]; $\pi*(r^2)$ [circular rocks]	None
% vegetation cover (high)	The area greater than 2m from ground level that was obscured by vegetation was approximated	Asin(square root)
% vegetation cover (medium)	The area less than 2m but higher than 0.75m from ground level that was obscured by vegetation was approximated	Asin(square root)
% vegetation cover (low)	The area less than 0.75m above ground level that was obscured by vegetation (primarily small bushes and shrubs, but see below) was approximated	Asin(square root)
% Low brush	Per cent of substrate concealed exclusively by low shrubs and brush	Asin(square root)
% Grasses	The area occupied by grasses was approximated	Asin(square root)
% Exposed earth	The area comprising exposed soil was approximated	Asin(square root)
Soil moisture	A subjective scale of 1 – 4 was created, where 1 represents very dry earth and 4 represents very moist earth	None
Number of stems from small bushes	The number of stems from small bushes or brush (stems counted at the soil – air interface). In cases where stem density exceeded 100, this value was approximated from several rough counts	Log_{10}
Median surface area of tree stems	All trees (diameter ≥3cm at 1-2cm above the soil – air interface) were measured, and the median surface area occupied by each of the individual stems was calculated. The median was used because it is less sensitive to extreme values than the mean	None
Basal area of trees	The sum of all tree surface areas in a plot	None
Number of saplings	Wattle or Pine where circumference was ≤ 2.9cm	None
Number of trees	Wattle or Pine where circumference was ≥ 3cm	None

Analysis

Principal Components Analysis was used to reduce redundancy in the vegetation measures, and the extracted components were then regressed against species diversity using a linear regression. Although this method allows me to examine how species diversity varies by habitat type, inferential statistics (i.e. P values) were not used because I did not control for spatial autocorrelation in species diversity among sites (in other words, by virtue of the fact that the animals may move among sites that are in close proximity, a high species diversity in a given site might result in a high species diversity in an adjacent site, even if the animals' preferred habitat is not found in the adjacent site).

Results

Species identified

Twelve species of reptile were identified in my surveys (5 snake species, 4 lizard species, 3 gecko species). These records can be found at the end of Chapter 2.

Sampling bias

Species diversity was not related to total time spent searching at a given site ($y = 0.00340x + 1.52$, df = 9, $r^2 = 0.03$, $P > 0.05$), or to sampling time per unit area (i.e., sampling time/area of site; $y = 18.6x + 1.91$, $r^2 = 0.04$, $P > 0.05$), though weak positive trends were apparent in both cases. Species diversity was not related to site area ($y = 0.000x + 2.24$, $r^2 < 0.01$, $P > 0.05$), to the estimated per cent of rocks flipped in an area ($y = -1.12x + 2.54$, $r^2 = 0.077$, $P > 0.05$), to the average time of day a given site was sampled ($y = 0.0230x + 2.36$, $r^2 < 0.01$, $P > 0.05$), or to the number of visits to a given site ($y = 0.0538x + 4.25$, $r^2 < 0.01$, $P > 0.05$). Hence, in no case did among-site sampling bias account for a significant amount of variation in species diversity.

PCA analysis

PCA is often used to reduce the complexity of large datasets. The analysis operates by identifying a series of linear relationships among the variables within the data set, and extracting these relationships as "components". Each extracted component therefore represents a particular phenomenon within the data set, and each component is uncorrelated with, and independent of, other extracted components. From the 14 measures of vegetation, I extracted 2 principal components comprising 66.4% of the variation in the original vegetation data (which means that a 33% loss of information in the vegetation data occurred). A third component, which comprised an additional 10.2%, was ignored. Presently, species diversity is not being considered, and these components only describe relationships among measures of vegetation.

The first component (Table 3) appears to represent the degree to which an area is forested. To illustrate, this component has high positive loadings on "per cent high cover", "per cent exposed earth", "number of trees", and "stand basal area", and negative loadings on "rock size", "per cent of low cover", "per cent of grass", "per cent of low brush", and "low brush stem density". Hence, this component is discriminating among forested and non-forested areas. The second component is ambiguous, but it may be related to the complexity of the vegetation in an area. Importantly, this component showed high positive loadings for measures related to shrub density and low cover, and strong negative loadings for "per cent grass" and "soil moisture". The component scores for both components (which, in this case, are quantitative measures of how each one of my 11 sample areas are described by the component) were saved and subsequently regressed against species diversity to determine the extent to which species diversity is related to vegetation patterns on a macro-scale.

