PAPER

Wild red deer (*Cervus elaphus L.*) grazing may seriously reduce forage production in mountain meadows

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Abstract

This study aimed at estimating the impact of red deer grazing on the productivity of meadows located in Pian Cansiglio, north-eastern Italian Pre-Alps. These meadows (185 ha; average elevation 1000 m asl are managed for hay/silage production (1-2 cuts per season) and are included in a protected area that hosts a high density of deer (around 30 heads/100 ha). In 2008 and 2010, dry matter (DM) production and loss due to deer grazing were estimated with exclusion cages (1 m^2; 48 exclusion cages in 2008 and 52 in 2010). Night counts with spotlights were conducted to index deer use of meadows plots. DM production inside the cages was fairly good for the area (first-second cut: 4963-2297 kg DM/ha in 2008, and 4145-2475 kg DM/ha in 2010). DM production outside the cages was significantly lower (first-second cut in 2008: 4199-1378 kg DM/ha, and in 2010: 3376-2052 Kg DM/ha). Therefore, the magnitude of losses was of 15-20% at the first and 25-40% at the second cut. DM losses in the different meadow plots were positively correlated with index of deer use, which in some plots was as high as 7-8 heads/ha. Deer grazing reduced also crude protein (CP) content of forage (15.6±4.4% DM inside exclusion cages and 13.8±3.5% DM outside), with losses being greater where CP content was higher. This study demonstrates that high densities of grazing deer may seriously impact on forage production and quality.

Introduction

In the last decades, wild red deer (*Cervus elaphus* Linnaeus, 1758) populations have greatly expanded in range and numbers in Europe and in Italy, as a result of a number of factors including land use and climate changes, protection from poaching and implementation of sustainable harvest plans, and reintroduction programmes (Mattioli *et al*., 2001; Milner *et al*., 2006; Carnevali *et al*., 2009). Due to its body size, feed intake, and adaptability to a wide variety of habitats where it may reach high population densities, red deer is considered as a *keystone species*, i.e. a species that may exert serious impacts on the structure and functioning of agro-forestry ecosystems (Côté *et al*. 2004; Gordon *et al*., 2004). These impacts include changes in vegetation structure and composition that influence plant richness and biodiversity (Russell *et al*., 2001; Schütz *et al*., 2003; Goetsch *et al*., 2011), and may result in damages to forest regeneration and productivity (Ammer, 1996; Motta, 1996; Motta *et al*., 2003; Tremblay *et al*., 2007). In addition, they may have cascading effects on the communities of birds (Holt *et al*., 2011; Martin *et al*., 2011), invertebrates (Rambo and Faeth, 1999; Melis *et al*., 2005) and other mammals (Smit *et al*., 2001; Muñoz *et al*., 2008).

Although it is generally recognised that red deer impacts affect mainly forest ecosystems (Putman and Moore, 1998; Rooney and Waller, 2003), the recent expansion of the species resulted in an increased use of cultivated areas, and claims of damages to agricultural crops are rising. Red deer is an intermediate feeder (Hofmann, 1989), and as such it tends to browse selectively but has also the ability to graze grass swards (Gebert and Verheyden-Tixier, 2001). Therefore, crops damaged may include fruit orchards and woody ornamental plants (Caslick and Decker, 1979; Porter, 1983; Fargione *et al*., 1991), cereals and oilseed crops (Decalesta and Schwenndeman, 1978; Wilson *et al*., 2009), but also grasslands (Trdan and Vidrih, 2008; Wilson *et al*., 2009; Kamei *et al*., 2010). These damages are linked to the seasonal availability of crops as respect to natural sources of food and to the deer density around and inside crop plots, which in turn is influenced by human interferences as hunting and disturbance, by seasonal displacements, and by the availability of cover (Putman and Moore, 1998; Trdan and Vidrih, 2008;Wilson *et al*., 2009; Kamei *et al*., 2010).

