

PAPER

Control of bracken (*Pteridium aquilinum*) and feeding preferences in pastures grazed by wild ungulates in an area of the Northern Apennines (Italy)

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Abstract

The diminution of pastoral activities in marginal areas, and consequently of livestock grazing, implies a strong encroachment of invasive vegetation. The conservation of the open areas is however particularly important for wildlife management. With this aim, this paper describes the results obtained in a protected area on the Apennine mountains (Italy), encroached by *Pteridium aquilinum* (L.) Kuhn. Two restoration practices were carried out by the Administration of the Regional Park of the *Laghi di Suviana e Brasimone* (Bologna, Italy), in order to reverse the infestation of bracken and restore pastures within the park. The pasture, only grazed by wild animals, was improved through different treatments (ploughing followed by cuttings *vs* harrowing), each followed by seeding of a forage mixture. Our results showed better performance of the ploughing both as pastoral value of recovered pasture and as botanical composition. Some differences in the effects of the two restoration techniques were also found on the biodiversity index and on floristic richness. Data about grazing selection of the single botanical species have also been collected. The results also showed different behaviour in feeding preferences for wild ungulates in comparison to domestic stocks, giving a better evaluation of the real forage availability for wild herbivores.

Introduction

In the last 50 years the abandonment of traditional agricultural practices has produced

significant effects on agro-silvo-pastoral land use in many European countries (Zechmeister *et al.*, 2003). In marginal and less-productive areas the pastoral activities have now almost completely disappeared (Cervasio *et al.*, 2007a; Peeters, 2008). This has led to both a decline of extensive livestock farming (Van den Pol-van Dasselaar *et al.*, 2008) and to a progressive spread of weeds and shrubs on pastures and open areas (Messeri *et al.*, 2007). The ecological consequences of grazing reduction have affected not only the vegetation structure, but also the floristic composition and the biodiversity of the herbaceous component (Rook and Tallwin, 2003; Cervasio *et al.*, 2009), which is highly modified by the presence of shrubs and trees. Furthermore, shrubs and trees encroachment can lead to the disappearance of open areas, with direct impacts on the homogeneity of the territory and on the presence of animal populations (Laiolo *et al.*, 2004). Therefore, maintaining a balanced ratio between open areas and forest is a key factor for the conservation of biodiversity in different types of landscape. Moreover, where animal presence can be maintained distant from cultivated lands it may be possible to enhance the management of wild ungulates and to achieve a reduction of crop damage (Stanislav and Matej, 2008). For these reasons, the improvement of open areas and the recovery of pastures are important, especially in upland regions, both for biodiversity conservation purposes (*i.e.* in protected areas) and for wildlife and hunting management (Genghini and Capizzi, 2005).

In many areas of abandoned lands one of the most intrusive weed on acidic soils is bracken (*Pteridium aquilinum* (L.) Kuhn), which tends to encroach open areas and pastures reducing the qualitative value of forage (Le Duc *et al.*, 2000). The bracken leaves decompose at such a slow rate that the soil remains covered by a deep litter layer and rough humus which reduces the growth of other plant species (Blackford, 2001). The litter also may release some allelopathic substances into the soil that favour bracken and limit the colonization by other plant species (den Ouden, 2000). In the northern Apennines, the spread of bracken in many abandoned or under-grazed areas represents a major issue for the management and conservation of these upland regions. In the last decade, actions of habitat improvement, mainly concerning the re-establishment of forage species, have been carried out for biodiversity conservation and for wildlife management purposes (Genghini and Capizzi, 2005; Cervasio, 2009). These actions, mainly represented by mechanical and agronomical treat-

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ments, can also be useful for bracken control. In fact, mechanical control reduces the presence of rhizomes, by cutting the fronds in the period of the higher consumption of carbohydrate reserves, or by ploughing, or harrowing, which are used to remove a consistent amount of the rhizomes present in the soil (Snow and Marrs, 1997; Marrs *et al.*, 1998). The mechanical control of weeds is particularly useful within the protected areas, where it can be an instrument of low environmental impact, alternative to the use of herbicides, widely used in many contexts for control of the bracken (Lowday and Marrs, 1992). The control of weeds can be also useful to increase the forage availability for the wild ungulates, keeping them away from crops. Unfortunately, the actual preferences of individual grass species by ungulates are little known (Prior, 1983; Gonzalez-Hernandez and Silva-Pando, 1999; Mattiello *et al.*, 2007). Moreover, to evaluate the resources available for herbivores is essential the knowledge of the nutritive quality of the vegetation; nevertheless, the methods currently available for the evaluation of the pas-

tures have been developed for the livestock, whose feeding behaviour is often different.

