Habitat preference of reintroduced dorcas gazelles (*Gazella dorcas neglecta*) in North Ferlo, Senegal

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Abstract

In March 2009, 23 dorcas gazelles (9 males and 14 females) were reintroduced in the Katané enclosure, a 440 ha fenced-in area in the North Ferlo Fauna Reserve (Senegal). In the enclosure, the dorcas gazelle live with other reintroduced (the mohor gazelles and the scimitar-horned oryx) and native ungulate species (the Red-fronted gazelle), as well other native mammals. Seven habitat types were characterized in the enclosure. Habitat preference of dorcas gazelles was studied using presence and abundance of gazelle signs (tracks, latrines, fecal deposits) and direct observations. Seasonal data were collected along a 6-km long transect in the enclosure. The presence of dorcas gazelles is significantly dependent on the type of habitat in the Katané enclosure and they prefer open habitats (plateaus) to habitats with less visibility. This preference did not change according to season and the number of fecal deposits increased with proximity to the fence.

1. Introduction

The dorcas gazelle (*Gazella dorcas*) is the smallest gazelle species, and formerly, was the most common throughout most of North Africa. Although defined as a typical desert and semi-desert plains species, it occupies a variety of habitats within its wide area of distribution, from the Sahel to the Mediterranean Sea, and from the Atlantic coast to the Red Sea (Baharav and Mendelssohn, 1976; Kacem *et al.*, 1994; Mallon and Kingswood, 2001; Chammem *et al.*, 2008).

At present, wild populations of dorcas gazelles are experiencing a drastic reduction in most of their distribution due to illegal hunting. Moreover, human activities, e.g.,

livestock grazing, agriculture and settlement around new wells, reduce the space available for this species, and social conflicts and political instability in some areas of its distribution reduce their probabilities of natural recovery (Mallon and Kingswood, 2001; Chammem *et al.*, 2008). As a result, the dorcas gazelle is globally classified as "Vulnerable" (IUCN 2011), but its status differs from country to country, from "extinct" in Senegal to "endangered" in Morocco or Tunisia to "vulnerable" in Algeria (Mallon and Kingswood, 2001).

As for other endangered North African ungulate species, *ex situ* captive breeding programs, reintroductions and the creation of reserves and protected areas are the main initiatives for conserving dorcas gazelles (Kacem *et al.*, 1994; Cuzin *et al.*, 2007; Abaigar et al., 2009).

The success of the reintroduction of any species may be measured at different times and by different criteria, but what is essential from the beginning of their release, in the establishment phase according to Armstrong and Seddon (2007), is that individuals are able to select the most suitable habitats for their most basic activities, food selection, protection against predators and reproduction.

The purpose of this study is to evaluate the habitat preference of reintroduced dorcas gazelles (*Gazella dorcas neglecta*) in North Ferlo, Senegal. Although the study area is a medium-sized fenced-in space, it offers a variety of habitats to select from. The challenge, for both individuals and populations, is to deal with the sudden change from strictly captive conditions to those which can prepare them for complete freedom. The final goal of this study is to provide habitat indicators for selecting the most appropriate areas and conditions for their release in the wild.

2. Study area

The study was carried out in the Katane enclosure, located in the North Ferlo Fauna Reserve (NFFR), in northeast Senegal. The NFFR has an area of 487 000 ha, and was created in March 1972 to protect the sahelian fauna in northern Senegal (Figure 1). Soils in the NFFR are mainly ferruginous with lateritic outcrops. In the north of the reserve, the soils are predominantly sandy, and in the fossil river valleys they are a mixture of sand, with small amounts of loam and clay (Michel et al. 1969).The climate is Sahelian, modulated by the area's continental character. Average annual rainfall at Linguere is 476.7 mm (46 years 1934-1979), and 481.6 mm at Matam (51 years,1922-1979) (Wispelaere, 1980 in Jebali ,2008). The rainy season only lasts 3 months, usually from the end of July to the end September, and temperatures are high all year long.