This study aimed at assessing the impact of red deer grazing on grass production of meadows located in a protected area of the eastern Italian Pre-Alps. In this area red deer has increased greatly in the last decade, causing significant damages to forest (Caudullo *et al*., 2003). Recently, an impact on grasslands has also been suggested (Mearns *et al*., 2007), but a comprehensive assessment is lacking. Therefore, specific objectives were to estimate the extent of the reduction of grass production due to deer grazing, and to verify whether this reduction: i) varied from spring to summer; ii) was related to deer use of meadow plots and to distance from forest edge; iii) resulted in changes of chemical composition of forage.

Materials and methods

Study area

The study was conducted in the Cansiglio forest, located in the north-eastern Italian Pre-Alps (Longitude 12°20′-12°29′E; Latitude 46°01'-46°08'N), between the provinces of Belluno, Treviso and Pordenone (Figure 1). The Cansiglio Forest covers approximately 7000 ha and is owned by the Italian Government. It has a characteristic bowl-shaped morphology, where a central basin lying at an elevation of about 1000 m asl is surrounded by mountain chains (Monte Pizzoc: 1565 m; Monte Millifret: 1581 m; Monte Croseraz: 1694 m; Monte Cavallo: 2250 m). This morphology and karst phenomena are responsible of a thermal inversion. Average annual temperatures are close to 6.8°C, which is 2-3 degrees less than in other pre-Alpine areas at the same elevation (Caudullo *et al*., 2003). Annual precipitations are abundant and close to 2000 mm (average±SD=1946±476 mm/year, from 1993 to 2010) with highest values in May and November (ARPAV, 2011).

Vegetation in the Cansiglio Forest is mainly beech (*Fagus sylvatica* L.) dominated woodland, with minor areas of Norway spruce (*Picea abies* (L.) Karst) and silver fir (*Abies alba* Miller). In the central basin, three areas, i. e. Pian Cansiglio, Cornesega and Valmenera (Figure 1), are covered by meadows and pastures for a surface of approximately 383 ha. The whole forest is Site of Community Importance according to directive 92/43/EEC *Habitat* and Special Protection Area according to directive 79/409/EEC *Birds* (Natura 2000 identification site code: IT3230077).

Grassland management

The grasslands in Pian Cansiglio are managed by four dairy farms, three of which are organic. The total surface managed is 305 ha, with an average farm size of 81 ha (SD=11). Meadows are in total 185 ha, with an average size per farm of 46 ha (SD=11), and pastures are 120 ha, with an average size per farm of 30 ha (SD=3). During the study period the four farms had a total of 339 livestock units (LU), with an average herd size of 81 LU (SD=31). The average stocking rate (LU/ha) was 1.03 (SD=0.25).

Meadows are normally cut two times per season, the first between mid and late June and the second around mid August. However, some plots are cut only once and then grazed.

Grasslands in Valmenera and Cornesega are managed by a single farm (meadows, 15 ha; pasture, 63 ha), with 34 LU and a stocking rate of 0.47. The few hectares of meadows are cut only once, after July 15, due to limitations imposed for the protection of corncrake (*Crex crex*) nesting. Due to these particularities, this farm was not included in the study.

According to botanical composition estimated on 79 sample sites (Wildi and Orloci, 1996), the meadows in Pian Cansiglio can be assigned to the two groups of high productive meadows. The most represented group cannot be classified as natural according to phytosociological criteria, because it includes mainly few species, as *Poa trivialis, Phleum pratense, Festuca pratensis,* and *Dactylis glomerata*, which have a high forage value and result from past actions of re-seeding and high inputs of fertilizers. The second group is less influenced by management practices and can be classified as a transition between *Centaureo transalpinae – Trisetum flavescentis* (Marshall 1974 corr. Poldini and Oriolo 1994) and *Centaureo carniolicae – Arrhenatheretum elatioris* (Oberdorfer 1964 corr. Poldini and Oriolo 1994). Small, localised areas are affected by *Deschampsia caespitosa*.