Species Diversity and Habitat

Species diversity was regressed against component scores of Components 1 and 2 (or equivalently, Factors 1 and 2). Species diversity did not correlate with Component 2 ($y = 0.180x + 2.18$, $r^2 = 0.014$), but it was inversely related to Component 1, indicating that reptilian diversity declined as the habitat increasingly resembled a forest (Figure 2, solid regression line, $y = -0.665x + 2.18$, $r^2 = 0.187$). However, this relationship was weak, primarily because the area UF (a shrub-dense open area on towards the north end of the reserve; Table 1, Figure 1) had a very high component score (i.e., it did not resemble a forest in any respect), but it did not host any species of reptile. When this data point is omitted from the regression, the R-Square more than doubles, and much clearer relationship between species diversity and Component 1 is observed (Figure 2, dashed regression line, $y = -0.924x + 2.47$, $r^2 = 0.431$). Hence, species diversity is clearly positively associated with non-forested areas, but some feature particular to the UF site (a

Table 3: Rotated component matrix (Varimax rotation with Kaiser Normalization). Component 1 appears to differentiate between forested and non-forested areas; bolded loadings represent vegetation measures that are associated with this component, with high positive loadings associated with forested areas, and high negative loadings associated with open areas. Component 2 may be representing the degree of vegetative complexity in a given area; italicized loadings represent vegetation measures that are associated with this component. High negative loadings may be associated with low diversity/complexity of vegetation, and high positive loadings associated with high diversity/complexity of vegetation.

	Component	
Vegetation Measure	1	2
Mean Rock Size	**-0.696**	0.168
Number of Rocks	-0.144	*0.696*
% High Cover	**0.952**	-0.012
% Medium Cover	-0.120	*0.687*
% Low Cover	**-0.686**	*0.671*
% Grasses	**-0.573**	*-0.692*
% Exposed Earth	**0.691**	0.293
Soil Moisture	-0.247	*-0.795*
Number of Saplings	0.388	-0.152
Number of Tress	**0.897**	-0.112
% Low Brush	**-0.718**	*0.597*
Number of Brush Stems	**-0.652**	*0.700*
Median Tree Area	0.419	0.219
Basal Area of Trees	**0.946**	-0.098