The predominant woody species are *Pterocarpus lucens*, *Combretum glutinosum*, *Grewia bicolor*, *Guiera senegalensis, Commiphora africana, Balanites aegyptiaca*, *Boscia senegalensi*s and *Acacia* sp*.* The herbaceous stratum includes a wide variety of annual species.

Some striped hyenas (*Hyaena hyaena)*, red-fronted gazelles (*Eudorcas rufifrons*), red-necked ostriches (*Struthio camelus camelus*) are also found in the reserve.

Figure 1 by here

The Katané enclosure

The 440-ha Katané enclosure, (15º 29´11.36" N, 14º 6´36.76" W) is fenced off using 1.8-m-high URSUS wire fencing (Figure 1). The primary purpose of the enclosure was to protect vegetation from livestock (cows, sheep, goats, and donkeys) to favor regeneration of habitat and vegetation before reintroducing antelopes.

Weather data from the Ranérou station show average rainfall of 438.3 mm (1991-2003) and high temperatures all year long, with the hottest month in May (average 34.3ºC, maximum > 41ºC) and the coldest in January (average 24.4ºC, minimum 14.5ºC) (see Jebali 2008 for original data).

The enclosure is a plain with no noticeable differences in altitude.

Woody species include a variety of trees and shrubs, most of which are over 3 m high (*Pterocarpus lucens, Adansonia digitata, Combretum glutinosum, Grewia bicolor, Guiera senegalensis, Commiphora africana, Ziziphus mauritiana, Adenium obessum, Balanites aegyptiaca, Boscia senegalensi*s, *Dalbergia melanoxylon, Acacia senegal, A. ataxacantha, A. seyal, Anogeissus leiocarpus, Crateva adansonii, Mitragina inermis, Calotropis procera, Leptadenia hastata*, etc.). There is an enormous variety of annual grasses: *Schenofeldia gracilis, Zornia glochidiata, Cenchrus biflorus, Cassia tora, Eragostris* sp*, Cucumis melo, Pennisetum pedicellatum, Digitalis* sp., *Aristida* sp*., Andropogon* sp*., Panicum* sp*., and Corchurus* sp.

The local people who live near the enclosure belong to the peul ethnic group. Their main source of income is transhumant livestock (cattle-zebu, goats and sheep) herding.

3. Materials and methods

3.1. Habitats in the Katané enclosure

Vegetation in the enclosure was characterized using the line-intercept method (Lucas and Seber, 1977) over 54 randomly-selected geo-referenced points. Species identification, altitude and cover (percentage) of each plant species were noted for herbaceous, shrub and tree strata along a 20-m-long line. In addition, type of soil, and whether *Schoenefeldia gracilis* was the predominant graminae species or not, were noted at each point (see Figure 1).

The abundance and presence of *Schoenefeldia gracilis* was considered relevant to the habitat of dorcas gazelles. At the beginning of the rainy season, the tender seedlings are eaten intensively by the gazelles; however, when mature, the plant becomes unpalatable. The dense growth of this native grass prevents the growth of other small

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species of graminae that are important in their diet, like *Zornia glochidiata* (unpublished data).

Each point was visited four times over a full year in order to cover the range of plant phenology, that is, at the beginning of the rainy season (end June-early July 2009), at the end of the rainy season (October 2009), early in the dry season (February 2010) and at the end of the dry season (May 2010).

Principal Components Analysis (PCA, STATISTICA for Windows, Statsoft, UK, Letchworth) was used to classify habitats. The variables were type of soil, (muddy, lateritic, sandy, mixed), percentage of tree, shrub and herbaceous cover, maximum height of the herbaceous stratum, richness/number of species in the herbaceous stratum and predominance of *Scheonefeldia gracilis* in the herbaceous stratum.

This multivariate analysis showed that the first three axes accounted for 82.2% of the variability as follows: The first axis accounted for 40.4% of the variability and opposed herbaceous cover (r= -0.80) and height (r= -0.75), and type of soil (r=0.66); the second axis accounted for 25.4% of the variability and opposed tree cover (r=0.84) and number/richness of graminae species (r=-0,62), and the third axis accounted for 16.3% of the variability and was related to shrub cover (r=0.77).

