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Estimating the rehabilitation of former farmlands into wildlife areas using the bat-eared fox as an indicator species

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Abstract

Agricultural activities such as overgrazing negatively affect the soil condition of an area, severely reducing its status as a wildlife habitat. The resulting erosion and degradation of the land has put serious strain on wildlife and biodiversity over large areas of Namibia. This study shows that damaged habitat on farmlands can be rehabilitated into active game areas again during a fairly short period of time, using eco-tourism as a tool for management and an alternative sustainable industry. Habitat preferences and density estimation of the bat-eared fox, here used as an indicator of the degree of rehabilitation of an area, was investigated and compared between a recently rehabilitated reserve area and a farm area. The soil type and existence of ‘fairy circles’ (produced by termites, a major food source of this species) were the primary variables predicting the abundance of bat-eared foxes. The existence of habitats suitable for the bat-eared fox within farmland that had been rehabilitated for five years, compared with the absence of bat-eared foxes in current farmland suggests that present rehabilitation-programs have been successful.

Keywords: agricultural pressure, degradation, habitat preferences, eco-tourism, restoration, *Otocyon megalotis*.

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1. Introduction

Over the past century, a large proportion of Namibia's wildlife areas have been given over to farmers. The severe degradation of the land following decades of drought, overgrazing and agricultural pressure has major consequences for wildlife and biodiversity. Recurrent long drought periods have put serious strains on the ability of the human population to make a livelihood through agriculture on the impoverished soil. Some of these areas are now being restored to wildlife and managed through eco-tourism.

The animal in focus, the bat-eared fox (*Otocyon megalotis*), is a species susceptible to disturbance and threatened by habitat encroachment from humans. The bat-eared fox is an opportunistic species with regard to food availability (Berry 1981, Nel 1978), and according to Malcom (1985) it is able to occupy newly formed or temporary areas unsuitable for other animals. Because of these characteristics the species is here used as an important indicator species, its density and number of individuals functioning as means for estimating the degree of rehabilitation of an area.

I investigated how human activities, such as farming, affect the range, distribution and use of habitats by the bat eared-fox and focused on the different population densities between two different areas, a reserve area undergoing rehabilitation and a neighbouring cattle and livestock farm area. This study is part of a larger one focusing on the ecology, habitat preferences and densities of small mammals inhabiting newly rehabilitated wildlife areas. The study was performed at the request of Wilderness safaris, a large safari company active in several countries throughout Africa. The company specializes in combining wildlife management and eco-tourism, trying to reconvert overused areas to their original conditions. Eco-tourism could become one of the more sustainable industries in Namibia, if properly managed, and is of high importance not only to wildlife but also because of the increased job opportunities it creates for people in the suburban areas.

Study species: the bat-eared fox

The bat-eared fox is a comparatively small, nocturnal canid (4-6 kg), which lives in two distinct populations in the eastern and southwestern parts of Africa. It is the only species in its genus, and it differs from other canids in several morphological features primarily associated with its dentition (Maas 1994). The most outstanding features are the extraordinary large ears that can measure up to 13 cm in length on a 30 cm shoulder high animal (Kingdon 1977, Skinner & Smithers 1990). The ears function as thermo regulators in addition to their main purpose of facilitating effective prey detection (Maas 1994).

The bat-eared fox breeds seasonally, with cubs born from late August to late October. Breeding is highly dependent on the rainy season and since the wet period can vary greatly, the species is adapted to find suitable habitat and reproduce rapidly as soon as the right conditions are met (Malcolm 1986). Few pups survive to maturity and usually only two or three pups are seen accompanying their parents (Smithers 1971). The cubs are fully-grown and leave their parents at six month of age (Estes 1991). Sibling groups may stay together for longer times and breeding starts at an age of approximately 18 months (Nel & Bester 1983). Some female offspring stay with their parents a few years before leaving (Estes 1991).

Bat-eared foxes mostly live in monogamous pairs (Malcolm 1986, Koop & Velimirov 1982). However, both polygynous, and non-reproductive males living in groups do occur (Malcolm 1986). Pairs are often seen together, sleeping, grooming, playing and protecting each other (Estes 1991). Unlike other canids in which pairs usually defend a territory, little hostility occurs between neighbouring groups and range overlap seems to be common (Koop & Velimirov 1982, Nel & Bester 1983, Malcolm 1986). The home range can extend from 0.25 to 1 km^2 (Estes 1991). Population density may reach 10 ind. /km^2, but 0.5-3 ind. /km^2 is more usual (Allen & Unwi Cop. 1984). The bat-eared fox is an opportunistic species that feeds predominantly on insects (Nel 1978, Berry 1981). *Hodotermes mossambicus* (a large harvester termite) and dung beetles are the two most common items in the animals' diet, but Orthopterans, beetles, larvae and ants are usually present as well. Small vertebrates are a consistent but minor part of the diet, and wild fruits and berries are, when available, an important part of the diet, especially during the dry season (Maas 1994, Malcolm 1986)

