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Abstract Extensive grazing applied in the form of low instantaneous pressure over a long period is a widespread management practice in protected areas. However this kind of stocking method does not always achieve the expected results, in particular because it fails to limit colonization by woody plants. This is the case in the relict xero-halophytic grasslands of the northern Mediterranean coastal region, subjected to widespread colonization by the shrub *Phillyrea angustifolia* despite the presence of extensive grazing. In this study, we investigated, for an equal annual stocking rate, the respective impact of high stocking density applied over a short period (mob grazing) and low stocking density applied over a long period on both *P. angustifolia* . and herbaceous cover, using an in situ experimental design run for 7 years. Only mob grazing was effective both in controlling the establishment and increasing the mortality of *P. angustifolia* individuals. We did not find any difference after the 7 years of experimentation between the two stocking methods with regard to the herbaceous community parameters tested: species richness, diversity, evenness, contribution of annual characteristic species. By contrast, the exclusion of domestic grazing led to a strong reduction of these values.The use of mob grazing may be well suited for meeting conservation goals such as maintaining open habitats in these grasslands

Keywords Extensive grazing,Mediterranean grassland**,** Mob stocking**,** *Phillyrea angustifolia***,** Stocking density**,** Woody colonization

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Introduction

Extensive grazing (Allen et al. 2011) by large herbivores is a widespread management practice used in protected areas to maintain open habitats and to enhance biodiversity (Van Wieren and Bakker 1998; Rosenthal et al. 2012). The use of natural ecosystems as rangelands by a small number of domestic herbivores is often seen as a suitable response to the disappearance of wild mega-herbivores (Gordon and Duncan 1988; Danell et al. 2006). Regarded as a surrogate of the original interactions between plants and herbivores, domestic grazing would appear to be well suited for the management of natural or semi-natural habitats (Gordon and Duncan 1988; WallisDeVries 1998). However, extensive grazing, that is a long grazing period with low stocking density (Rosenthal et al. 2012), has not always met with the success expected. In particular, it sometimes fails to prevent colonization by woody plants and so to preserve open habitats (Adams 1986; Rambo and Faeth 2001; Mesléard et al. 2011).

The effectiveness of a stocking method may vary according to its intensity, the period of application and the stocking cycle (Savory 1983; Salihi and Norton 1987; Ralphs et al. 1990; Hart and Ashby 1998; Fynn and O'Connor 2000; Dumont et al. 2009). Over the past decades, the potential of short but intensive grazing periods to improve vegetation diversity and to control woody plant dynamics has attracted growing attention in range management (Jeltsch et al. 1997; Todd and Hoffman 1999; Holechek et al. 2000). It has been suggested that mob grazing (grazing at a high stocking density for a short time period, S R M 1998) may be able to control the recruitment and the development of species which would otherwise be neglected by herbivores because of their low nutritional value or palatability (Savory 1988; Perevolotsky and Seligman 1998). Nevertheless, the suitability of using mob grazing depends on the vegetation dynamic (Allen et al. 2011; Briske et al. 2008) and its use in conservation management remains controversial.

In the coastal deltaic zones of the northern Mediterranean region, xero-halophytic grasslands managed for economic and/or conservation purposes are subjected to strong colonization by shrubs, principally the native *Phillyrea angustifolia* (narrow-leaved mock privet) (Saumitou-Laprade et al. 2010). Colonization by *P. angustifolia* is considered a threat to this habitat, impacting its value for livestock and conservation because of the disappearance of characteristic species and wildlife using this habitat (Mesléard et al. 2011). This is particularly the case in the Camargue (Rhône delta), where the strong dynamic of encroachment of this common Mediterranean field colonizer has been attributed to the ineffectiveness of traditional extensive grazing, characterized by low stocking density and a long grazing period (Mesléard et al. 2011).