The aim of this work was to assess the efficacy of two mechanical treatments of habitat improvement for the bracken control, treatments formerly designed and performed by the Administration of a protected area located in the northern Apennines. At the same time, a further aim was to study the wild ungulates grazing selection, concerning the individual herbaceous species occurring on the restored canopy. This is also important for the effective evaluation of the quality and availability of the pasture resources, specifically related to wild ungulates.

Materials and methods

The study was carried out within the Parco Regionale dei Laghi di Suviana e Brasimone (BO), a protected area located in the Emilia-Romagna region, near the Tuscan border, in northern Apennines, Italy (44°07' N, 11°05' E). The concentration of human activities on the flatter and most-fertile soils and the reduction of silvo-pastoral management of the territory, especially in last decades, caused a sharp reduction in open areas throughout the Park surface: Cervasio (2009) reports that open areas passed from 10% of the total surface to 6% in about 45 years. Moreover, the open areas are currently experiencing a widespread invasion by bracken (Ponzetta *et al.*, 2010). The Park includes an important reproductive area of the red deer (*Cervus elaphus*) population living in Northern Apennine. From recent data, collected by the method of distance sampling, in the 2008-2011 period the average density of deer in the Park was 9.4-12 deer/100 ha, increasing in autumn-winter and decreasing in spring-early summer. In particular, by a census conducted in 2010 during the roaring period, it was estimated in the Park a population of 367 deer (Nicoloso *et al.*, 2011). The site Lamaccia, monitored in this study, is located within the Park surface, at 1150 m asl, with a maximum slope of 25% and about 4 ha wide. The main vegetation type present in the area before treatments, comprised a plant community on sandstone soil, dominated by *Pteridium aquilinum* (L.) Kuhn, which originated after grassland abandonment and cutting of beech forest (Speranza and Ubaldi, 2002). In the studied area, two different restoration techniques (A and B) were used in 2004.

Treatment A: cutting of bracken, ploughing to a depth of 30 cm, disking and sowing of a forage mixture. After sowing, maintenance

cuts were performed once a year in 2005 and 2006, during summer, when the fern fronds were completely grown, simulating a summer cut for hay.

Treatment B: cutting of bracken, harrowing and sowing of a forage mixture. No cut was performed after sowing.

The forage mixture adopted, with a seeding rate of 80 kg ha⁻¹, was composed of: *Bromus inermis* Leyss. (30% by seed weight), *Dactylis glomerata* L. (30%), *Festuca ovina* L. (25%), *Trifolium pratense* L. (10%) and *Lotus corniculatus* L. (5%). Restored areas were exposed only to grazing by wild herbivores, mostly red deer, roe deer and wild boar; there was no livestock present in the surrounding area. Each treatment was applied to four plots arranged in a randomised block design (about 0.5 ha wide). Data collection on restored pastures started in 2006. The botanical composition was assessed for a four-year period (2006-2009) on July, by means of linear analysis (one transect in each plot, thus each treatment was assessed by means of four replications) according to the method of Daget and Poissonet (1971). For an overall analysis of obtained results species were assembled into functional groups that comprised species belonging to grasses and legumes (*i.e.* the families with higher forage interest) and species belonging to other botanical families, as usually performed in pastoral research (Cavallero *et al.*, 2002). The transects were 6.6 m long, 33 intercepts (one every 20 cm) were materialized on the ground by means of a metal stick and the species touching the stick were identified. The number of times the *i*-species was found in the transect was considered as species frequency (SF_{*i*}) in that transect (Targetti *et al.*, 2010). Then the specific contribution (SC_{*i*}), *i.e.* the percentage presence of a given species in the sward, was found as follows:

$$SC_i = \frac{SF_i}{\sum SF_i} \times 100$$

Afterwards the pastoral value (PV) coming from each linear analysis was found using the following formula:

$$PV = (SC_i \times SI_i) / 5$$

where SI is a specific index, variable from 0 to 5, which summarizes the potential value of each forage species. The PV is a quantitative and qualitative parameter (theoretically ranging from 0 to 100) that represents the forage potential of the pasture vegetation (Cavallero *et al.*, 2002). It is referred to domestic livestock

as it is the only available for an overall assessment of the quality of the pasture (Cavallero *et al.*, 2002; Roggero *et al.*, 2002). To assess the diversity of recovered pastures, the Shannon Wiener Index (H') was calculated using data collected along the transects as follows (Magurran, 2004):

$$H' = - \sum p_i \ln p_i$$

where p_{*i*} is the proportion of the specific frequency of the *i*-species, in our case represented by SC_{*i*}/100. Floristic richness (R) was also evaluated, by the number of species occurring along each transect.

The direct impact of the utilization of recovered pastures by wild animals was assessed by calculation of the Defoliation Rate index (DR) using the method of Jougla and Dorée (1987); this was only calculated between 2007-2009. This method allows to assess the actual feeding utilisation of the vegetation and, consequently, to evaluate the grazing animal impact on the different botanical species (Ponzetta *et al.*, 2010). The utilisation of each herbaceous species was evaluated using the Contribution to the Defoliation Rate (CDR) method, proposed by Orth *et al.* (1998). For each species observed along the transects a visual judgement was given regarding its utilisation, *i.e.* whether the individual plant was not utilised at all, partially utilised or intensively utilised. The CDR of each species must refer to its percentage presence (SC) in order to evaluate whether wild animals have a particular preference for a given species. If the CDR/SC_{*i*} ratio for the *i*-species is greater than 1, this species is highly selected. A ratio equal to 1 shows that the species is utilized by animals in proportion to its presence, whereas if the ratio is lower than 1, the utilisation of this species is proportionally lower than its availability and the species is considered avoided by animals (Coppa *et al.*, 2011). ANOVA was performed to test the effect of agronomical treatments, year of sampling and their interaction. Differences between significant sources of variation were tested, for all the studied parameters, using the Mann-Whitney test. Regressions were also performed to find out significant relationships among parameters. All analysis were conducted with statistical software PASW Statistics (SPSS, 2009).

Results and discussion

Although the duration of the survey did not allow definitive assumption on the long-term

evolution, it elucidated the short-term pattern of the changes following two different agronomic practices, in relation to composition of sward and to the species richness. Moreover, in comparison to long-term studies, the temporal scale used in this work is in accordance with the frequency of the agro-pastoral interventions for the control of intrusive shrubs and for the pastures management.

Botanical composition and ecological indices

Year of sampling never resulted significant for all studied parameters, while treatment and interaction treatment x year affected them in a remarkable way. Botanical composition, in terms of functional groups, was clearly affected by the different habitat improvement treatments (Table 1).

Particularly, the presence of bracken was always significantly lower in the ploughed sectors (A), and it appeared to be continuously reducing. In the harrowed plots (B) the percentage of its presence remained over 20%. The effects of the treatments produced, in each year, a remarkable reduction of bracken, especially after ploughing (Pakeman *et al.*, 2002), with a consequent improvement in the quality of restored pastures. Previous works, which were conducted in surrounding encroached pastures, reported percentage presence of bracken ranging from 30% to 40%. (Cervasio *et al.*, 2007b, 2009).