Throughout their range, bat-eared foxes are particularly associated with open, dry country, such as open plains, or shrub savannah (Smithers 1971). They require areas of short grass ranging from 25 to 35 cm (Mackie & Nel 1989, Malcolm 1986) and reach the highest densities where burrows or thicker brush are available (Smithers 1971, Waser 1980, Koop & Velimirov, 1982). As a rule they shun woodlands and desert areas (Smithers 1971), but may appear along woodland boundaries and in clearings (Lamprecht 1979).

The bat-eared fox is as many animal species today threatened by habitat encroachment due to human activity, where hunting, agricultural expansion and use of agricultural chemicals constitute only a few examples. During the colder months, when the bat-eared fox is in its prime condition, it develops a long, eye-catching fur. As a consequence, it is regularly hunted during this time (Skinner & Smithers 1990). Because of its preference for termites and other harmful insects damaging the crops, the bat-eared fox is actually a real asset to the farmer. However, due to its resemblance with jackals it is often killed, wrongly believed to prey on sheep and injure cattle. Larger carnivores such as hyena, black-backed jackal and the wild dog prey upon this small canid, and large numbers are also killed on roads (Smithers 1971). Currently in Namibia this is a serious problem. Another cause of mortality is epidemics such as rabies. The risk of rabies infection can be expected to increase where wildlife comes into closer contact with domestic dogs (Maas 1994).

Study area

The area of our study is situated in the southwestern region of Namibia, and lie on the Tchaub-River 20 kilometres from the Namib Desert. It constitutes 7 000 ha of rehabilitated wildlife area, known as the Witwater reserve (now incorporated into the Kulala Wilderness Reserve), and 4 500 ha of farmland, Betesda and Witwater farm. The reserve area has been privately owned by Wilderness Safaris since 1996. Earlier the area was owned by a neighbouring farmer and used for grazing livestock. It is a semi desert area dominated by extensive grasslands and dwarf shrub savannah. The high temperatures and the low precipitation in the region, result in a very arid climate. The rainy season extends from October to April and the mean annual rainfall in the area ranges from 50 to 100 mm (Ministry of Agriculture, Water and Rural Development).

Throughout the area there are mountains, mostly of granite and limestone, surrounded by gravel plains and patches of soft sand. Many flat plains of rock and stone expand through the area. These come alive during the rains, when they will quickly be covered with tall thin grass and creeping yellow flowers, attracting herds of gemsbok (*Oryx gasella*), springbok (*Antidorcas marsupialis*), steenbok (*Raphicerus campestris*) and klipspringer (*Oreutragus oreutragus*).

During drier periods there are fewer large mammals around, but still at night black-backed jackals *(Canis mesomelas*), aardwolves (*Proteles pictus*), cape-fox (*Vulpes chama*) and bat-eared foxes forage for termites, insects, reptiles and small rodents. Spotted hyena (*Crocuta crocuta*) is sometimes recorded here (personal observation).

River valleys and pans are located throughout the area. Though dry on the surface, their permanent underground water sustains trees and bushes, such as camel thorn *(Acacia erioloba*) and nara melon (*Acanthosicyos horrida*). Other common river-valley trees include the anaboom (*Acacia albida*), the shepherd's tree (*Boscia albitrunca*), the wild green-hair tree (*Parkinsonia africana*), and the weeping false ebony (*Euclea pseudebenus*). The thriving vegetation found in these valleys during the rainy season attracts numerous insects and birds, as well as larger mammals like gemsbok, kudu (*Tragelaphus strepsiceros*) and springbok. These valleys also harbour small populations of nocturnal cats such as leopards (*Panthera pardus*) and caracals (*Felis caracal damarensis*), particularly in ephemeral river channels which cut through the extensive low mountain ranges in this region.

A main lodge constituting nine bungalows and one lapa (main building), a tented camp composed of six tents and one lapa, the maintenance quarters and an airstrip are situated on the reserve area. The two farm areas consist of two ranches with human settlings, large herds of livestock and airstrips.

2. Materials and Methods

The study was performed from September to December 2000. It consists of two parts, the first part being observations of animal activity and the second a habitat inventory.