In this study, we questioned the respective effectiveness of high stocking density for a short period (mob stocking) compared to low instantaneous stocking density for a long period, to control the recruitment of *P. angustifolia*. We hypothesized that for an equal annual stocking rate, mob grazing would result in lower recruitment of new individuals and higher mortality of *P. angustifolia* individuals than stocking applied over a long period. To be considered as a possible stocking method, the absence of negative impact of high instantaneous grazing pressure on herbaceous cover still needs to be demonstrated. We therefore investigated the impact of mob grazing on both P. angustifolia and herbaceous cover. For this purpose, we performed an in situ experiment for 7 years based on three grazing modalities:

(1) a low annual stocking rate of 0.11 native Camargue bulls ha^{-1} year^{-1} applied during 6 months (from October to March), as usually found locally and in existence for roughly three decades (control),
(2) a short grazing period (2 days) but with high stocking density (same annual stocking rate as the control),
(3) the cessation of domestic grazing.

Materials and Methods

Study Site
The study was carried out on the xero-halophytic grasslands of the Tour du Valat estate (Rhône delta, Southern France, 43°29′ N, 4°40′ E). The Tour du Valat estate, one of the largest in the Camargue (2600 ha), is composed of xero-halophytic grasslands, saline steppes and natural marshes, some of which are kept flooded until summer. The Camargue is characterized by a Mediterranean climate with cold winters and warm dry summers (Heurteaux 1970). Precipitation (570 mm year^{-1})

occurs mainly during autumn and spring. Xero-halophytic grasslands represent the most diverse habitat of the Rhône delta (Molinier and Tallon 1968) and are a priority habitat (code 6220, European Union Habitats Directive 1992). They are dominated by *Brachypodium phoenicoïdes* L (thin leaf false brome), but are characterized by a high proportion of annual species including those characteristic of the Mediterranean region, the main ones being: *Trifolium scabrum* L. (rough clover), *Trifolium suffocatum* L. (suffocated clover),

Euphorbia exigua L. (dwarf spurge), *Brachypodium distachyon* (L.) P. Beauv (purple false brome), *Linum strictum* L. (flax), *Filago pygmaea* L. (pygmy cotton rose), *Medicago monspeliaca* (L.) Trautv. (Montpellier's medick), *Catapodium rigidum* (L.) C.E. Hubb. (rigid rye-grass, Bensettiti et al. 2005; M.N.H.N 2015). These grasslands face strong colonization by a sclerophyllous shrub *P. angustifolia* (Mesléard et al. 1991). This Oleaceae extends at low altitudes from the Western Mediterranean to Croatia (Pannel and Ojeda 2000) and can locally colonize relatively salty habitats (Mesléard et al. 1991). Its reproduction is favoured by its ornithochorous dispersion (Saumitou-Laprade et al. 2010) and germination of seeds is facilitated by frugivorous birds (Traveset et al. 2008). A survey carried among all the local cattle breeders (200) ranked *P. angustifolia* as one of the most problematic species for rangelands (Mesléard et al. 2015). At the scale of the Tour du Valat estate, over the last decades more than 30% of grasslands have been transformed to *P. angustigolia* stands (Mesléard et al 2015).

Grazing Treatment

The experimental design included three treatments (Fig. 1). The first treatment 'L' (Low stocking density) was the original grazing pattern applied over a 180 ha field from October to March (6 months); it corresponds to the control in this study. Over the 7 years of the experiment, the livestock consisted of 50 Camargue bulls, half of them adult animals (290–350 kg, equivalent to 640–770 lbs, about 1 AU), a quarter 2-year-old calves (180–220 kg, equivalent to 400–490 lbs, about 0.6 AU) and a quarter 1-year-old calves (110–140 kg, equivalent to 240–310 lbs, about 0.4 AU). This treatment, 'L,' corresponding to an annual stocking rate of 0.11 AU ha^{-1} year^{-1} (Table 1), had been in place for approximately 20 years. Over the coldest months, marshes are generally not accessible to livestock, but during the growing season and the warmest months (April–May to October), domestic herbivores are generally shifted to the flooded marsh area. The second grazing treatment, 'H', (High stocking density), consisted of the same annual stocking rate (0.11 AU ha^{-1} year^{-1}), applied over a very short period of 2 days in early February. February does not correspond to the period when *P. angustifolia* is most palatable, which is later in spring when *P. angustifolia* enters the regrowth stage. Nevertheless, we chose this period for application of the H treatment because it corresponds to the period of the highest probability for livestock to find water in the channels crossing the rangeland. In addition, a strong disturbance in the H treatment by trampling or grazing at the time of herbaceous monitoring could have resulted in over-estimation of the grazing impact. The third treatment, 'N', consisted in the cessation of domestic grazing through fencing. The experiment started in autumn 2001.

