

Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: a case study from Bou Hedma national park

A. OULED BELGACEM^{1*}, M. TARHOUNI¹ AND M. LOUHAICHI²

¹Institut des Régions Arides, Range Ecology Laboratory, 4119 Médenine, Tunisia

²International Center for Agricultural Research in the Dry Areas, PO Box 5466, Aleppo, Syria

Correspondence to: A. O. Belgacem, Institut des Régions Arides, Range Ecology Laboratory, 4119 Médenine, Tunisia. E-mail: azaiez.ouledbelgacem@ira.rnrt.tn

ABSTRACT

Ecosystems protected from heavy grazing impacts, such as national parks and refuges, are generally considered to sustain higher plant species diversity and better ecosystem composition and structure compared to heavily grazed areas. To evaluate the impact of livestock grazing, we sampled vegetation characteristics from two areas having different grazing intensity levels. The first site has high protection from grazing and is located inside the Bou Hedma National Park in Southern Tunisia. The second site has a low protection from grazing and is situated within an open area located immediately outside the park boundary where human populations and their livestock have unrestricted access to ecosystem resources. Total plant cover, density, perennial species cover and their contribution were compared between the two grazing level sites. Results show that considerable positive effects occur in the areas protected from grazing. As compared to the overgrazed (open) sites. Several species known for their high palatability, such as *Cenchrus ciliaris* L., *Salvia aegyptiaca* L., *Echiochilon fruticosum* Desf. and *Helianthemum sessiliflorum* Desf., are more abundant inside the park than outside. These results are very important for managers to apply this technique as a tool for increasing the resilience of arid ecosystems, qualified very vulnerable to climate change.

key words: protection; herbaceous dynamics; exclosure; grazing impacts; arid rangelands; national park; Tunisia

INTRODUCTION

Some suggest that the Mediterranean region, which is subject to pronounced climatic and edaphic drought, lacks terrestrial ecosystems that have not been altered by human activities (Aronson et al., 1993a, 1993b; Ramade, 1997). Three-quarters of Tunisia's land mass is at risk of desertification (Floret and Pontanier, 1982). Presaharian Tunisia, located between the isohyets 100 and 200 mm, have experienced the consequences of desertification during the past few (4) decades creating major environmental problems in the region (Floret and Pontanier 1982; Ouled Belgacem and Neffati, 1996). Within this region, the natural vegetation cover, composed primarily by sparse steppic species, is altered by various human activities (Floret et al., 1983; Le Floc'h, 1995). In particular, overgrazing occurs as rangeland availability is reduced by cultivation and ploughing and animals become more concentrated on these lands with limited resources. Conversion of natural ecosystems to farmland, exploitation through selective harvesting, fuel wood removal, charcoal production and livestock grazing are the major causes of rangeland degradation, habitat change and biodiversity loss (Ramirez-Marcial et al., 2001; Reyers, 2004). Disturbances created by these activities can impair ecosystem dynamics, structure and composition at the local and regional scales, can lead to degraded plant community structure, and reduce ecological resilience (Sumina, 1994; Hubbell et al., 1999). In these lands, low fodder availability can result in regular losses of herds in droughts and rendering livestock a driven rather than driving variable in the system. This situation, so-called non-equilibrium conditions, also known as 'New Rangeland Ecology', is expected to occur under dry climates (Sullivan and Rohde, 2002; Vetter, 2005; Gillson and Hoffman, 2007).

To protect natural vegetation, human related impacts should be limited and ecosystem regeneration promoted. This regeneration can be achieved with rangeland protection that reduces grazing pressure, and focuses on improved vegetation structure and soil fertility (Martiniello et al., 1995). Ecosystems conservation should remain a high priority for land conservation organizations. These organizations can create protected areas that offer effective solutions to many of these ecological problems.

Vegetation dynamics and improved rangeland health can be monitored using a suite of ecological indicators (OCDE, 1994). These indicators become effective tools for natural resource managers and policies makers whose goal is to assess vegetation dynamics in Bou Hedma National Park and to evaluate the role of rangeland protection in maintaining ecological equilibrium using these ecological indicators (i.e. plant cover, density, biomass).