Observations

The method used for recording animal activity was line transect sampling. Observations were made from a 4-wheel-drive vehicle, driving at approximately 20 km/h along the entire road network (~740 km) in the study areas. The road network was divided into four continuous transects (220 km, 190 km, 160 km and 170 km respectively). Identifications were made using 8 x 42 mm (108 m /100 m) binoculars. After sunset and before sunrise, the binoculars were aided by an 800 000 CL spotlight. The whole area around the vehicle was scanned. The numbers of groups observed (per area) and the total numbers of foxes were recorded.

The bat-eared fox is a nocturnal animal, and about 85% of its activity occur after dark (Lamprecht 1979). Therefore, transects were traversed at night, starting approximately an hour before sunset and during early mornings before sunrise and an hour thereafter. The exact location of all study animals were recorded by a GPS-unit (Garmin GPS 12). Date, time, and place were noted. Since most of the observations were made at night, eye reflections and types of movement were very important in differentiating between animals from a far distance.

Animal species recorded were bat-eared fox, cape fox, aardwolf, oryx, black-backed Jackal, african wildcat (*Felis lybica*), striped polecat (*Ictonyx striatus*), springbok, spotted hyena, steenbok, klipspringer and caracal. See also Svedin 2002 (unpubl.).

Population density was estimated in two ways. To obtain the *crude population density*, estimates were done for the total reserve area with a line transect sampling technique. The line transect sampling method resulted in four unbroken transects, all differing in length (220 km, 190 km, 160 km and 170 km respectively). The Burnham density method was used to calculate the population density over each of the four different transects. ($D = n \times f(0)/2L$), where D is the estimated density of the species, n is the total number of animal seen, L is the total length of the transects and f (0) the probability density function at zero distance from the transect (Burnham *et al.* in Knott & Venter 1987). This method relates to the transect as a strip of limitless width in which the observer records all the animals seen and not just those out to a particular distance. In addition, estimation over the four different habitat types was carried out to obtain the so called *ecological density*.

Habitat inventory

To obtain a general view of the different habitat types in the study areas a habitat inventory was performed during mornings from the beginning of October to the end of November. A systematic, aligned grid-sampling technique was used, in which the area was divided into squares. The squares measured 1 km^2, and a total of 61 squares were fitted inside the boundaries of the reserve area. The farm area contained 37 squares.

All squares of the grid were surveyed one at a time, and data were collected on grass-height, food availability, soil type, number of and proximity to fairy circles (circular formations on ground devoid of grass, probably due to high termite activity), roads, riverbeds, fences, and human settlements. Before being investigated, each square was divided into four 0.25 km^2 quadrants, among which only the one to the lower left was surveyed and further divided into 100 m^2 squares. In the 1 km^2 squares, data on number of roads, mountains, fences and human settlings, was collected from a vehicle. The 0.25 km^2 quadrants was used for the collection of data concerning soil type (i.e. soft sand or gravel ground), as well as number of fairy circles, grass height, and availability of prey items. To obtain an adequate estimate of the different parameters surveyed in the 0.25 km^2 quadrants, two persons walked through the quadrant, each on a straight line, sited 100 m apart, scanning approximately 50 m on each side of the line. The four 100 m^2 squares, situated in the corners of the 0.25 km^2 quadrants, were then surveyed for active termite mounds and possible prey items. To obtain an accurate estimate of termite abundance, all active mounds in those squares were counted and to appreciate the abundance of alternative food items, lizards, crickets and beetles were counted.

Habitat parameters

The various habitat parameters measured in each square were grass-height, number of fairy circles, soil type (mountainous, soft, gravel, stony, or bare ground), presence or absence of riverbeds, number of roads and fences, indications of foraging activity, and food availability in terms of termite activity and other possible food items.

Grass-height was measured because according to the literature, the bat-eared fox favours a certain range of grass height (Mackie & Nel. 1989, Malcolm 1986). The species favour grass high enough to hide them from predators but still low enough to enable good visibility of the area. *Fairy circles* were noted because they seem to constitute a suitable habitat for termite activity and represent a preferred site for denning and foraging. *Mountains* were distinguished from other soil types and classified as unsuitable habitats for the bat-eared fox (classified as habitat 1) and were therefore excluded in the practical part of the inventory (not surveyed). *Geomorphic features* were considered important since different types such as soft sand, gravel, stony, mountainous or bare ground provide different potential for denning, foraging and termite activity. *Riverbeds* were noted as either present or absent, and considered important because the specific structure may facilitate movement, and the onsite vegetation can provide both protection and food. Human-induced landscape features such as roads and fences were also recorded. *Roads* were counted since they may be regarded not only as a source of human disturbance, but also a structure that may facilitate movement. *Fences* were noted because of their potential disturbance and hindrance to natural movement patterns between different foraging areas. *Food availability* was included as it represents a habitat preference for the bat-eared fox, with termites as the primary food source. Termite mounds and surface invertebrates were counted in order to estimate the abundance of food. *Diggings* were considered a strong indicator of small mammals' foraging activity.