Fig. 1 Experimental design: L low stocking density (50 bulls during 6 months on 180 ha; annual stocking rate = 0,11 AU ha^{-1} year^{-1}), H high stocking density (50 individuals during 2 days on 2 ha; Annual stocking rate = 0,11 AU ha^{-1} year^{-1}), N no domestic grazing

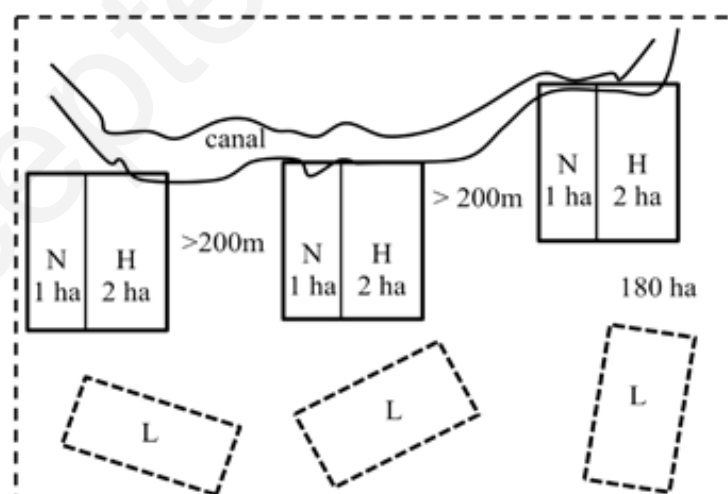| Treatment	L	H	N
Number and class of head (from 2001 to 2008)	25 mature bulls 25 young cattle (half 1 year, half 2 years old)	25 bulls mature 25 young cattle (half 1 year, half 2 years old)	0
Stocking density	19 AU ha^{-1}, during 2 days	0,22 AU ha^{-1}, during 180 days	0
Annual stocking rate	0,11 AU ha^{-1} year-1	0,11 AU ha^{-1} year-1	0

Table 1
Number and class of head, stocking density and annual stocking rate in the treatments L (low stocking density), H (high stocking density) and N (no domestic grazing)

Data Collection

For the H and N treatments, the vegetation survey was conducted in three replicate fenced pastures for each of the two treatments, of respectively two hectares (H: grazed) and one hectare (N: ungrazed), placed within about 190 ha of the rangeland (L treatment), along a canal to enable the domestic herbivores to find water (Fig. 1). H and N replicates were placed more than 200 m apart in order to minimize any possible spatial dependence phenomenon. In the L treatment, three replicate sites of 2 ha each were chosen at random within the remaining 180 ha, taking care that they were well separated and more than 200 m away from all the six fenced pastures (Fig. 1).

The number of living and dead individuals of *P. angustifolia* was counted when the experimental treatments were set up in May 2001, and then in May 2008 in order to estimate the recruitment of new individuals during the experiment. The individuals of less than 7 years (i.e. individuals who were established between spring 2001 and spring 2008) were counted separately. When in doubt, the age of individuals was determined by counting the growth rings of the main stem. Counting was conducted along transects of 2.5 × 10 m (the same in 2001 and 2008), distributed at random and placed from west to east, with four transects in each of the three replicate sites of the three grazing treatments.

In mid-April 2001 and in mid-April 2008, we monitored herbaceous vegetation in the same five 40 × 40 cm permanent quadrats per site, considered as pseudo-replicates, randomly located within each site of the three treatments, checking that quadrats at each site were more than 10 meters apart.

Species frequencies were recorded by the pinpoint method at 36 pinpoints (3 cm apart from each other), through a set of two crossing lines in each quadrat (Damgaar et al. 2011). The number of species within the quadrat was recorded. The vegetation structure in each quadrat was described by:
the species richness,
the Shannon diversity index H′ (Pielou 1975) where
H′ =
$\sum_{i=1}^{S} p_i \log_2 p_i$
with pi = proportion of species i and S = total number of species
the evenness J′ = H′/log$_2$S
the contribution (% cover) of annual species,
the contribution of Mediterranean characteristic annual species.