The specific contributions of legumes were always significantly different between treatments, being higher in the ploughed treatment, except for the last year of observation when no statistical difference was found. Grasses presence was significantly greater for the A treatment only in the first year of the trial. In both treatments, grasses (mainly the sown species) were well represented, and over time was even observed a continuous process of re-colonisation by grasses not present in the original mixture. Legumes occurred on restored plots with minimal specific contribution, due to their low presence in the original mixture (15% by weight) in comparison to grasses. In the later years the presence of legumes was considerably reduced, especially in the harrowed sectors, where no cutting was performed after sowing. Legumes are mainly represented by heliophilous species and their presence can be highly affected by competition for light performed by tall grasses (Doležal *et al.*, 2011). Thus, they can persist only if the biomass of other surrounding species is naturally scarce or is removed. This has probably determined the lower SC value of legumes in the B sectors.

The specific contribution of forbs, represented entirely by native species, was never significantly different among treatments. Their presence, increasing over time, demonstrates the ongoing process of natural re-colonization of the pastures in the two treated

areas. Ward and Jennings (1990) indicated the re-colonization of bare ground by species of open grassland as the main outcome following the removing infestation of bracken. The botanical composition in the A and B sectors tends to become more similar over time, up to the year 2009, when no significant differences were found in any parameters, except for the presence of *Pteridium aquilinum*, which is constantly lower in the ploughed sector.

Additionally, the results of the pastoral and ecological parameters, shown in Table 2, demonstrate a better efficiency of ploughing for the creation of high quality sward. Higher PV in the ploughed sectors can be explained by the greater presence of sown species, and especially of the legumes which are characterized by higher SI.

The presence of bracken produced a significant depression of some pastoral and ecological parameters. Figure 1 shows the relationships between bracken, expressed by its specific contribution, the SC of legumes and the pastoral value. Both these parameters appear strongly influenced by bracken SC, particularly for the pastoral value, which increases quickly in the recovered pasture with the bracken decline ($R^2=0.72$, $P<0.001$). The significant depression of the SC of legumes due to the presence of bracken is probably due to the shading which inhibits the development of heliophilous species (den Ouden, 2000). The decrease of PV in relation to the presence of

Table 1. Effects in time of the two treatments on the specific contribution of functional groups and of bracken.

	2006			2007			2008			2009		
	Treatment A, %	Treatment B, %	P value	Treatment A, %	Treatment B, %	P value	Treatment A, %	Treatment B, %	P value	Treatment A, %	Treatment B, %	P value
Grasses	29.4	15.7	*	35.0	33.9	ns	32.5	21.9	ns	33.2	26.0	ns
Legumes	28.3	19.0	*	25.3	1.3	*	15.1	4.0	*	13.9	5.3	ns
Forbs	38.6	43.5	ns	38.8	42.3	ns	51.4	44.4	ns	52.3	45.0	ns
Bracken	3.7	21.8	*	0.9	22.5	*	1.0	29.7	*	0.6	23.7	*

* $P<0.05$; ns, not significant (Mann-Whitney test).

Table 2. Effects in time of the two treatments on various values and indices.

	PV			H'			R			DR		
	Treatment A, %	Treatment B, %	P value	Treatment A, %	Treatment B, %	P value	Treatment A, %	Treatment B, %	P value	Treatment A, %	Treatment B, %	P value
2006	39	23	*	2.03	2.39	ns	15.9	17.2	ns	-	-	
2007	40	15	*	2.37	1.92	*	18.3	12.1	*	34.2	1.8	*
2008	27	12	*	2.76	2.01	*	22.5	12.5	*	37.5	9.9	*
2009	31	14	*	2.36	2.30	ns	18.3	16.8	ns	22.4	5.4	ns

PV, pastoral value; H', Shannon Wiener index; R, floristic richness; DR, defoliation rate. * $P<0.05$; ns, not significant (Mann-Whitney test).

bracken can be explained both by the already observed reduction of legumes, that represent the botanical family of best forage quality, and also by a general negative influence of the bracken on the sown species (grasses and legumes) which tend to reduce their presence over time. As stated before, SI used in this work were evaluated for domestic stocks, so the calculation of PV for faunistic purposes could be not completely accurate. Nevertheless, at this moment the occurring SI are the only existing for an overall assessment of the pasture quality.