Habitat Classification

Based on the inventory, the areas were sorted into four different habitat categories:

1. Mountainous areas including mountains, rock outcrops and ridges.
2. Areas with gravel or stony ground. Grass height outside the preferred range of 25-35 cm (Mackie & Nel. 1989, Malcolm 1986). Grazed and trampled areas and areas in proximity to humans and human activity.
3. Areas characterised by bush savannah, grass height in preferred range, mix of hard gravel and soft sand, high availability of food items such as termites, lizards, crickets and beetles.
4. Bush savannah, grass height in preferred range, mix of hard gravel and soft sand, rich food supply, diggings indicating foraging activity of bat-eared fox, active or abandoned dens in the area.

Statistics

When analysing the data statistically, the Kruskal Wallis Test was used to reveal differences in the number of observations made in each of the four different habitat types. Also, differences in the number of foxes observed in each of the habitat types were analysed with the Kruskal Wallis Test.

When comparing the reserve area and the farm area in respect to habitat distribution and various habitat parameters, the Mann-Whitney U Test was applied. This test was also used when comparing “hot-spot-squares” with randomly chosen squares regarding habitat quality and different habitat parameters on the reserve area.

For all correlations the Spearman Rank Test was used.

3. Results

3.1 Estimates of habitat types

When comparing the reserve area with the farm area, a difference was found regarding the distribution of the four habitat types (W = 3283.5 P < 0.0401). The two dominating habitat types on the farm area were habitat 2 and 3, while on the reserve area habitat 3 and 4 were the dominating ones (fig 1).

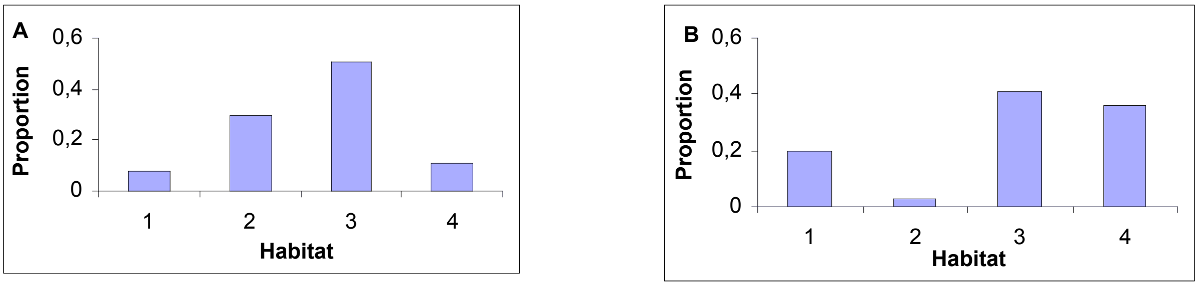

Fig. 1. The proportional distribution of the four different habitat types on (A) the farm area and (B) the reserve area. For habitat description see methods.

Within each of the four habitats, a difference was found in the number of foxes (H = 14.48 P < 0.002) and in the number of groups observed (H = 15.44 P < 0. 001) during the three month study period. A strong correlation was found between the number of foxes observed in an area and the habitat quality of that area (R = 0.34 P < 0.0072) (fig 2), as was the case with the number of groups observed in an area and the habitat quality of that same area (R = 0.36 P < 0.0039). Habitats 3 and 4 were confirmed to be the favoured habitats. No signs of activity by the bat-eared fox were found in any of the two farm areas.

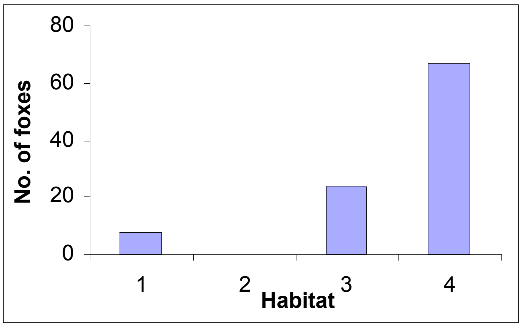

Fig. 2. The correlation between habitat quality and number of foxes observed in the different habitats. For habitat description see methods.

Significant differences were found between the reserve and farm sites in regard to soil type in habitats 3 and 4 ($W = 1856.0$ $P < 0.0085$), number of fairy circles in all habitats ($W = 3429.0$ $P < 0.0002$), and availability of secondary prey items in all habitats ($W = 2597.5$ $P < 0.0019$). Secondary prey items were more abundant on the farm, and fairy circles more numerous in the reserve (fig 3).