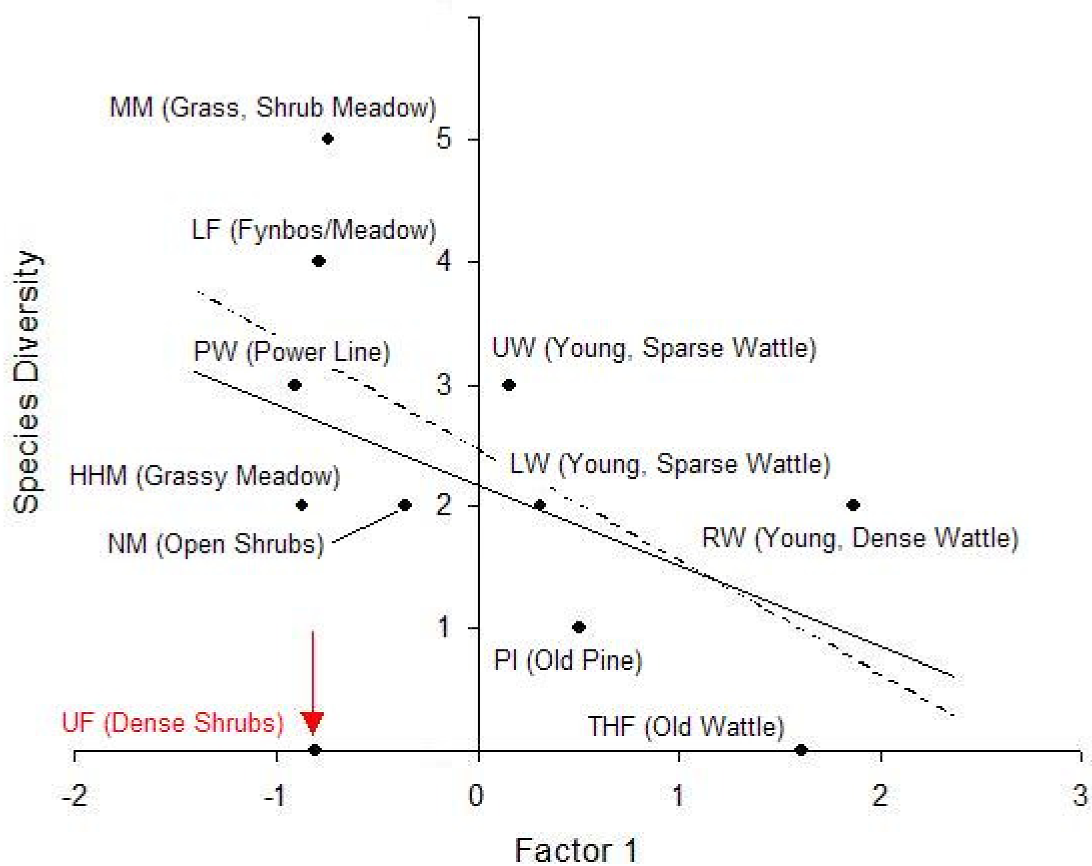

Figure 2: Species diversity and a function of Factor (Component) 1. Each point identifies one of my 11 sites, and the species diversity at that site (y axis) in relation to Factor 1 (x axis). Proceeding along the x axis from left to right (-ve to +ve), the sites increasingly resemble a forest habitat. Species diversity correlates negatively with Factor 1, so species diversity decreases as sites increasingly resemble forests. The solid line reflects this relationship when considering all 11 sites; the dashed line considers this relationship while omitting site UF (see text).

non-forested area) is not conducive to reptilian diversity. This feature may be stem density and the density of low shrubs. When stem density (Figure 3A) or per cent low cover (Figure 3B) is regressed against species diversity, a quadratic relationship is observed. Thus, an optimum stem density or brush cover exists in a given habitat, and deviations from the optimum result in a decrease in reptilian diversity. Importantly, site UF featured extensive low brush cover and a very high brush stem density, and this phenomenon may explain why the site UF scored very high on component 1, but did not host reptiles. From Figure 3B, the optimum per cent brush low cover appears to be around 50%, whereas per cent brush cover at site UF slightly exceed 80%.

Species endemism

Of the 12 species identified in my surveys, 6 were found exclusively in open areas, 4 were found exclusively in forested areas, and 2 species were found both in open and forested areas (Figure 4). However, two of the four species endemic to forested areas have been incidentally observed in other habitats during non-survey hours. So the actual number of species restricted to forested areas is two: the Ocellated Thick Toed Gecko (one observation), and an unknown species of gecko (three observations).

Discussion

Reptilian diversity in general on Wildcliff Nature Reserve appeared to be most strongly associated with open areas, and in particular, open areas with a moderate density of low shrubs and/or a moderate brush stem density (these two vegetation measures are obviously correlated). Conversely, diversity was negatively associated with forested areas. The patterns observed in the present study are likely attributable to the favourable thermal environments found in open areas, coupled with a density of shrubs that does not hinder locomotion, but that nonetheless provides sufficient refuge from potential predators. Similarly, a ‘preference’ for areas with a moderate shrub density may concurrently be related to the thermal requirements of reptiles, whereby a very low or high shrub density may be associated with very warm and very cool environments, respectively, that fall outside a preferred range of temperatures.

Importantly, 66% (2 of 3) gecko species identified on the reserve were found exclusively in forested areas. So although forested areas generally host a lower species diversity than do open areas, there is still a low level of endemism in these wattle forests.