Analyses

Analyses were performed by Generalized Linear Model using a nested-design analysis of variance (ANOVA). We tested the impact of the three grazing treatments on three parameters related to the *P. angustifolia* population (number of new, old and dead individuals), and five parameters related to the herbaceous vegetation (Species Richness, diversity, evenness, contribution of annual species, contribution of species characteristic of the Mediterranean region). For analyses related to individuals and dead individuals of *P. angustifolia*, pseudo-replicates were nested in sites and all effects (grazing treatment, sites, pseudo-replicates) were nested in time. For the analysis on new individuals of *P. angustifolia*, site and pseudo-replicate effects were nested in grazing treatment. For the analysis of the herbaceous vegetation, pseudo-replicates were nested in grazing treatment and all effects were nested in time. The resulting models show average estimates with their 95% confidence interval. When a significant difference occurred, we used a post hoc Scheffé test to identify what type of grazing pressure was responsible for the observed difference. All analyses were performed with Statistica version 12.0 (StatSoft Inc.).

Results

P. Angustifolia

Although it explained 10% of the variance, we did not find a significant time effect on the number of individuals (Table 2). Only 5.5 and 3.6% of the variance was respectively explained by the factors "site" and "pseudo-replicates", the impact of which was not found significant by the analysis in either case. By contrast, we found a strong treatment effect nested in time on the number of individuals, which explained 80% of its variance (Table 2). The number of individuals in the H treatment only

significantly differed from the two other treatments in 2008 (Sheffé-test P = 0.0015). The mean number of individuals (per 25 m^2) before and at the end of the experiment were, respectively, 3.6 and 5.2, for L treatment, 4.6 and 5 for N treatment, 4.4 and 0.7 for H treatment (Fig. 2). Over the 7 years of experimentation, the average rates of increase of *P angustifolia* individuals were thus 1.4, 1.1 for L, and N respectively, and 0.2 for H.

Table 2
Results of the ANOVA (F and P values) as the number of living and death individuals of P angustifolia as outcome variables and the predictor variables: treatment, site, pseudo-replicates and time

Factors variables	Nb of individuals	Nb of dead individuals
Treatment	$F_{(2, 180)} = 11.7$ P = 0.000001	$F_{(4, 44)} = 30.1$ P < 0.000001
Site (time)	$F_{(6, 180)} = 0.8$ P = 0.52	$F_{(4, 44)} = 0.1$ P = 0.98
Pseud-repl. (Site × Time)	$F_{(9, 180)} = 0.5$ P = 0.93	$F_{(9, 44)} = 1.0$ P = 0.50
Time	$F_{(1, 44)} = 1.6$ P = 0.22	$F_{(1, 44)} = 34.4$ P = 0.00001