Red deer population

As a State property since 1871, the Cansiglio Forest is a protected area and hunting is forbidden. Red deer in Cansiglio and in all the surrounding areas became extinct in the mid 1800s. The species reappeared in the forest in the late 1980s, when a few individuals escaped from a fenced area (Mattioli *et al*., 2001). The population, at that time demographically isolated, increased slowly and in 1997 the estimated number of red deer was of about 200 heads (Stiz, 1997). Since then, also as a result of immigration from the expanding populations of the surrounding areas, the population growth was impressive. In the red deer management unit comprising the forest plus a buffer area for a total of approximately 85 km^2, the population size between 2008 and 2009 has been estimated at around 2800-3000 heads, with a population density higher than 30 heads/km^2 (Bottazzo and Nicoloso, 2010). This density is very high, as compared to that of the species in other Alpine areas (Carnevali *et al*., 2009), and is favoured by both the protection status and the good habitat suitability of the Cansiglio forest. The seasonal displacements of the population are not known in details. However, population density decreases in winter due to partial migration towards wintering areas at lower elevations, while it increases again in spring and summer, to peak probably during the rutting season between September and October (Bottazzo and Nicoloso, 2010). In the forest there are no large predators, and other wild ungulate species include roe deer (*Capreolus capreolus*, L. 1758) and fallow deer (*Cervus dama*, L. 1758). In contrast with red deer, for these species there are no recent standardized counts, but population densities are considered much lower than those of red deer.

Data collection

The study was conducted in the summers of 2008 and 2010 on the meadows of the four farms located in Pian Cansiglio (Figure 1). Pastures were excluded, because of mixed grazing by livestock and deer. Grass production and consumption by deer were estimated using exclusion cages, made of wire mesh, with a size of 1.0×1.0×1.2 (height) m. The cages (48 in 2008 and 52 in 2010) were distributed in order to cover all the meadow plots of each farm, and to sample different distances from the forest edge, as shown in Figure 1. Their location was geo-referenced with a portable GPS to allow re-positioning after each cut and in different years, and implemented into ArcGiS 10 (ESRI 2010) to calculate their distance (m) from the forest edge, using an ortophotograph (year 2006; 1:10.000) of the area. The cages were placed in April, before

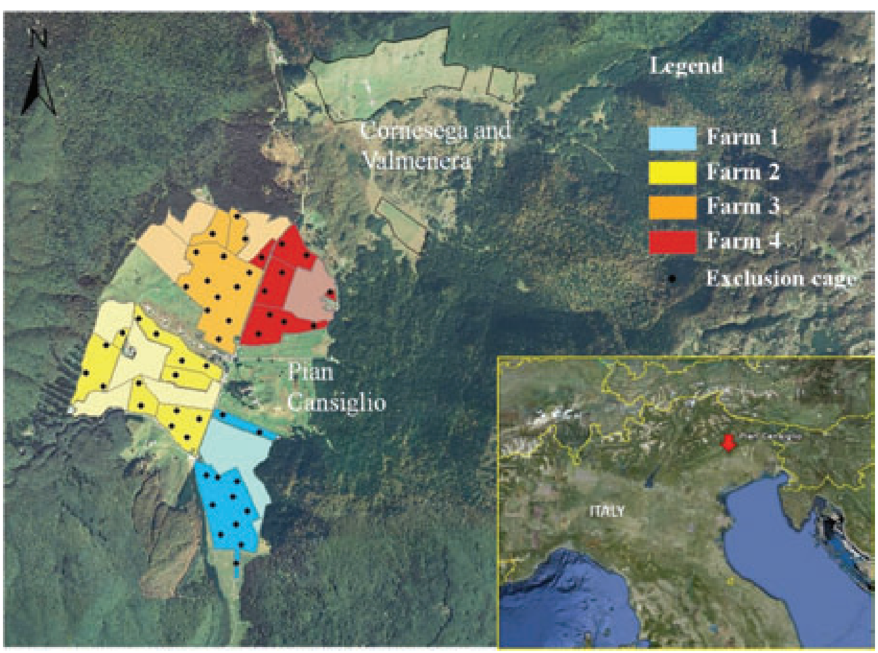

Figure 1. Study area with the meadows surveyed for each farm. Black dots indicate location of exclusion cages, and numbers indicate the different plots.

the resumption of vegetative growth. Immediately before the first cut, the grass grown inside the cages was manually harvested by cutting at an approximate height of 5 cm from the ground. The same procedure was followed for a sample area of 1×1 m chosen randomly at a distance of 1-2 m from the cages. The cages where then removed to allow mowing, and re-positioned with the aid of the GPS immediately after harvest. The sampling procedure was repeated before the second cut.