With this classification, we defined seven habitats within the enclosure, which are related more to the structure of vegetation than to plant species composition; see figure 1 for habitat location in the enclosure.

Mare. Flood area with muddy soils and very dense vegetation cover, of which the herbaceous (>100 cm high) stratum is over 70%, shrub cover is 30% and tree cover ranges from 3 to 48%. The mare occupies 4.4% (19.1 ha) of the total surface in the enclosure. Some trees, like *Anogeissus leiocarpus*, *Mitragina inermis*, and *Cissus cuadrangularis*, are characteristic of this habitat, and high densities of *Cassia tora* over 1.2 m tall *a*re quite common.

Clearing in *mare*. Its main characteristic is that lateritic and sandy outcrops reduce the density and cover of vegetation in the area close to the *mare*; as a result, there are

clearings with higher visibility surrounded by dense vegetation cover. This type of habitat occupies 4.2% (18.3 ha) of the total enclosure.

Plains or plateau. Areas where visibility is excellent (> 90%) because soils are largely lateritic or a mixture of lateritic and sand. There are no trees and shrubs cover less than 7%. On the lateritic outcrop, herbaceous cover is less than 20%, but in mixed or sandy soils it is as much as 60%. Grass is 50-60 cm tall. The plateaus occupies 15.9% (70 ha) of the total enclosure.

Forest with clearings. Area with variable visibility depending on the lateritic and sand outcrops which form clearings in the middle of a forest of *Combretum* sp, *Guiera senegalensis* and *Grewia bicolor*. Tree cover is less than 12%, shrub cover varies from 1 to 34% and herbaceous cover > 50% with 45-120 cm high grass. This type of habitat occupies 18.1% (79.6 ha) of the total enclosure.

Grassy clearings. Areas where the herbaceous cover is predominant (61-96%), while shrubs and trees are scarcely represented (less than 10% and 2.4%, respectively). Soils are sandy and clay, and *Cassia tora* over 100 cm high is the predominant annual species. This type of habitat occupies 18.5% (81.3 ha) of the total enclosure.

Forest. Located in the mid-eastern part of the enclosure, it is the most available habitat in the enclosure (35.9%, 158 ha). Visibility in the area is low due to important, although variable, shrub and herbaceous covers (11-50% and 70% respectively); moreover grass is 75 to 150 cm high. Tree cover is scarce (less than 5%) but the presence of *Acacia* sp. and baobab (*Adansonia digitata*) is important in this part of the enclosure.

Dense forest. In this habitat visibility is considerably reduced due to trees where their cover is maximal: 26 to 81%. Herbaceous and shrub covers are also important (50-86%, and 10-27% respectively). The dense forest occupies just 3% (13.2 ha) of the extension in the enclosure.

3.2. Animals

On 29 March 2009, 23 dorcas gazelles (9 males and 14 females) from the breeding group reintroduced in the Geumbeul Reserve (Abaigar *et al.*, 2009) were transferred to the Katané enclosure (NFFR). The animals were selected by genetic and demographic criteria to provide the entire representation of founders and minimum inbreeding, and represent all age classes (from two months to 9 years), while favoring the most fertile (two to six years old).

In the Katané enclosure, the gazelles were released and settled as follows: a) the eldest male with the adult females (13) plus the young (males (3) and females (1)) in a 3-ha acclimatizing enclosure, b) two adult males in two small 0.45 -ha individual pens, and c) three adult males directly in the main enclosure. The two adult males were kept in individual pens to monitor their adaptation and assure their survival as they were selected as breeders for the next generations. The other three adult males were released directly in the main enclosure to be used as "controls". These control-adults-males were continuously monitored to detect any possible unexpected or hazardous circumstance in the enclosure. All the gazelles were individually marked (by ear tags) before release in order to ease their identification with binoculars.

The animals were kept that way for six weeks, and during that time, food for the group in the acclimatizing enclosure was gradually changed from the "artificial" diet in the Guembeul Reserve (peanut straw and pellets) to a natural one, although as in the Guembeul Reserve, water was provided "ad libitum". The acclimatizing enclosure also encouraged the gazelles to explore a growing number of spaces for social relationships.