The ecological parameters, expressed by the Shannon Wiener index (H') and the Richness values (R), were similar at the beginning of the data collection for the initial homogeneity of the sward following the treatments, but in 2007 and in 2008 they showed a significant increase in the ploughed area (A). Probably, in the harrowed sectors (B), the continuous presence of bracken has hindered the success of the sward mixture and limited the recovery of other spontaneous species. In 2009, the H' and R values return to be similar in the A and B sectors, probably due to the gradual re-colonization of the ploughed pasture by native species. As also observed by Isselstein *et al.* (2005), the ecological parameters tend to become homogeneous with the gradual re-naturalization of the sward, especially in the absence of maintenance practices.

The bracken presence also shows a significant negative interaction ($P < 0.001$ in both cases) with the ecological parameters, Shannon Wiener index (H') and floristic richness (R) (Figure 2). In fact bracken strongly reduced the overall ecological value of pasture, confirming what already found in previous researches concerning relationships between quality of pastures and intrusive species (Messerli *et al.*, 2010).

Wild ungulates grazing selection

The defoliation rate showed always higher values in the ploughed sectors (A), with significant difference between treatments, except for the year 2009.

Utilised species presented a different CDR/SC ratio in different years. Table 3 reports the average values across treatments of the CDR/SC ratio and the Specific Index of each species. It is interesting to notice that some species considered of no fodder importance (13 out of the 47 occurring along transects), namely species with a $SI=0$, were actively utilized by wild ungulates. Among these species outstanding values were recorded for *Cruciatia laevipes* Opiz., *Prunella vulgaris* L., *Ranunculus acris* L., *Silene vulgaris* (Moench)

Garcke, *Urtica dioica* L. and *Veronica chamaedrys* L. Also species with a SI value close to the maximum (5), considered of high forage interest, were selected by the grazers, as their CDR/SC ratio was greater than 1. They are represented both by species present in the sowing mixture used (*Dactylis glomerata* L., *Trifolium repens* L.) and by spontaneous species considered of high fodder importance

(*Lolium perenne* L.). At the same time, other species, considered of great forage interest for domestic animals, were often characterised by a CDR/SC ratio lower than 1, e.g. *Achillea millefolium* L., *Festuca arundinacea* Schreber, *Lolium multiflorum* Lam. and some clovers (*T. campestre* Schreber and *T. hybridum* L.).

Finally, there was also a significant negative relationship ($R^2=0.77$, $P < 0.001$) between the

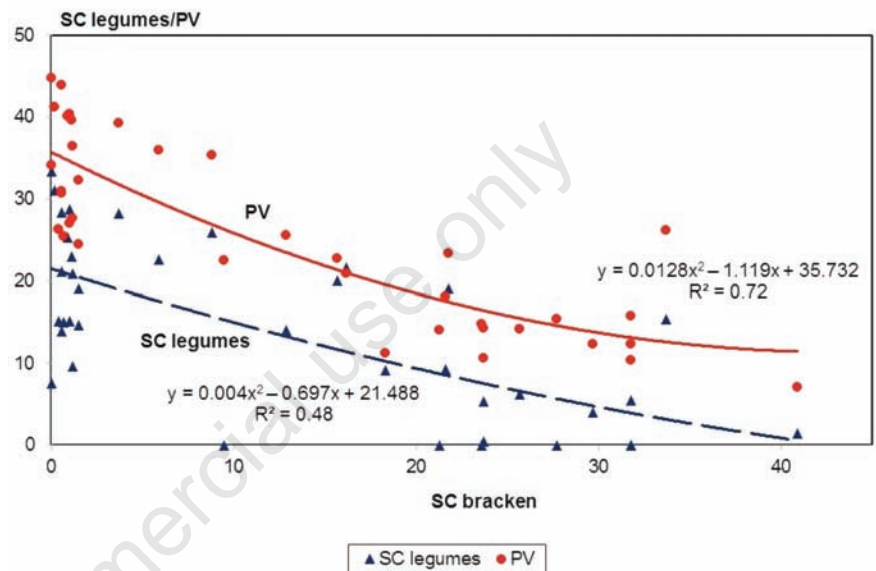


Figure 1. Relationships between specific contribution of bracken (SC bracken) and specific contribution of legumes (SC legumes) and pastoral value (PV).