MATERIALS AND METHODS

Study Area

Bou Hedma National Park (34° 39' N and 9° 48' E), which covers an area of approximately 5115 ha (Figure 1), was named a UNESCO World Heritage site in 1977. The park has a low arid bioclimate (Le Houérou, 1959, 2001) with an approximate mean annual rainfall of 180 mm, a mean annual temperature of 17.28°C, and minimum and maximum monthly mean temperatures of 3.88°C (December) and 36.28°C (July), respectively.

Total rainfall at Bou Hedma during the 2004/2005 growing season (the studied period) was 146.4 mm (Table I). Precipitation during the autumn (September, October and November) was moderate (66 mm). It should be noted that precipitation during this season is critical for the

seedlings emergence of annual plants and the early growth and development of the perennial plants.

The Bou Hedma soils are skeletal in the mountainous area, superficial and stony in the piedmont and sandy to sandy-loamy in low-lying flat areas. On the mountainous massif, natural vegetation is dominated mainly by vestigial forest species such as *Juniperus phoenicea*, *Periploca angustifolia*, *Rhus tripartitum*, *Olea europaea*, *Rosmarinus officinalis* and *Stipa tenacissima*. *Artemisia herba-alba*, *Anarrhinum brevifolium*, *Gymnocarpos decander* and *Helianthemum kahiricum* colonize the piedmont. The flat area is dominated by pseudo-savannah vegetation with *Acacia tortilis subsp. raddiana* as the only tree stratum. However, the understorey stratum is dominated by many species such as *Rhanterium suaveolens*, *Cenchrus ciliaris*, *Haloxylon schmittianum*, *Haloxylon scoparium* and *Salvia aegyptiaca*. With this original physiognomy of the herbaceous vegetation and in presence of *Acacia tortilis subsp. raddiana*, it seems important to study the effect of protection in understorey stratum.

Measurements and Data Collection

The experiment was conducted during the 2004/2005 growing season, at two stations located within and adjacent to Bou Hedma national park in southern Tunisia. The two stations differed in grazing intensity. The station inside the park had been lightly grazed (some wild fauna species), while the station outside the park, a communal grazing land, had been heavily grazed by herds of sheep and goats.

To study the effect of protection on vegetation structure, three parameters were measured: total plant cover (TPC), density and species frequency of the herbaceous stratum and woody species. The quadrat point method (Daget and Poissonet, 1971; Floret et al., 1978) was used at both stations: inside (protected) and outside (grazed) the park. A total of 73 transects, each 20 m in length, were randomly established (43 inside and 30 outside the park). A thin gauged pin was allowed to free-fall to the ground every 10 cm along the tape. The first feature contacted by the end of the pin was recorded (as a hit). A total of 200 hits per tape were recorded by species. TPC, in each tape, is calculated as: $TPC = \frac{n}{N} \times 100$ with n is the number of hits of all plant species and N is the total number of hits (200 hits in our case). The specific frequency of presence (SFP) is the number of hits of the specific species: $SFP_i = \frac{n_i}{N} \times 100$ with n_i is the number of hits of species i . Hence the SFP is the equivalent of the specific cover of each species. The specific contribution of presence (SCP in per cent) of the species i , on the TPC, is calculated as: $SCP_i = \frac{SFP_i}{SSFP} \times 100$. On the other hand, density of perennial species, per square meter, was determined within 20 m² and within 2 m² for annuals plants for each tape.

Data Analysis

All data were subjected to analysis of variance (ANOVA) using SPSS 11.5¹ (SPSS, Inc., 2002). Stations (inside or outside the park) were the independent variables whereas TPC, species frequency and density were the dependent variables. No transformations were required to meet parametric assumptions for ANOVA.

RESULTS

Statistical analysis of TPC showed a significant difference between the two stations (Table II). TPC was approximately 50 and 31 per cent inside and outside the park, respectively. Inside the park, vegetation cover was mainly dominated by perennials (58 per cent) but the annuals were fewer (42 per cent). Under open grazing outside the park, perennials became fewer (16 per cent) and the annuals dominated (84 per cent). Perennial species contribution was significantly different between the inside and the outside of the park ($p < 0.05$). We estimate that the perennial plant cover is about 5 and 30 per cent for outside and inside the park, respectively. However, the respective annual species cover is about 20 and 26 per cent. These results indicate that areas with a high animal density are characterized by abundance and a remarkable increase in annual species recovery rates. It is the therophytization phenomenon which characterizes plant communities in the arid zone or in a contrasted climate with an arid season.