After the 6 weeks in the acclimatizing enclosure and individuals pens, the gazelles were released in the main 440-ha enclosure by simply removing part of the acclimatizing enclosure fence and allowing the gazelles to explore the rest of the space.

There are another three ungulate species in the Katané enclosure, the scimitar-horned oryx (*Oryx dammah*) and the mohor gazelles (*Nanger dama mhorr*) reintroduced there

in 2003 (Jebali, 2008), and the red-fronted gazelle (*Eudorcas rufifrons*) from the surrounding wild population.

Carnivore species observed in the Katané enclosure are: common jackal (*Canis aureus*), ratel (*Mellivora capensis)*, caracal *(Caracal caracal),* serval (*Felis serval)*, so as different Mustelidae, Viverrinae and Herpestinae for what the fence is permeable so as for the warthog (Phacochoerus africanus).

3.3. Field studies

Direct observations and signs of dorcas were recorded along a 6 km long transect inside the enclosure. Indirect signs of gazelles were their tracks, latrines and fecal deposits. Tracks, latrines and fecal deposits of dorcas are easily distinguishable from those of the other species of gazelles (mohor and red-fronted gazelles) as for the size and shape. Other signs, like resting places, paths or scent marks over plants were discarded because of the difficulty in either detecting and/or assigning them to the dorcas, or in distinguishing them from other antelope species present in the enclosure. All locations of signs and direct observations of animals were referenced using a Garmin GPS (eTrex summit model).

The 6-km-long transect covered all the habitats defined above proportionally and then the effort invested was proportional to the type of habitats in the enclosure. All signs of gazelle and carnivore activities within a 2.5 m margin on each side were recorded. Six surveys were carried out from June 2009 to February 2011 covering all seasonal variations. For the purposes of this study, seasons were defined as follows: 1) early rainy season, end May to first weeks in July (one survey), 2) end of the rainy season, from late September to December, when the rain stops and food availability for ungulates is maximum, as well as free water in the *mare* (two surveys), 3) early dry

season, from January to March when there is absolutely no rain, but temperatures are not as high (two surveys), and 4) end of the dry season (April-May) (one survey) . The position of each animal sign and direct observation were later processed as UTM coordinates using a geographic information system (ArcGIS, ESRI 2011, Redlands, California, USA) to determine the precise habitat where it was found, and calculate the distance of each sign or observation from the closest fence and closest trough in the Katané enclosure.

3.4. Statistical analysis

General Linear Models (GLM) Type VI sums of squares, was used to determine the effect of parametric variables related to enclosure features (distance from the sign to the nearest fence) and non-parametric factorial variables (season and habitat). Moreover, because collection of field data lasted almost two years, we added the effect of time since the Dorcas gazelles were released in the enclosure as a parametric variable in the GLM. Multiple comparisons (LSD test) were used to compare significant habitat and seasonal differences

Distance from troughs was not included in the model, as due to their locations in the enclosure, it was not an independent variable and showed a significant ($p < 0.05$) negative correlation ($r = -0.23$) with distance from fences. Moreover, two out of three troughs are located in the "plateaus" habitat, and their use is habitat dependent. The "dense forest" habitat was excluded also, because so few signs were found in it (n=5). Statistical analyses were performed with STATISTICA 7.0 for Windows (Statsoft UK, Letchworth).

4. Results

Dorcas gazelle distribution is significantly dependent on the type of habitat (see Table 1). Furthermore, the number of fecal deposits increased with proximity to the fence (r=-0.13), and the number of gazelles directly observed increased with time since release (r=0.2) (Table 1). The only significant (p<0.05) seasonal effect was the increase in fecal deposits during the dry seasons (average±sem, early rain season= 0.18±0.06, late rain season= 0.17±0.04; early dry season= 0.49±0.07; late dry season= 0.46±0.075); in addition, although not significant (p=0.081), the number of gazelles observed at the beginning of the rainy season was higher than during the rest of the year.