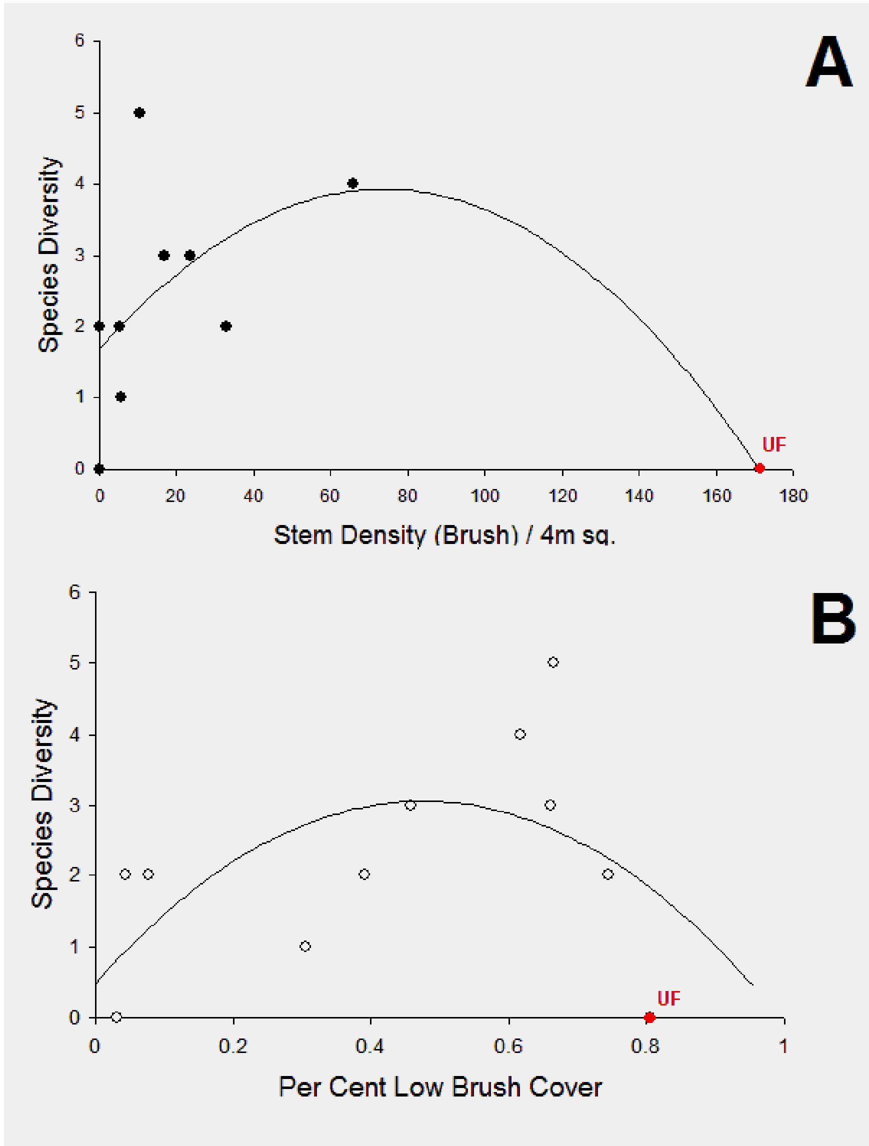

Figure 3: Relationship between reptilian species diversity and (A) the number of brush stems per $4m^2$ ($y = -0.0004x^2 + 0.061x + 1.69$, $r^2 = 0.442$) and (B) the per cent low brush (transformed by dividing per cent cover by 100, then performing an asin[square root] on this value) cover per $4m^2$ ($y = -11.4x^2 + 10.8x + 0.484$, $r^2 = 0.295$). The site UF is highlighted in red because it had the highest stem density and per cent low brush cover of any site, and in both cases, this site appears to be driving the observed quadratic relationships.