The perennial plant density was significantly affected by grazing ($p < 0.05$). Density inside the protected area was higher than outside the park (Table III). In the park, statistical analysis of species density showed significant differences for many plants such as *S. aegyptiaca*, *C. ciliaris*, *Helianthemum sessiliflorum*, *H. schmittianum*, *H. kahiricum*, *R. suaveolens* and *Deverra tortuosa* ($p < 0.05$). The highest cover of these species was recorded inside the park. Their densities varied from 0.14 to 0.54 plants m^{-2} inside the park but never exceeded 0.09 plants m^{-2} outside it. Several species (*Lotus creticus*, *Argyrolobium uniflorum* and *Peganum harmala*) had significantly higher density outside the park than inside ($p < 0.05$). Densities ranged from 0.08 to 0.09 plants m^{-2} and 0.01 to 0.03 plants m^{-2} outside and inside the park, respectively. A non-significant difference was observed for some species such as *Atractylis serratuloides*, *Launaea resedifolia*, *Lycium shawii*, *Marrubium deserti*, *Polygonum equisetiforme* and *Salsola vermiculata* where plant density ranged from 0.01 to 0.05 plants m^{-2} inside the park and 0 to 0.06 plants m^{-2} outside the park.

There were significant differences between the cover inside and outside the park ($p < 0.05$) for many species such as: *Cynodon dactylon*, *C. ciliaris*, *R. suaveolens*, *H. schmittianum*, *H. scoparium*, *S. aegyptiaca*, *H. kahiricum*, *H. sessiliflorum*, *M. deserti* and *D. tortuosa*. Mean species cover varied from 1.11 to 10.98 per cent inside the park. However, *P. harmala*, *A. uniflorum* and *L. creticus* are significantly more frequent outside the park with mean cover varying from 0.5 to 4.32 per cent. Other species such as *Plantago albicans*, *Echiochilon fruticosum*, *P. equisetiforme*, *A. serratuloides* and *L. shawii* did not appear to benefit from protection. No significant difference was recorded between their cover inside and outside the park. *P. equisetiforme* and *A. serratuloides* have low palatability and are subsequently only grazed by livestock during drought.

DISCUSSION

The results suggest that protection affected significantly the TPC. This last was higher inside than outside Bou Hedma national park. Similar results have been reported from other ecologically comparable zones (Ayyad and El-Kadi, 1982; Floret and Pontanier 1982; Grouzis,

1988; Ouled Belgacem et al., 2005; Louhaichi et al., 2009), indicating progressive increase of total vegetation cover in protected areas as compared to overgrazed areas which are characterized the expansion of bare soil. In fact, protection reduces erosion and improves soil structure due to the abundance of litter and other plant debris (Ould Sidi Mohamed et al., 2002). Higher plant cover reduces water losses by evapo-transpiration, maintains a favourable microclimate for regeneration of annual herbaceous species and permits the development of perennial herbaceous species (Floret and Pontanier 1982; Ouled Belgacem et al., 2008).

The data show that protection leads to a significant expansion of perennial herbaceous plant cover at the expense of annual herbaceous species. Similar results were reported by Floret (1981), who studied different ecosystems in southern Tunisia. We also concur with Floret's view, that perennial species cover is an important measure of how vegetation cover recovers after protection. In arid ecosystems, Floret and Pontanier (1982) and Westrom and Steen (1993), reported an expansion of perennials species and decline of annual species after a long period of protection.