Fig. 2 Number of individuals and numbers of dead individuals per 25 m^2 estimated in the three grazing treatments for the years 0 (o) and +7 (●) estimated by the GLM procedure (with their 95% confidence interval). L low stocking density (50 bulls during 6 months on 180 ha; annual stocking rate = 0,11 AU ha^{-1} year^{-1}), H high stocking density (50 individuals during 2 days on 2 ha; annual stocking rate = 0,11 AU ha^{-1} year^{-1}), N no domestic grazing. Significant differences are indicated by letters a and b
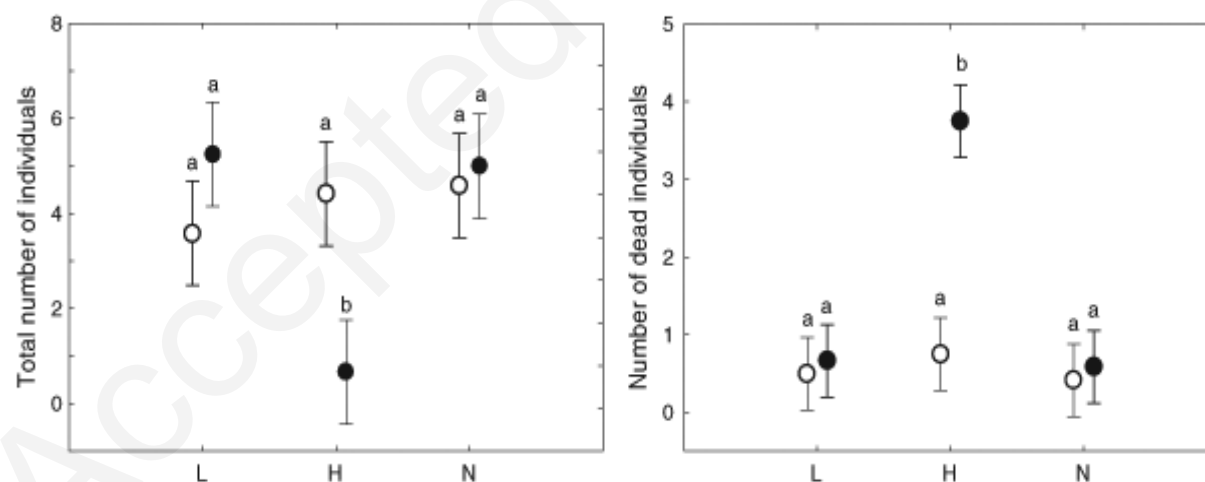
The number of dead individuals did not significantly differ between the three grazing treatments in 2001, but we found a significant difference in the number of dead individuals between years (Table 2), the factor 'time' explaining 52% of its variance. We also found a significant impact of the grazing treatment, which explained 46% of the variance. The difference in the number of dead individuals between years was

only significant for the H treatment (Sheffé-test P < 0.001). The estimated number of dead individuals per 25 m^2 was 0.5, 0.4, 0.7, for L, N and H, respectively, in 2001, and 0.7, 0.6 and 3.8, respectively, in 2008 (Fig. 2).

We found a significant impact of the grazing treatment on the number of new individuals, which explained 93.3% of the variance of this number

(Table 2). The H treatment led to a significantly different number of *P. angustifolia* new individuals compared to the L and N treatments (Sheffé-test $P < 0.001$, $P = 0.013$ respectively), while no significant difference was found between treatments L and N (Sheffé-test $P = 0.069$). The factors 'site' and 'pseudo-replicates' only explained 5 and 1.7% of the variance of the number of new individuals and were not significant (Table 2). The number of new individuals recruited per $25\ m^2$ estimated by the GLM procedure was 2.4, 1.4 and 0 for L, N and H treatments, respectively (Fig. 3).

Fig. 3 Number of new individuals per $25\ m^2$ recruited in the three grazing treatments between the years 0 and +7 estimated by the GLM procedure (with their 95% confidence interval). L low stocking density (50 bulls during 6 months on 180 ha; annual stocking rate = 0,11 AU ha^{-1} $year^{-1}$), H: high stocking density (50 individuals during 2 days on 2 ha; annual stocking rate = 0,11 AU ha^{-1} $year^{-1}$), N: no domestic grazing
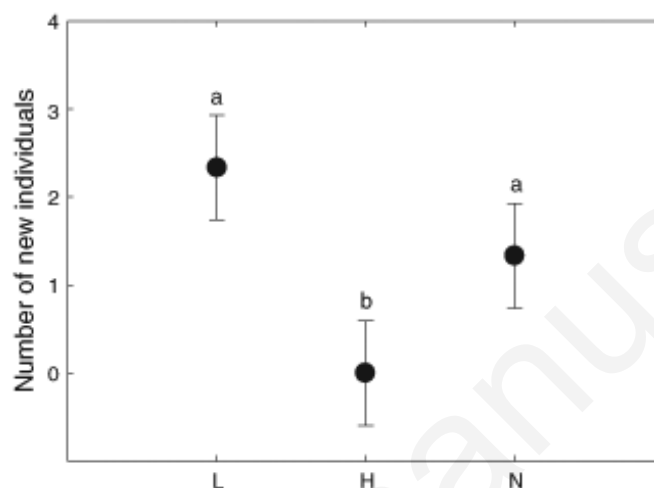
Herbaceous Response

The factors 'time' and 'site' significantly altered the herbaceous species richness (Table 3). They respectively explained 78 and 17% of the variance of SR. Richness did not differ between the three treatments in 2001 (average of 22.8 species per $0.8\ m^2$), nor between these three SR values in 2001 and those of the L and H treatments in 2008. The SR was lower in the N treatment in 2008 than in 2001 (Sheffé-test $P = 0.034$), with 25 and 17.2 species per $0.16\ m^2$, respectively.