Table 1 by here

Gazelle signs were significantly higher in the plains or plateaus than in the rest of the habitats (see Table 2). The number of fecal deposits is higher in the plateaus than in the forest with clearings, in the grassy clearings, or in the forest, but not the *mare* or in the clearing around it. Nor were latrines found in the *mare* or the clearing. On the whole, the plateau is the habitat with the most signs of gazelle presence, followed by the *mare*, the clearing around the *mare* and the grassy clearings. The forest and forest with clearings are the two habitats with the least signs of dorcas gazelles (see Table 2).

Table 2 by here

There is no seasonal variation in preference of habitats by dorcas gazelles in Katané.

5. Discussion

Measuring the success of reintroduction is always a controversial matter, as the criteria and time or period for determining the success or failure of a reintroduction project have to deal with the inherent complexity of such projects. However, there is a consensus in reintroduction biology that habitat conditions must be measured to determine the persistence of a reintroduced population, and that "habitat conditions" alludes not just to food availability, but to the whole set of biological requirements of the species, as well as predators, competitors and parasites (Amstrong and Seddon,

2008). Alternatively, the persistence of a reintroduced population in a suitable habitat is related to their ability not just as individuals, but as a population, to exploit and adapt to the environment provided after their release (which is an enormous challenge for animals born and reared in captivity for generations).

In spite of the progressive increase in the number of ungulate reintroduction projects in North Africa and the Middle East (Cano *et al.*, 1993; Abaigar *et al.*, 1997; Dunham, 1997; Abaigar *et al.*, 2005; Jebali, 2008; Molcanova and Wacher, 2008; Islam *et al.*, 2010; Wronski *et al.*, 2011), there are few cases where the animals live completely in the wild, and most of them live in protected, fenced-in areas of different sizes, from a few hundred hectares, like the mohor gazelles living at R´Mila Reserve in Morocco (Cuzin *et al.*, 2007), to the several hundred thousand hectares where the sand gazelles live in Saudi Arabia (Islam *et al.*, 2010). Thus animal reserves and protected fenced-in areas have to deal with the challenge of being the "final" release area for some species in some areas of their distribution. Even if the protected area is an intermediate step in the process of reintroduction, they have to achieve the species' requirements in order to ensure the provision of natural resources for their survival.

Indirect signs (tracks, fecal deposits, latrines, etc.) are not only unequivocal traces of an animal's presence, but also reveal biological and ecological features of individuals and populations. They have been monitored to determine habitat use, territoriality and social organization of several reintroduced gazelle species (Essghaier and Johnson, 1981; Abaigar *et al.*, 2005; Attum *et al.*, 2006; Wronski and Plath, 2009). The main advantages of this method are that it is economical and noninvasive, and can be used when the species is cryptic or elusive to human presence. In the case of dorcas gazelles, tracks are related to walking and exploring as they move from one place to another. An isolated fecal deposit may sometimes be found close to the tracks, but most of them are close to resting places or in the feeding area. In addition, as in other ungulates, latrines both limit territory and serve as a point of communication (Walther 1978; Essghaier and Johnson, 1981; Wronski and Plath, 2009). This communication

could be related to reproduction, as easily observed in captivity, because both males and females regularly use the latrines (pers. obs.). The latrines are also a point of interspecific communication in the Katané enclosure and it is ease to observe large latrines with deposits of dorcas gazelles, red-fronted gazelles, mohor gazelles and scimitar-horned oryx.

The Katané enclosure, where the dorcas gazelles were released, contains almost all the typical habitats of the Sahel where this species is still present; it includes from open stony areas (lateritic outputs) to densely wooded areas around temporary flood zones. In this context our results confirm two important features related to habitat selection. One is that the dorcas gazelles actively and significantly select from the variety offered by the reintroduction site, and the other, that they select open areas for all their activities, as revealed by indirect signs of their presence and by direct observations. And according to our results, this preference of habitat for the plateaus has no seasonal changes. Therefore, in an area where food and water availability is not a limiting/restricting factor for the presence of dorcas gazelles, the structure of the habitat is the most important factor in selection.