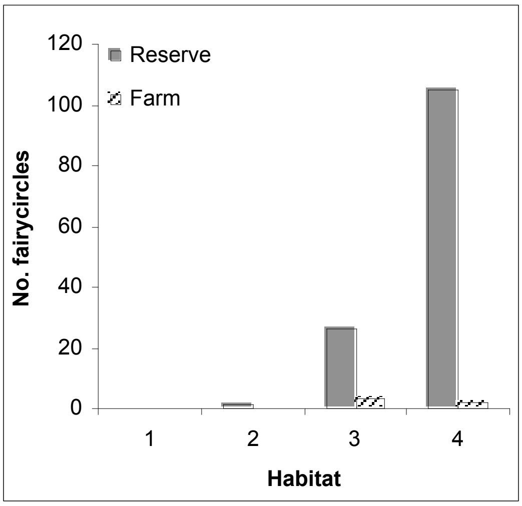

Fig. 3. The number of fairy circles in the different habitat types for the reserve and the farm area, respectively. For habitat description see methods.

The soil types predominating in habitat three and four on the farmland were stony and bare grounds, followed by a small portion of gravel grounds. On the reserve area, soft sand and bare grounds were the predominating structures in the preferred habitats, while only a small fraction constituted hard gravel and stony grounds (fig 4).

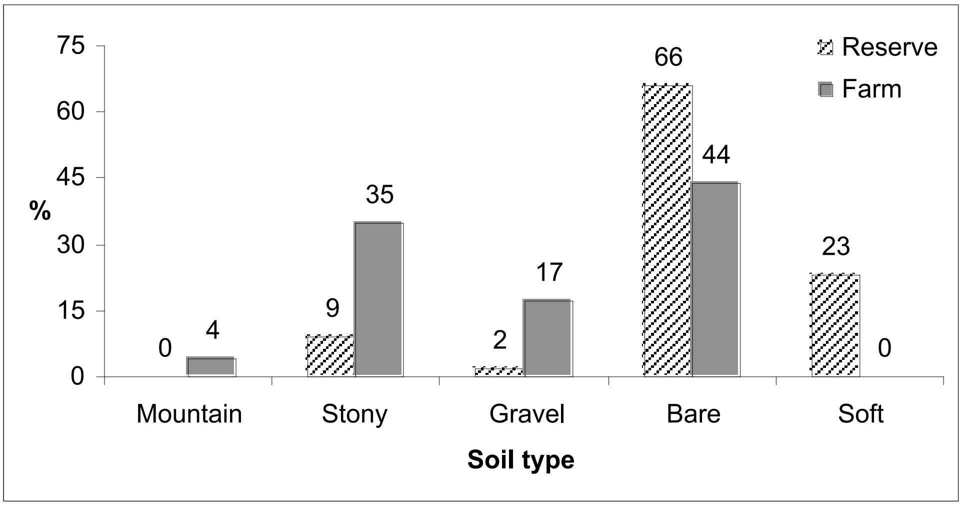

Fig. 4. The disparity concerning soil type over habitat three and four between the reserve and the farm area.

The number of roads differed considerably between the two areas ($W = 1893.0$ $P < 0.0039$), as did the number of riverbeds ($W = 2633.5$ $P < 0.0028$). Roads were more numerous in the reserve area and riverbeds occurred more frequently in the farm area.

No variation regarding grass height ($W = 2889.0$ $P < 0.13$), termite abundance ($W = 2866.0$ $P < 0.26$) or signs of foraging activity, such as diggings, ($W = 2869.5$ $P < 0.14$) were found when comparing the reserve area with the farm area. There were no deviations concerning the number of fences between the reserve area and the farm area ($W = 2907.0$ $P < 0.31$).

There was a positive correlation between the number of bat-eared fox family groups observed in an area and the number of fairy circles within that area ($R = 0.26$ $P < 0.045$). The total number of foxes observed in an area tended to correlate positively with the number of fairy circles in that particular area ($R = 0.23$ $P < 0.074$) (fig 5A). The soil type of an area was also found to strongly correlate with both the number of family groups observed ($R = 0.33$ $P < 0.0091$) and the total number of foxes counted in that area ($R = 0.30$ $P < 0.019$) (fig 5B).