Table 3
Results of the ANOVA (F and P values) as the number of new individuals of P. angustifolia as outcome variable and the predictor variables: treatment, site and pseudo-replicates

Factors variables	Nb of new individuals
Treatment	F(2, 18) = 17.1 P = 0.00007
Site (treatment)	F(6, 18) = 0.9 P = 0.50
Pseud-repl. (treatment)	F(9, 18) = 0.3 P = 0.96

The factors 'time' and 'grazing-treatment' significantly altered the Shannon–Weaver index (Table 4). They respectively explained 91 and 6% of the index variance. The Shannon–Weaver index was lower in the N treatment in 2008 than in 2001 (Scheffé-test $P < 0.001$), but did not differ between the three treatments in 2001 or between those treatments and the L or H treatments in 2008.

Table 4
Results of the ANOVA (F and P values) as the species richness, the Shannon–Weaver index, the evenness, the contribution of annual species, the contribution of the characteristic Mediterranean annual species as outcome variables and the predictor variables: treatment, site, pseudo-replicates and time

Factors variables	Sp. richness	Shannon–Weaver Index	Eveness	Contribution annual sp.	Contribution. characat. sp.
Treatment (time)	$F_{(4, 56)} = 0.7$ P = 0.62	$F_{(4, 56)} = 2.9$ P = 0,03	$F_{(4, 56)} = 6.7$ P = 0.00019	$F_{(2, 56)} = 7.7$ P = 0.00005	$F_{(4, 56)} = 5.3$ P = 0.001
Site (time)	$F_{(4, 56)} = 3.9$ P = 0.0078	$F_{(4, 56)} = 0.5$ P = 0.71	$F_{(4, 56)} = 1.2$ P = 0.31	$F_{(4, 56)} = 2.8$ P = 0.036	$F_{(4, 56)} = 4.4$ P = 0.0038
Pseud.-repl. (Treat. × Time)	$F_{(24, 56)} = 0.4$ P = 0.99	$F_{(24, 56)} = 0.5$ P = 0.96	$F_{(24, 56)} = 1.0$ P = 0.52	$F_{(24, 56)} = 0.8$ P = 0.73	$F_{(24, 56)} = 0.4$ P = 0.99
Time	$F_{(1, 56)} = 17.4$ P = 0.00011	$F_{(1, 56)} = 39.4$ P < 0.000001	$F_{(9, 56)} = 11.4$ P = 0.00013	$F_{(1, 56)} = 23.0$ P = 0.001	$F_{(1, 56)} = 2.5$ P = 0.11

The factors 'time' and 'grazing-treatment' significantly altered evenness. They respectively explained 56 and 33% of its variance (Table 3). We found no impact of the factors 'site' or 'pseudo-replicates' on this variable. Evenness was lower in the N treatment in 2008 than in 2001 (Scheffé-test P = 0.002, Fig. 4).