Samples collected inside and outside each cage were oven dried at 65°C until constant weight, ground, and analysed for residual dry matter (DM) content (AOAC, 1990) in order to estimate the DM produced and that removed by deer. In addition, the contents of crude protein (CP), ash (AOAC, 1990), and neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) (Van Soest *et al.*, 1991) were determined in 130 samples in 2008 (34 cages x 2 positions (inside and outside) at the first cut and 31 cages x 2 positions at the second) and in 138 samples in 2010 (41 cages x 2 positions (inside and outside) at the first cut and 28 cages x 2 positions at the second).

The DM production inside the cages was used as an estimate of meadows productivity, while that outside the cages gave an estimate of the residual production left after deer grazing. The DM loss was calculated as the difference between them. DM productions and losses were expressed as kg/ha. The loss of CP was calculated as the difference between the CP content (% DM) of the samples collected inside and those collected outside the cages.

Index of deer use of meadow plots

During the summer 2008, night counts of deer with spot-lights were conducted from vehicles driving three transects that covered the meadow plots surveyed. The three transects were covered simultaneously by three teams over 1-2 h, starting at least 3 h after sunset. Counts were replicated on 29 May, 19 June, and 24 July. The aim of these counts was to obtain an index of the use of the different meadow plots by red deer, roe deer and fallow deer. To this purpose, the number of deer in each group observed for each species was recorded, and its location was plotted on a map (1:10.000). Based on this location, the deer counted were then assigned to each plot using ArcGIS 10 (ESRI 2010). The index of deer use was expressed for each plot as number of deer/ha. Given the very low numbers of roe deer and fallow deer counted (see results), the index was calculated only for red deer.

Statistical analysis

Forage productions (DM, kg/ha) and chemical composition (% DM) were analysed with the PROC MIXED procedure of SAS (2006), using a mixed linear model with the fixed effects of farm (4 levels), cut (2 levels), year (2 levels), sampling position (2 levels: inside vs outside of the cage) and the interaction between cut, year and sampling position. Cage nested within farm was used as random effect.

The effect of distance from forest edge on DM losses was tested with a mixed linear model where year was used as fixed effect, distance (m) of the cage from the forest edge as a covariate, and cage as a random effect.

Finally, simple Pearson correlation analyses were used to test whether in the different meadow plots there was any relation between the index of deer use (average of all counts) and the DM losses (sum of losses at the first and second cut), and whether the CP content of grass inside the different cages was related to the CP losses.

Results

The analysis of variance of DM production showed highly significant effects for year ($F=7.04$; $df=1$; $P<0.01$), cut ($F=532.60$; $df=1$; $P<0.001$), sampling position ($F=69.85$; $df=1$; $P<0.001$), farm ($F=20.65$; $df=3$; $P<0.001$), and the interaction between cut, year and sampling position ($F=10.99$; $df=4$; $P<0.001$). The LS means for this interaction are given in Figure 2. The DM production inside the cages at the first and second cut was 4963±139 kg/ha and 2297±136 kg/ha in 2008, and 4145±133 kg/ha and 2475±153 kg/ha in 2010. The residual DM production outside the cages was remarkably lower in both cuts, with 4199±139 kg/ha at the first and 1378±136 kg/ha at the second in 2008, and 3320±133 kg/ha and 1913±153 kg/ha in 2010.

The distance from forest edge significantly affected the DM losses in 2008 ($b=-1.69$; $t=-2.28$; $SE=0.74$; $df=42$; $P<0.05$), but not in 2010 ($b=-0.48$; $t=-0.65$; $SE=0.48$; $df=42$; $P=0.52$). For each m of increasing distance from forest, DM losses decreased of approximately 1.7 kg DM/ha in 2008, while did not change in 2010.

The maximum number of red deer observed during the night counts was 686 heads, while the maximum numbers of roe deer and fallow deer were 3 and 20 heads respectively. The index of meadows use by red deer varied widely between plots, without a clear temporal trend (average 2.1±2.0 heads/ha). There was a significant correlation with total DM losses (n of meadow plots=15; $r=0.70$; $P<0.01$ Figure 3).