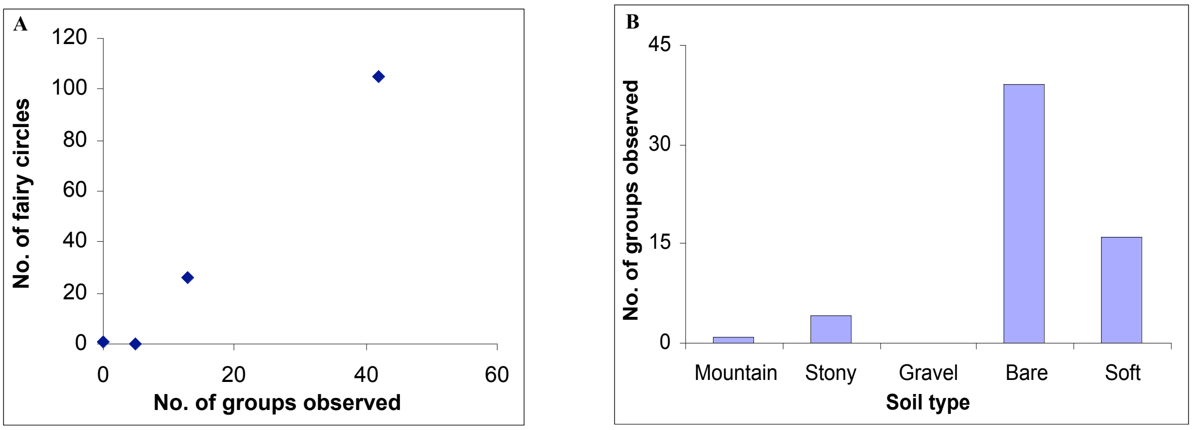

Fig. 5. (A) The correlation between the number of groups observed in an area, and the number of fairy circles within that same area. (B) The correlation between soil type and the number of groups observed.

There was no correlation between the number of groups observed and the number of fences ($R = 0.11$ $P < 0.39$), roads ($R = 0.16$ $P < 0.22$), riverbeds ($R = -0.12$ $P < 0.36$) or grass heights ($R = 0.053$ $P < 0.68$) observed in a specific area. Nor was there any correlation between the number of foxes observed and the above mentioned parameters: fences ($R = 0.099$ $P < 0.45$), roads ($R = 0.15$ $P < 0.25$), riverbeds ($R = -0.13$ $P < 0.31$) and grass height ($R = 0.052$ $P < 0.69$).

The number of groups did not correlate with termite abundance ($R = 0.22$ $P < 0.090$), secondary prey item abundance ($R = 0.054$ $P < 0.68$) nor total food abundance ($R = 0.14$ $P < 0.29$), and nor did the number of foxes observed correlate with the above mentioned parameters: termite abundance ($R = 0.20$ $P < 0.13$), secondary prey item abundance ($R = 0.051$ $P < 0.70$) or total food abundance ($R = 0.12$ $P < 0.37$).

When comparing “hotspot-squares” (squares with a density of 4 foxes / km^2 or more), with randomly chosen squares, differences regarding habitat quality ($W = 4.5$ $P < 0.067$), termite abundance ($W = 3.5$ $P < 0.068$), and grass height ($W = 6.0$ $P < 0.060$) approached significance. The habitat quality tended to be higher on the hotspots, as did the termite abundance. The grass height tended to be in the preferred range more often on the hot spots than elsewhere. No difference was found regarding the number of fairy circles ($W = 8.0$ $P < 0.38$), however the samples did differ notably in that respect, with such structures being more numerous on the hotspot areas. Concerning the number of riverbeds ($W = 7.5$ $P < 0.24$), number of roads ($W = 8.5$ $P < 0.44$), availability of other food items ($W = 9.0$ $P < 0.517$), and type of soil type ($W = 8.0$ $P < 0.33$) no distinctions could be made between the two samples. One reason for this lack of significance may be the small sample size of only six squares in each sample.

3.2 Estimation of animal abundance

The crude density (individuals/km^2) over the four different transects, ranking from one to four, were estimated to be 0.57; 0.016; 0.069 and 0.024 respectively. The ecological density (individuals/km^2) over the four different habitat types, ranking from one to four, was estimated to be 0.67; 0; 0.96 and 3.04 respectively.

The ecological density implies that there is a preference for certain habitats consistent with the patterns in the statistical analysis in this study. To further support these findings and to eliminate possible statistical errors due to biased sampling, randomisation tests comparing the number of foxes over the different habitat types were done. The tests showed a significant difference between habitat 1 and 4 (P = 0.050) and between habitat 3 and 4 (P = 0.034).