Fig. 4 Evenness and contribution of Mediterranean characteristic annual species in the three grazing treatments for the years 0 (o) and +7 (●) estimated by the GLM procedure (with their 95% confidence interval). L low instantaneous pressure (50 bulls during 6 months on 180 ha; annual stocking rate = 0,11 AU ha^{-1} year^{-1}, H: high instantaneous pressure (50 individuals during 2 days on 2 ha; Annual stocking rate = 0,11 AU ha^{-1} year^{-1}), N no domestic grazing. Significant differences are indicated by letters a and b
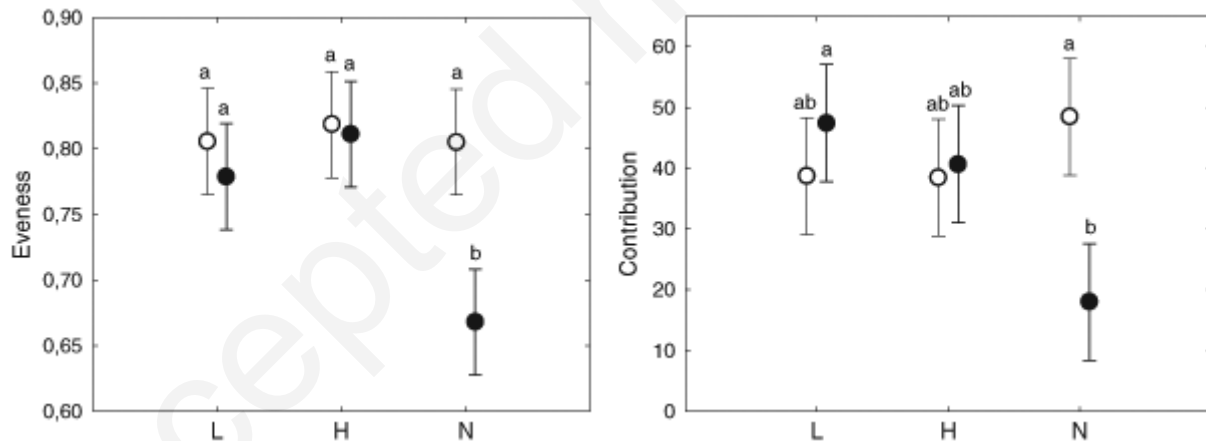
We found a significant impact of the three factors 'time', 'grazing-treatment' and 'site' on the contribution of annual species (Table 4), which respectively contributed 67, 22 and 8% of the variance of this variable. The contribution of annual species did not differ significantly among the three treatments in 2001, or between these three treatments in 2001 and the L and H treatments in 2008. It was lower in 2008 than in 2001 in the N treatment (Scheffé-test P < 0.001), and lower in the N treatment than the L and H treatments in 2008 (Scheffé-test P = 0.001, P = 0.002 respectively).

We found no time effect but a significant impact of grazing-treatment and site on the contribution of characteristic annual species, which respectively contributed 42 and 35% of the variance (Table 4). The number of Mediterranean characteristic species was significantly lower in the N treatment in 2008 than in 2001 (Scheffé-test P = 0.006, Fig. 4).

Discussion

The change of grazing modality strongly altered the mortality and the recruitment of *P. angustifolia*. High stocking density was effective in controlling the recruitment of new individuals and increasing the mortality of this shrub. We did not record a

lower rate of recruitment in the plots subjected to low stocking density than in the plots without grazing. A previous study (Mesléard et al. 2011) even showed a higher rate of recruitment of P. angustifolia in the areas with low stocking density than in the ungrazed areas, where the establishment of new *P angustifolia* seedlings became negligible after the cessation of grazing due to the development of the herbaceous cover.

Although we made no specific measurements to characterize the mechanisms leading to this impact of H treatment (high stocking density) on *P.angustifolia*, the observations made immediately after the departure of livestock showed an impact of trampling mostly on seedling and young individuals, and an impact of grazing mostly on adults. In the L treatment (low stocking density), it has already been demonstrated that the impact of Camargue bulls on seedlings or adults is low (Mesléard et al. 2011). The presence of livestock at high stocking density also led to the immediate mortality of some *P. angustifolia* adults, which can only be explained by physical damage.

Considering only the results on *P. angustifolia*, we are tempted to conclude that mob stocking would help the maintenance of Mediterranean xeric grasslands. The results on the herbaceous community support such a positive conclusion as analyses did not show any differences between the two stocking methods tested in SR, diversity, evenness and contribution of annual characteristic species. In contrast, 7 years without domestic grazing led to a strong decline in the proportion of herbaceous annual species, and consequently a reduction of diversity, evenness and contribution of annual characteristic species. This increase in the cover of perennial species with the cessation of grazing has been reported in many studies (Allen and Mason 1995; Milchunas et al. 1988; Noy-Meir et al. 1989; Peco et al. 2005; Firincioglu et al. 2007; Golodets et al. 2010), and was therefore highly predictable.