The chemical composition of forage is given in Table 1. On average, forage quality was good, with CP and NDF contents of 13-15% DM and 56-60% DM at the first cut and 18-19% DM and 51% DM at the second. The statistical analysis showed significant differences for chemical composition. Crude Protein content was affected by cut ($F=153$; $df=1$; $P<0.001$),), farm ($F=24.76$; $df=1$; $P<0.001$), sampling position (($F=24.76$; $df=1$; $P<0.001$), and the three-way interaction between year, cut and sampling position ($F=3.25$; $df=4$; $P<0.05$). In all cuts and year, CP content of forage was 1-3% lower outside than inside the cages. However, CP losses depended on the initial quality of the forage, as indicated by a strong positive corre-

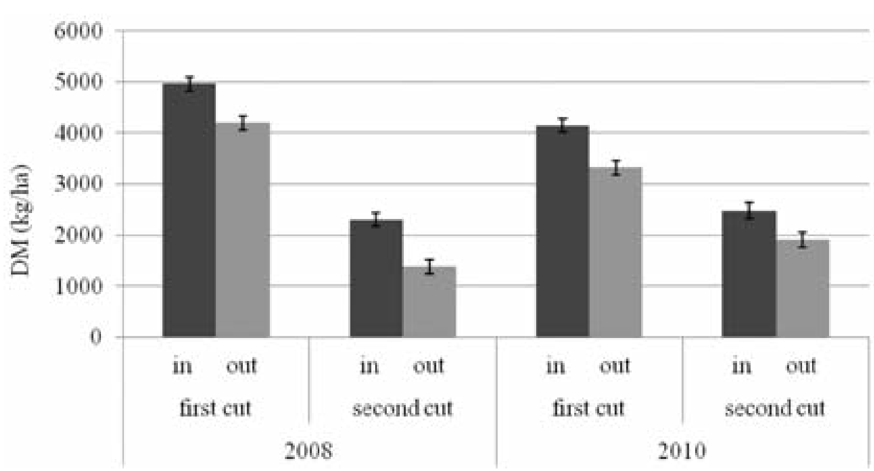

Figure 2. LS means of dry matter production per year, cut and cage side (in = inside; out = outside). Bars indicate SE.

Table 1. LS means (SE) of chemical composition (% DM) per year, cut and sampling position.

	2008				2010			
	First cut		Second cut		First cut		Second cut	
	Inside	Outside	Inside	Outside	Inside	Outside	Inside	Outside
CP	13.0[a] (0.52)	11.8[b] (0.52)	18.6[a] (0.52)	17.4[b] (0.52)	15.2[a] (0.48)	12.1[b] (0.48)	18.1[a] (0.55)	16.2[b] (0.55)
NDF	60.2 (0.91)	60.1 (0.91)	51.2 (0.91)	50.9 (0.91)	56.4 (0.84)	55.8 (0.84)	50.8 (0.96)	50.3 (0.96)
ADF	34.4 (0.50)	33.9 (0.50)	28.9 (0.50)	28.4 (0.50)	30.5 (0.46)	29.8 (0.46)	28.1 (0.53)	27.6 (0.53)
ADL	3.0 (0.17)	2.7 (0.17)	3.9 (0.17)	3.8 (0.17)	3.7 (0.15)	3.5 (0.15)	3.8 (0.18)	3.7 (0.18)
Ash	6.5 (0.24)	6.3 (0.24)	9.5 (0.24)	9.5 (0.24)	6.3 (0.23)	6.2 (0.23)	7.7 (0.25)	8.1 (0.25)

CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignine; [a,b]different letters indicate that, within each year and cut, values differ significantly at P<0.05 between inside and outside.

lation between the CP content of the samples inside of the cages and the corresponding CP losses (n=128; r=0.66; P<0.001; Figure 4).

Also for ADL, ADF, and Ash contents the three-way interaction was statistically significant, but post-hoc tests showed no significant differences between sampling position. This interaction was not significant for NDF (F=2.02; df=4; P=0.092).