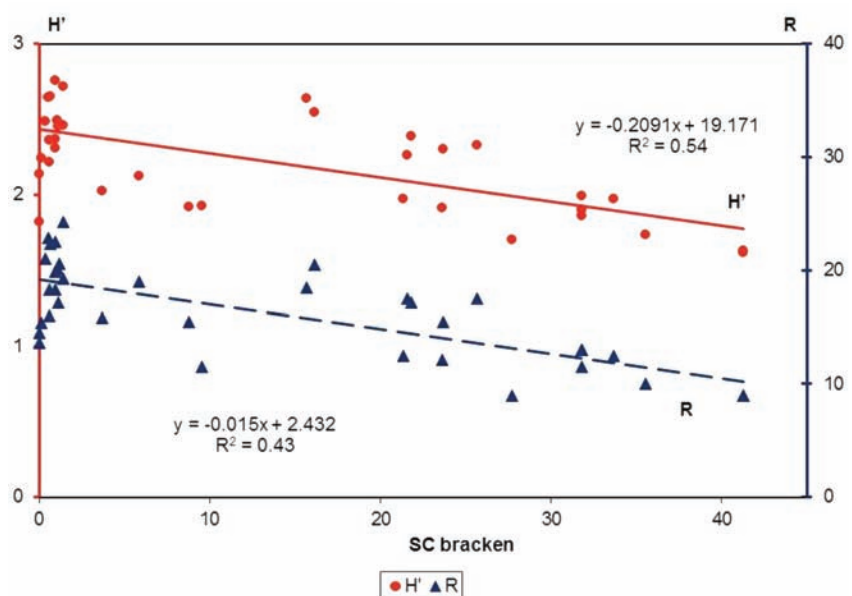


Figure 2. Relationships between specific contribution of bracken (SC bracken) and Shannon Wiener index (H') and floristic richness (R).

Table 3. CDR/SC ratio (average data across treatments and years) and specific contribution index of species occurring in the restored areas.

Species	CDR/SC	SI
<i>Achillea millefolium</i> L.	0.95	2
<i>Bromus inermis</i> Leyss.	2.27	3
<i>Carex otrubae</i> Podp.	1.37	0
<i>Cirsium arvense</i> (L) Scop.	0.02	0
<i>Cirsium eriophorum</i> (L) Scop.	0.34	0
<i>Cruciata laevipes</i> Opiz.	1.92	0
<i>Cytisus scoparius</i> L.	0.94	0
<i>Dactylis glomerata</i> L.	1.31	5
<i>Festuca arundinacea</i> Schreber	0.96	3
<i>Festuca ovina</i> L.	0.91	1
<i>Fragaria vesca</i> L.	0.01	0
<i>Galium mollugo</i> L.	1.20	0
<i>Holcus mollis</i> L.	2.06	2
<i>Hypericum perforatum</i> L.	1.36	0
<i>Juncus effusus</i> L.	0.37	0
<i>Knautia arvensis</i> (L.) Coulter	0.34	0
<i>Lamium album</i> L.	0.90	0
<i>Lathyrus pratensis</i> L.	1.29	2
<i>Leontodon hispidus</i> L.	1.04	0
<i>Leucanthemum vulgare</i> Lam.	1.07	0
<i>Lolium multiflorum</i> Lam.	0.30	4
<i>Lolium perenne</i> L.	2.10	5
<i>Lotus corniculatus</i> L.	1.73	3
<i>Plantago major</i> L.	1.14	1
<i>Poa pratensis</i> L.	1.80	4
<i>Poa trivialis</i> L.	0.21	2
<i>Potentilla reptans</i> L.	0.04	0
<i>Ranella vulgaris</i> L.	2.80	0
<i>Ranunculus acris</i> L.	1.80	0
<i>Rubus idaeus</i> L.	0.97	0
<i>Rubus ulmifolius</i> Schott	0.32	1
<i>Rumex acetosella</i> L.	0.82	0
<i>Salvia pratensis</i> L.	0.86	0
<i>Silene vulgaris</i> (Moench) Garcke	2.17	0
<i>Stellaria graminea</i> L.	0.58	0
<i>Stellaria media</i> (L) Vill.	0.99	0
<i>Teucrium scorodonia</i> L.	1.04	0
<i>Trifolium campestre</i> Schreber	0.20	2
<i>Trifolium hybridum</i> L.	0.25	2
<i>Trifolium pratense</i> L.	1.02	4
<i>Trifolium repens</i> L.	1.38	4
<i>Urtica dioica</i> L.	2.27	0
<i>Valeriana officinalis</i> L.	0.14	0
<i>Veronica chamaedrys</i> L.	1.75	0
<i>Veronica officinalis</i> L.	0.93	0
<i>Vicia cracca</i> L.	0.66	2
<i>Viola tricolor</i> L.	1.26	0