Whether grazing should be considered a disturbance has long been debated (Milchunas et al. 1988; Hobbs and Huenneke 1992; Milchunas and Lauenroth 1993). Here, the stocking method consisting in high stocking density, applied during a restricted period of time, fulfills the main criteria of a disturbance (Rykiel 1985) and as such, it had the desired effect on *P. angustifolia*. Yet, as a disturbance, we might also expect high stocking density applied during a restricted period of time to favor species richness, especially of annual species, by the strong control of dominant species and the creation of regeneration niches (Pickett and White 1985; Bullock et al. 1995; Suding and Goldberg 2001). However, 7 years of application of this high stocking density during a restricted period did not lead to major alterations of the herbaceous community parameters. Various reasons could explain the lack of impact observed: (1) a period of grazing unfavorable to change: February, the month when the mob stocking was applied, corresponds to the end of winter or early spring, a period of low plant growth in the northern Mediterranean coastal zone (Perevolotsky and Seligman 1998), which potentially limited the impact on the vegetation cover; (2) the high inertia of the xero-halophytic grasslands, which meant that 7 years was too short a duration to observe significant changes; (3) a scale of observation that was unsuited to taking into account the effects of grazing (Briske et al. 2008); (4) a set of variables chosen to characterize the herbaceous vegetation that was unsuited to describing changes (Noss 1990; Hickman et al. 2004; Fuhlendorf et al. 2006; Jaunatre et al. 2013). However we observed significant changes in terms of Shannon–Weaver index, SR, evenness and proportion of annuals in the plots where domestic grazing was excluded, which suggested that 7 years may be long enough to achieve significant changes in community parameters.

For decades, there has been a consensus on the use of grazing in protected areas where the maintenance of open habitat is a major goal (Olff and Ritchie 1998; Bakker 1989; WallisDeVries et al. 2007). The introduction of a small number of domestic herbivores in continuous stocking can thus be seen as the reestablishment of a natural balance between vegetation and animals (Gordon and Duncan 1988; WallisDeVries 1998). However, one of the aims of grazing used as a management tool is to interrupt the successional dynamic that, without intervention, would cause colonization by woody species and consequently the decrease of herbaceous biodiversity and/or the local disappearance of species targeted by the management strategy. Yet, only high stocking densities can cause the reduction of poorly palatable species by herbivores (Perevolotsky and Seligman 1998; Rutherford and Powrie 2011). Our purpose is not to substitute one kind of dogma for another by rejecting continuous stocking and advocating the sole use of mob stocking. However, when colonization by woody plants is evidently the main and immediate threat, the priority action to be taken is to provide the appropriate means to stop this encroachment, while preserving or enhancing the herbaceous community. In our field experiment, the low annual stocking rate (Dumont et al. 2012), applied in continuous stocking, proved not to be a good method to keep the grassland intact according to the European Directive criteria (European Union Habitats Directive 1992). By contrast, applied in the form of mob grazing before the period of full re-growth, it showed no evidence of negative impact on the herbaceous community but was clearly effective in controlling encroachment by woody species.

Previous studies conducted in the Rhône delta showed that bulls in semi-free ranging favored the spread of poorly palatable species (Mesléard et al. 2011, 2015). Our results strongly suggest that grazing in the form of concentrated heavy grazing during short periods, by its impact on recruitment and on adult individuals, can help to prevent such colonization and also to restore open habitats.

Conclusion

In rangeland, the stocking period and stocking rate are generally considered as the most controllable management decisions (Ash and Strafford Smith 1996; Metzger et al. 2005; Briske et al. 2008). However, extensive grazing may correspond to a low annual stocking rate (Rosenthal et al. 2012), in the form of long grazing periods with low stocking density or in the form of short periods with higher stocking density. Thus, as in our example, mob stocking is also a potential management option (Del Pozo et al. 2006). In a context where climatic conditions are not a limiting factor for herbaceous cover development, mob grazing may be used as a stocking method, alternating or not with low grazing pressure, to fulfill particular objectives such as the control of bush encroachment. In this case, the grazing period will have to be chosen not only according to the carrying capacity but also according to the seasonal vulnerability of herbaceous species. The introduction of drastic methods of woody plant control may not be an optimum management strategy for grass and forage consumption; nevertheless, it could be a pivotal medium- or long-term management strategy to conserve characteristic flora, fauna and habitat (Marone and Lill 1985; Osem et al. 2002).

Acknowledgements

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