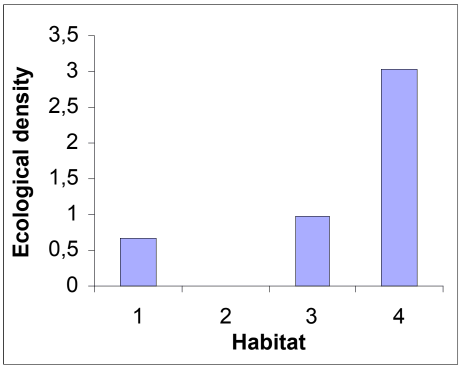

Fig. 6. The ecological density of foxes (individuals/km^2) over the four different habitat types. For habitat description see methods.

4. Discussion

The main focus of this study was to determine whether former farmlands have the ability to regenerate, managed through eco-tourism, and become active game areas again. Of interest was also to study to what extent and how long rehabilitation takes from the commencement of management. The animal in focus, the Bat-eared fox is an opportunistic species, sensitive to human disturbance, and an early colonizer of new areas. Because of these characteristics the Bat-eared fox is used as an important indicator for estimating the degree of rehabilitation of the Sossusvlei Nature Reserve.

The 7 000 ha Sossusvlei wildlife area under rehabilitation was compared to 4 500 ha of farmlands with respect to habitat quality. A difference in the proportional distribution of habitat types was found between the reserve and the farm, with a larger proportion of high quality habitats for the bat-eared fox on the rehabilitated area. High quality habitats are characterised by bush savannah with a grass height of 25-35 cm, a large proportion of bare and soft grounds suitable for foraging and denning, and a high availability of food. Low quality areas are characterised either by mountains or by hard and stony grounds with a grass height outside the range of 25-35 cm. Proximity to humans and human activities may also degrade the quality of an area, and were taken into account in the study. The higher proportion of high quality habitats on the rehabilitated area probably depends on reduced disturbance from humans and absence of herds of trampling and grazing domestic animals which degrade the habitat for wildlife.

In this study, a strong correlation was found between the habitat quality of an area and the number of foxes in that particular area, stressing the importance of high quality patches maintained by the absence of human impacts and domesticated animals. In a study by Wallgren (2001) it was shown that the bat-eared fox is often encountered at long distances from human settlements. In this study no bat-eared foxes were observed on the farm area, further stressing this species' susceptibility to human disturbance and its high demands on suitable habitats. Svedin (2002) found a correlation between animal density and habitat quality when studying five small mammals in the Witwater private reserve. The results from this study showed that animal densities are clearly higher in areas of high quality habitats.

The somewhat surprising finding of the higher abundance of secondary prey items on the farm area may be due to the lower pressure of natural predators such as the bat-eared fox and other small mammals. An optimal grazing pressure and amount of trampling sometimes enhances a species' abundance i.e. certain plants and invertebrates. The Sossusvlei area has endured a long period of drought (over 10 years; Nick Grobler, pers. comm.) and the higher availability of food in an area should attract predators. In this case however, the advantage of a rich food source seems to be balanced by other disadvantages of the habitat. The lack of variation in termite abundance and signs of small mammals foraging activity between the two areas suggests that both areas are suitable for foraging. The signs of foraging show that other small mammals do in fact forage on the farm area. Aardwolves (*Proteles cristatus*), black-backed jackals (*Canis mesomelas*), cape foxes (*Vulpes shama*) and african wildcats (*Felis lybica*) were sometimes encountered when surveying the area. The lack of variation in grass height between the areas implies that the areas should be equal to one another considering protection from predators and the ability for the bat-eared fox to screen the area. The reasons why the bat-eared fox was never sighted on the farm must then depend on other factors, such as perhaps soil type and/or disturbance.

When interviewing the two farmers on whose areas part of the study was performed, information about livestock, farm history and daily activities were obtained. According to them the area has been exposed to a thirteen year long period of severe drought and has now been heavily overgrazed for more than five years. The livestock is guarded by dogs which regularly drive the herds from one grazing site to another. The dogs also protect the livestock from possible predators. It is quite possible that the livestock and the dogs constitute a disturbing element to wildlife and that the severely overgrazed area has turned into a low quality habitat, unsuitable for most wildlife including the bat-eared fox. Legal and illegal hunting is another possible reason why the fox is absent on the farm area. The hunting season lasts from the end of May to end of August, but the farmers have the right to go hunting all year round on their private properties. There is also a huge problem with poachers intruding on the property once or twice a week (personal comments Nick Groster and Tony Rust).

Fairy circles were more numerous on the reserve area. Fairy circles frequently appear on the soft, open slopes of mountain bases, and as many abandoned dens situated in fairy circles were discovered during the period of this study, they seem to often indicate good denning areas (personal observation). This would explain the positive correlation between the number of fairy circles in an area and the number of foxes observed in that area. The beginning of our study period coincided with the denning period of the bat-eared fox. At one occasion a pair of foxes was encountered when investigating a den situated in a fairy circle.