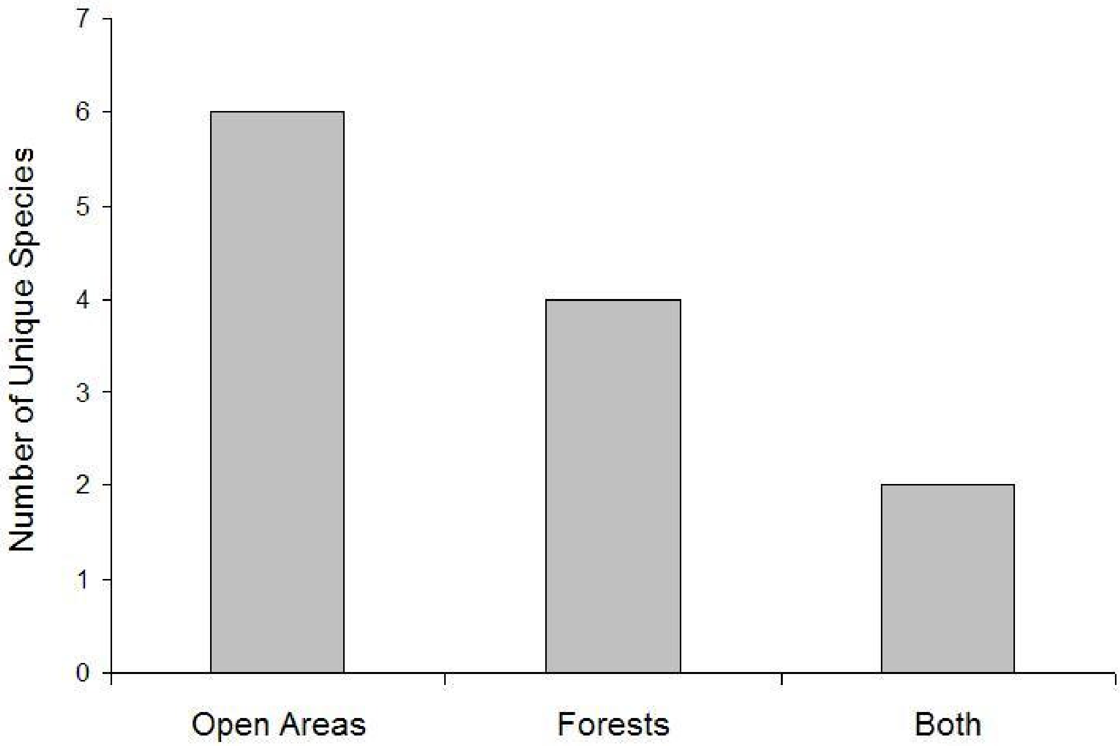

Figure 4: The number of unique reptile species (‘endemic’ species) found in each type of habitat. “Open Areas” are areas that scored a negative value in the PCA; “Forests” are areas that scored positive values in the PCA. “Both” refers to the number of species that were found both in forested and open areas.

In a similar vein, several studies (primarily focusing on arthropods) have reported a lower species diversity in exotic vegetation stands, but have noted concurrently that community assemblages differ among habitat types (Donnelly and Giliomee 1985; Breytenbach 1986; Samways et al. 1996). Indeed, data from a recently disturbed habitat (the Power Line, where Black Wattle was cleared less than 5 years ago, and the current vegetative community consists primarily of low shrubs) show that these 2 Gecko species may not persist in open areas. That is, 1 of the 3 species identified on the Power Line, the Cape Skink (*Trachylepis capensis*) was associated exclusively with open areas, while the remaining 2 species, the Cape Girdled Lizard (*Cordylus cordylus*) and the Spotted Skaapsteker (*Psammophylax rhombeatus*) had been previously found both in forested and open areas. This indicates that reptiles will indeed re-colonize an area within 5 years of disturbance. But despite the fact that the Power Line is directly adjacent to forest sites where the 2 Gecko species were found, no Geckos were found on the Power Line. The Ocellated Gecko is thought to require moist conditions (Branch 1998), and hence, perhaps it prefers lower temperatures; this may be why it was found exclusively in forested areas. Hence, the eradication of Black Wattle on Wildcliff Reserve is unlikely to have a substantial negative impact on species diversity in general, but it may result in the loss of gecko diversity.

There is, however, a major source of error in this design that warrants careful consideration: my primary sampling method involved flipping cover objects (primarily rocks), so my design assumes that all species and all animals in all habitats use cover objects similarly. This may not be the case. For example, in shrub-dominated meadows, animals may opt to conceal themselves or forage within dense shrubbery, and if this is the case, they would have been less likely to be observed in my study. Second, with regard to the site UF which hosted no reptile species, the conclusion that this phenomenon is due to shrub stem density must be considered tentative. This is because site UF was the only site with no species that also had a high shrub stem density, so this observation has to be independently replicated at other sites before we can safely associate a lack of reptilian diversity with high stem density.

In conclusion, the removal of Black Wattle on Wildcliff Reserve will likely not have detrimental effects on reptilian diversity in general, as diversity appears to correlate positively with open areas. However, the removal of Black Wattle may eradicate two gecko species that were found exclusively in forested areas.

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