This species clearly prefers open areas (plateaus) for several reasons: one is security, as due to its small size, open areas with high visibility provide the gazelles with an opportunity to detect predators (jackals) at a distance enough to flee. This is essential to ensure species survival, as it has been proven that predation can be a major problem for successful gazelle reintroduction (Dunham, 1997; Dhaoui *et al.*, 2008). The denser areas around the plateaus are used to escape or to find protection in case of danger. Moreover, open areas provide an excellent place for latrines which form visible territorial delimitations. Intraspecific communication is also easy in open areas, especially for a small species like the dorcas gazelle, which uses visual rump patch patterns for communication in different situations (Alados, 1986). In addition, these open areas provide high densities of *Zornia glochidiata*, a very important species of graminae in the gazelle diet in Katané. Finally, displacement along open areas is more

comfortable than in dense forested areas. So although the dorcas gazelle is considered a habitat-generalist among the gazelles species, and although it is able to occupy a great variety of habitats (regs, mixed stony and dune areas, steppes, plateaus, wadis, mountain piedmont) (Baharav and Mendelssohn, 1976; Kacem *et al.*, 1994; Mallon & Kingswood, 2001; Chammem *et al.*, 2008), a common characteristic of their habitat structure is that it is an open area and/or plains.

Our results show that only the number of fecal deposits have significant seasonal variation, with a higher number during the dry season, probably because during the wet season the feces are easily destroyed or displaced.

In a protected fenced-in area, the fence marks the maximum limit of occupancy for an individual or population, and it is also related to human activity, in our case livestock grazing, as the fence marks its limit. Exploring this limit (fences) seems to be a constant in gazelle reintroduction, whether they are released in small enclosures like the Cuvier´ gazelle in Boukornine National Park (6 ha), Tunisia (Abaigar *et al.*, 2005) or in larger areas, like the mohor gazelle in Bou-Hedma National Park (2000 ha), Tunisia (Abaigar *et al.*, 1997). There is also a relationship between the dorcas gazelles released in Katané and the fence, as the number of fecal deposit increased as we came closer to the fence, which clearly shows marking behavior in their exploratory activities.

After two years since the reintroduction of dorcas gazelles in the Katané enclosure and their continuous monitoring, we can conclude that the gazelles immediately recovered their ability to explore the entire habitat available, and that they choose the most suitable habitat according to their biological and behavioral traits. These results are relevant for several different reasons. First, it has demonstrated the capacity of gazelles born and reared in captivity for generations to recover natural behaviors. Second, recovery of these abilities guarantees the success of the reintroduction project, and, finally, these results show the type of habitat where gazelles should be

released in the wild, or alternatively, where the gazelle will head for once released from the enclosure.