The soil type differed between the two areas compared. Soft sand and bare grounds were the predominating structures in the reserve area while stony and bare grounds dominated the farm area. One reason for the differentiation may be the different grazing pressures of the two areas, the farm area being highly utilized by domestic animals, trampling and eroding the ground. Another reason could be naturally occurring differences. More numerous in the farm area were structures such as riverbeds that some years cause flooding and erosion of the land. Another formation found in the farm area possibly influencing the soil type was a geological vault, running through the centre of the farm. Soil type is a very important habitat parameter since it highly influences the suitability of an area. Two factors vital for the bat-eared fox's existence in an area, foraging possibilities and denning sites, are both dependent on the type of soil dominating that area. Soft sand and bare grounds facilitate animal abundance since they constitute good areas for denning and foraging. Hard and stony grounds however obstruct denning behaviour and may complicate foraging. A strong positive correlation was found between fox abundance and type of soil type. Therefore, the difference in fox abundance over the two areas may, to some extent, be explained by the differences in soil type between the areas.

Roads were more numerous in the reserve area compared to the farm areas. Roads can constitute a source of disturbance but may also facilitate movement and foraging. The foxes were often encountered foraging and in motion alongside and on the roads. The use of roads in the reserve was also restricted in order to lessen the disturbance on wildlife and enhance rehabilitation. The number of fences did not differ between the two areas and there was no correlation between the occurrence of foxes and number of fences, indicating that fences do not constitute a noticeable disturbance for the fox. This is not a very surprising result, as the fences were fairly open and easy to pass through. No correlation was found between the occurrence of riverbeds and fox abundance, a surprising finding at first since the more shallow groundwater found along the riverbeds allow for more varied vegetation and therefore offer shelter and possible food sources for the bat-eared fox. Due to the long and severe drought no surface water was visible in the area. For this reason, dry riverbeds may not be more attractive to the animals than the surroundings. There is a possibility that the situation would be different during a rain period. The lack of correlation between grass height and fox abundance was also an unexpected result. In earlier works, Mackie & Nel (1989) and Malcolm (1986) showed that grass height is of major importance for the occurrence of Bat-eared fox. The reason why this study did not reveal such a correlation may be due to the sample size or to the lesser importance of grass height compared to soil type. Another reason could be that grass height and visibility is not an issue for the bat-eared fox when ground predators are few.

The prevalence of foxes did not correlate with either termite abundance or secondary prey item abundance, nor did it correlate with total food abundance. This is a rather peculiar finding, as the Bat-eared fox uses a large proportion of its active time to scavenge for food. Also, most foxes during the study were actually performing foraging behaviour when encountered. However the habitat inventory was carried out during day time, and as most surface active invertebrates are nocturnal, the survey may not be a good reflection of actual food abundance.

In the reserve area there were some patches where the bat-eared fox was more frequently encountered and in more dense groups than expected by chance. These sites are called hotspot squares and when compared to randomly chosen squares, the hotspots tend to have a higher habitat quality (exclusively in habitat three and four), higher termite abundance and a grass height more regularly within the preferred range of 25-35 cm. No other distinctions could be found between the two samples and a contributing cause to this may be the small sample size of only six squares in each sample group. All the hotspots were situated far from the lodge, the maintenance quarters, the airstrip and the reception, indicating that the bat-eared fox discriminates suitable areas if in close proximity to humans and human activity. One hotspot, however, was situated quite close to the research base. One reason to this may be the proximity to water and food. The camp was, compared to the other sites of human disturbance, a small and relatively quiet site with few people.

Two methods were used to estimate the density of the Bat-eared fox in the reserve area. The line transect method estimates the population density over the whole area, while the quadrate sampling (ecological density) gives an estimation calculated from habitat usage and gives a description of habitat preference. The ecological density is a more accurate and useful one since it tells us much more about the actual population densities and population dynamics linked to habitat quality and patchiness. Considering that habitat preferences were observed (see Fig. 2), this measurement was potentially more informative than the overall population density.

In summary, fairy circles and soil type seems to be highly important characteristics of the habitats chosen by the bat-eared fox during the denning period. This may also be an important reason why the fox discriminates the farm area as a suitable habitat. Another central cause contributing to the absence of foxes in the farm area may be the disturbing elements of grazing livestock, hunting and domestic dogs. The overgrazed and eroded agricultural areas constitute low quality habitats for the bat-eared fox. Only five years has elapsed since the management began on the reserve and the land has indeed shown a remarkable ability to rehabilitate back into an active game area. The goal of managing valuable nature through eco-tourism has so far been a successful one in the Kulala Wilderness Reserve.

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