Intense grazing of rangelands often results in highly competitive palatable species being replaced by less palatable species which are often considered less desirable plants (Callaway and Tyler, 1999). Our results are in agreement with those obtained in Australia and USA (UNESCO, 1990), Syria (Deiri, 1990), Burkina Faso (Grouzis, 1988) and Tunisia (Le Houérou, 1977; Floret and Pontanier, 1982) showing that protection allowed the regeneration of several rare or declining species such as

C. ciliaris, *S. aegyptiaca*, *E. fruticosum*, *H. sessiliflorum*, *H. schmittianum*, *H. scoparium*, *H. kahiricum*, *M. deserti* and *D. tortuosa* which were affected by various anthropogenic factors. The appearance, inside the park, of some species known for their high palatability such as *C. ciliaris*, *S. aegyptiaca*, *E. fruticosum* and *H. sessiliflorum* affirmed the positive effect of protection. The abundance of *D. tortuosa* inside the park is probably because it appears in abandoned agricultural fields. The widespread distribution of *C. dactylon* can be explained by its capacity to colonize different types of soils and its large ecological amplitude (Chaieb and Boukhris, 1998).

In terms of plant cover and density, *R. suaveolens* was far more abundant inside the park, that is, it increased under protection and decreased under grazing. These results are consistent with those of Floret (1981) who found that restoration was achieved by a constant increase in the density and cover of existing species. According to Jauffret and Lavorel (2003), chamaephytes such as *R. suaveolens* can resist to intense or frequent disturbances by growing less tall and resprouting and tend to be less palatable than most grasses. This response is negative because it reflects the concurrent degradation of vegetation cover and soil (Van de Koppel and Rietkerk, 2000).

Outside the park, the effect of intense grazing is to reduce the cover of perennial species (Le Houérou, 1959; Bakker et al., 1983). Grazing is generally selective and often leads to the replacement of palatable species by less palatable ones which are less desirable such as *Astragalus armatus* and *P. harmala* (Olf and Ritchie, 1998; Callaway and Tyler, 1999). If the abundance, outside the park, of *P. harmala* is expected and justified due to its unpalatability (Waechter, 1982; Jauffret and Lavorel, 2003), the relative high density of *L. creticus* and *A. uniflorum* may be attributed to the abundance of young seedlings of both species known by their high dynamics and their low long-term protection tolerance (Ould Sidi Mohamed et al., 2002). Similar results were reported by Floret and Pontanier (1982), Deiri (1990), Primack (1993), West and Smith (1997) and Aronson and Le Floch (1995). Several

authors have considered the decline of perennial species to be a good indicator of plant cover degradation (Le Houérou, 1977; Ould Sidi Mohamed et al., 2002; Tarhouni et al., 2006). Noy-Meir and Walker (1986) reported that when there is a decrease in perennial grasses whose superficial roots encourage soil aeration, there is a decrease of water infiltration coupled with decline of ligneous species. The deterioration of these species accelerates erosion and desertification (Primack, 1993). The abundance of some species in the grazed area (*A. uniflorum* and *L. creticus*) is probably because their germination is stimulated by grazing. However, the abundance of *P. albicans* outside the park can be attributed to its high reproductive capacity, its ability of vegetative multiplication and its resistance to drought (Henchi et al., 1986; Neffati, 1994).

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Figures:



Figure 1. Geographical location of Bou Hedma National Park in Tunisia.

Tables

Table I. Monthly rainfall (mm) at Bou Hedma National Park during the 2004/2005 growing season

S	O	N	D	J	F	M	A	M	J	J	A	Total
6.9	48.6	10.5	22	6	5.5	4.7	8	29	1.5	3.7	0	146.4

Table II. Total plant cover (per cent) and contribution of perennials and annuals species (per cent) inside and outside Bou Hedma National Park

	Inside the park	Outside the park	p-value
Total plant cover (per cent)	50	31	**
Contribution of perennial species (per cent)	58	16	**
Contribution of annual species (per cent)	42	84	**

** $p < 0.05$.

Table III. Density (plants m⁻²) and species cover (per cent) inside and outside Bou Hedma national park