Acknowledgements

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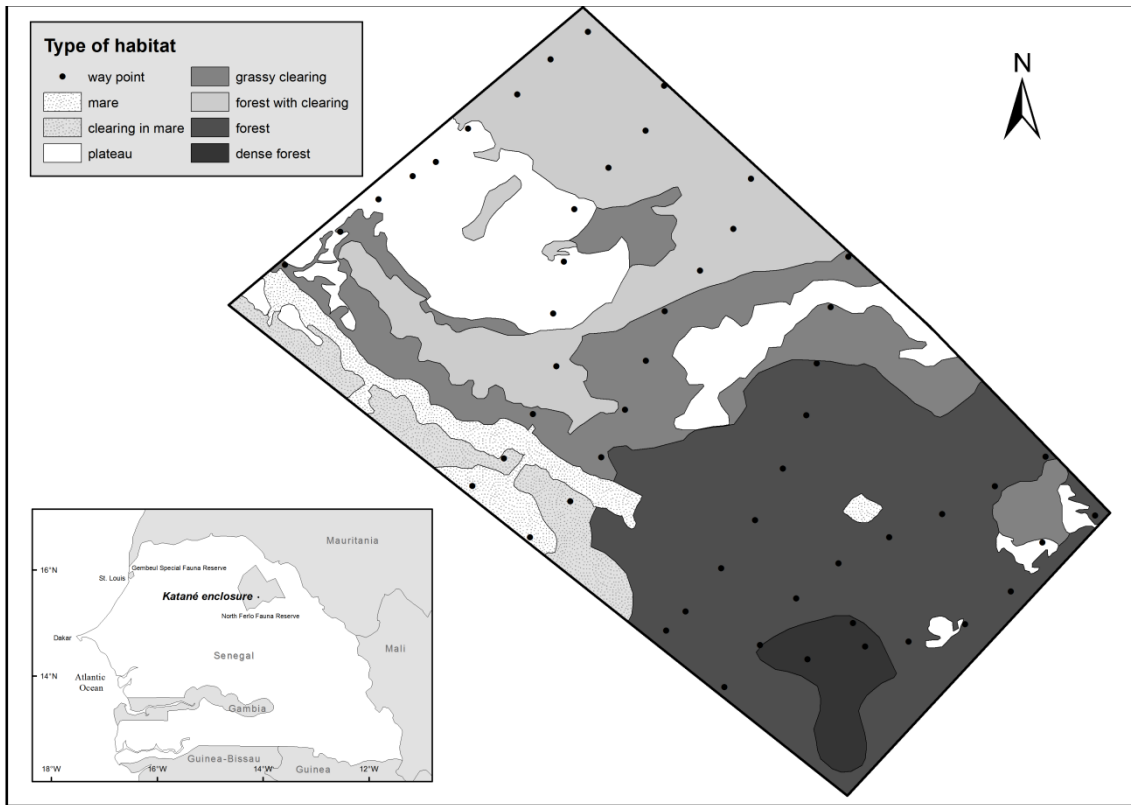
Figure 1. Location of the study area, the Katané enclosure in the North Ferlo (Senegal), and definition of the types of habitats.

Table 1. Statistical results and parameters after general GLM for Dorcas gazelle signs and direct observation in the Katané enclosure. P<0.05)

	total signs		fecal deposit		tracks		latrines		gazelle	
	F	P	F	P	F	P	F	P	F	P
time since release	ns		ns		ns		ns (0.06)		8.01	0.005 (r=0.2)
distance to the fence	ns		6.48	0.012 (r= -0.13)	ns		ns		ns	
season	ns		3.1	0.027	ns		ns		ns (0.081)	
habitat	16.36	< 0,0001	2.52	0.03	7.3	0.00001	2.71	0.02	6.01	0.000
habitat * season	ns		ns		ns		ns (0.06)		ns	
r	0.551		0.43		0.46		0.39		0.37	
r2	0.308		0.183		0.211		0.152		0.137	
F, df=25	5.83		3.0		3.53		2.4		2.11	
P	<0.0001		<0.0001		<0.0001		0.0007		0.0017	

Table 2. Average ± sem number of Dorcas gazelle sign by type of habitat in the

Katané enclosure. Different letters indicate significant differences between habitat

sampling; p<0.05, LSD comparisons

	mare	*mare*-clearings	plateau	forest-clearings	grassy clearings	forest
fecal deposit	0.38±0.18 **a**	0.5±0.28 **a**	0.58 ± 0.07 **ab**	0.23± 0.05 **ac**	0.34± 0.11 **ac**	0.22± 0.05 **ac**
tracks	0.15± 0.1 **a**	0.30± 0.21 **a**	0.8± 0.11 **b**	0.21± 0.05 **a**	0.27± 0.11 **a**	0.07± 0.03 **a**
latrines	0	0	0.21± 0.05 **a**	0.033± 0.019 **b**	0.09± 0.04 **b**	0.02± 0.015 **b**
gazelle	0.23± 0.23 **a**	0.10± 0.10 **a**	0.36± 0.10 **ab**	0.011± 0.011 **ac**	0.09± 0.05 **ac**	0.03± 0.02 **ac**
total signs	0.77± 0.028 **a**	0.9± 0.27 **a**	1.95± 0.16 **b**	0.48± 0.09 **a**	0.80± 0.02 **ac**	0.35± 0.07 **ad**
n	13	10	110	91	41	95