CDR, Contribution to the Defoliation Rate; SC, specific contribution; SI, specific index.

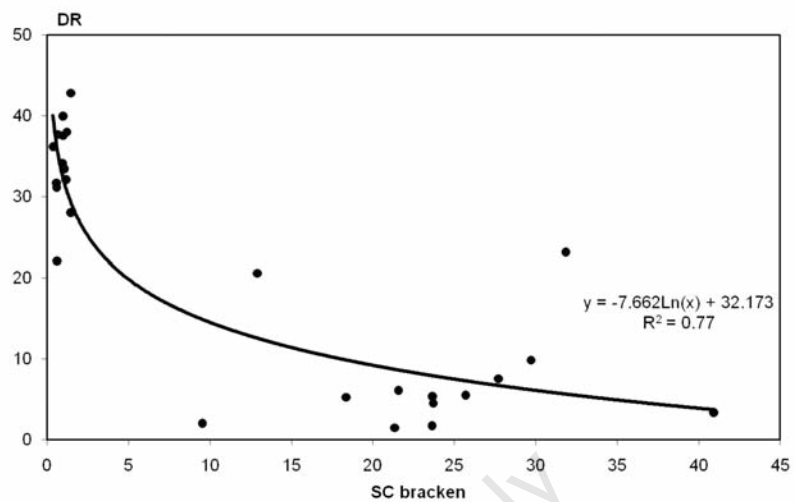


Figure 3. Relationship between specific contribution of bracken (SC bracken) and defoliation rate (DR).

presence of bracken and the defoliation rate (Figure 3). This parameter permitted an assessment of the selection of the different plant species, showing that in some cases the behaviour of the wild ungulates can be considered similar to the behaviour of domestic animals. On the other hand, the wild fauna also utilized many species not usually considered of any fodder importance, mainly coming out by re-colonisation of autochthonous species. These results confirm what was found by other authors (Casanova *et al.*, 1981; Prior, 1983; Mattiello *et al.*) regarding the preference by wild animals for native plants. In any case, utilisation of a given species by grazing ungulates is affected by many factors, such as vegetative stage, and the presence of other herbaceous species within the pastoral vegetation, as already reported (Orth *et al.*, 1998; Coppa *et al.*, 2011).

Conclusions

Both types of agronomic interventions (ploughing and cutting *vs.* harrowing) were effective in reducing the infestation by bracken, but only the deep ploughing has reduced the bracken presence to very low levels for a longer period, improving the ecological and forage characteristics of the recovered pasture. Furthermore, the study highlighted the importance of regular mowing to maintain the sward, mainly in relation to the bracken control. The absence of this practice has produced

immediate negative effects, with a general deterioration of botanical composition and pastoral value, decrease of sown species and worsening of ecological parameters.

The use of the defoliation rate method gave important information on the overall utilization of the pasture and on the selection, made by the wild ungulates, on some spontaneous species, usually not grazed by livestock. This is important in the assessment of the effective availability and quality of forage in pastures used by wild animals. The compilation of a list of specific indices, appropriately focused on wild animals, should be encouraged in order to enhance the assessment of a pastoral area for faunistic purposes and in order to suitably judge the efficiency of programmes for the restoration of pastures.

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