Species	Density (plants m ⁻²)			Species cover (per cent)		
	Inside	Outside	p-value	Inside	Outside	p-value
<i>Argyrolobium uniflorum</i>	0.02 ± 0.01	0.18 ± 0.01	**	0.04 ± 0.01	0.19 ± 0.02	**
<i>Artemisia campestris</i>	0.08 ± 0.00	0.03 ± 0.01	*	0.69 ± 0.04	0.22 ± 0.02	**
<i>Astragalus armatus</i>	0.03 ± 0.00	0.06 ± 0.01	*	0.56 ± 0.07	1.24 ± 0.04	**
<i>Atractylis serratuloides</i>	0.02 ± 0.01	0.2 ± 0.01	*	0	0.4 ± 0.03	*
<i>Atriplex halimus</i>	0.05 ± 0.01	0	*	0.03 ± 0.01	0	*
<i>Cenchrus ciliaris</i>	0.37 ± 0.06	0.06 ± 0.02	**	2.52 ± 0.54	0.51 ± 0.17	**
<i>Cynodon dactylon</i>	—	—		10.98 ± 1.66	5.01 ± 1.18	**
<i>Deverra tortuosa</i>	0.14 ± 0.02	0.05 ± 0.01	**	4.4 ± 0.84	0.53 ± 0.01	**
<i>Echiochilon fruticosum</i>	0.1 ± 0.02	0.04 ± 0.02	*	0.4 ± 0.01	0.33 ± 0.01	*
<i>Fagonia cretica</i>	0.39 ± 0.01	0.06 ± 0.01	**	0.23 ± 0.03	0.74 ± 0.12	**
<i>Gymnocarpus decander</i>	0.04 ± 0.00	0	*	0.28 ± 0.01	0	**
<i>Haloxyton schmittianum</i>	0.19 ± 0.02	0.1 ± 0.02	**	3.38 ± 0.22	1.53 ± 0.15	**
<i>Haloxyton scoparium</i>	0.07 ± 0.01	0.05 ± 0.01	*	2.31 ± 0.10	0.24 ± 0.01	**
<i>Helianthemum kahiricum</i>	0.16 ± 0.03	0.09 ± 0.02	**	1.11 ± 0.30	0.43 ± 0.22	**
<i>Helianthemum sessiliflorum</i>	0.22 ± 0.03	0.03 ± 0.00	**	1.03 ± 0.32	0.02 ± 0.01	**
<i>Launaea resedifolia</i>	0	0.01 ± 0.00	*	0	0	*
<i>Lotus creticus</i>	0.05 ± 0.02	0.46 ± 0.01	**	0.01 ± 0.00	0.28 ± 0.07	**
<i>Lycium shawii</i>	0.03 ± 0.05	0.03 ± 0.06	*	1.36 ± 0.04	0.97 ± 0.05	*
<i>Marrubium deserti</i>	0.01 ± 0.00	0.02 ± 0.01	*	0.46 ± 0.02	0.08 ± 0.02	**
<i>Peganum harmala</i>	0.01 ± 0.00	0.08 ± 0.01	*	0.08 ± 0.01	2.05 ± 0.09	**
<i>Plantago albicans</i>	0.4 ± 0.1	0.34 ± 0.05	*	0.39 ± 1.12	4.32 ± 0.41	*
<i>Polygonum equisetiforme</i>	0	0		0.44 ± 0.01	0.06 ± 0.02	*
<i>Rhanterium suaveolens</i>	0.14 ± 0.01	0.09 ± 0.02	**	2.94 ± 0.41	1.58 ± 0.63	**
<i>Salsola vermiculata</i>	0.01 ± 0.00	0.01 ± 0.00	*	0.1 ± 0.01	0.17 ± 0.02	*
<i>Salvia aegyptiaca</i>	0.54 ± 0.04	0.03 ± 0.01	**	1.13 ± 0.69	0	**
<i>Salvia verbenaca</i>	0.07 ± 0.01	0.03 ± 0.01	*	0.42 ± 0.11	0	**
<i>Stipagrostis ciliata</i>	0.09 ± 0.01	0.03 ± 0.01	*	0.35 ± 0.06	0.10 ± 0.01	**
<i>Stipagrostis plumosa</i>	0.07 ± 0.01	0.03 ± 0.00	*	0.19 ± 0.03	0.04 ± 0.01	**
Total	3.191	2.11	**	34.73	20.30	**

*p > 0.05.

**p < 0.05.