Discussion

Grass production differed slightly between the two years, most probably as a result of climatic variability, and was in line with what expected from these groups of high productive mountain meadows (Ziliotto *et al.*, 2004; Scotton *et al.*, 2005). Also the difference between the first and the second cut was predictable (Gruber *et al.*, 1999; Spanghero *et al.*, 2003). A significant source of difference was the farm. This effect was expected and was included in the model because sward improvements and fertilizers inputs vary between the four farms studied.

The production losses observed in this study were remarkable and fairly constant throughout the study period, varying within a narrow range of around 800-1000 kg DM/ha in both cuts and years. These amounts account for approximately 15-20% of the forage productivity at the first cut, and for 25-40% of that at the second cut. The negligible occurrence of other deer species observed during the night counts, and the positive correlation between the index of deer use and the production lost in the different plots, confirmed that these losses are a direct consequence of red deer grazing. In general, the losses observed confirm preliminary indications obtained in the same area by Mearns *et al.* (2007), while are higher than those reported by Trdan and Vidrih (2008) and

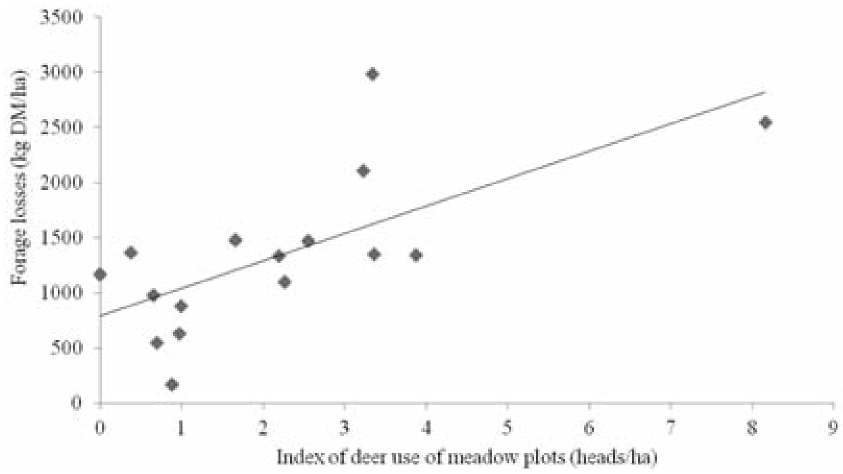

Figure 3. Correlation between index of deer use and total forage dry matter losses in meadow plots.

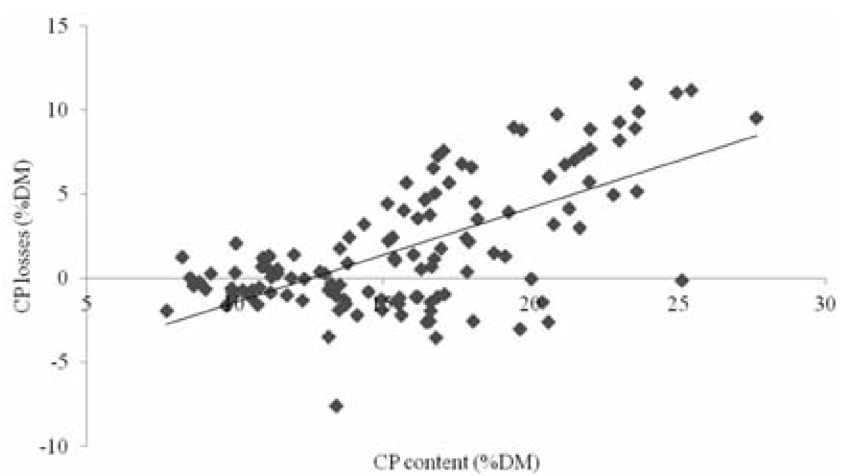

Figure 4. Correlation between crude protein (CP) content (% DM) and losses (in-out, % DM).

Wilson *et al*. (2009). There may be many reasons why losses in this study were so remarkable and did not vary between cuts and years. Red deer density in Cansiglio is high because the species, which is very sensitive to hunting disturbance (Pedrotti *et al*., 2007; Kamei *et al*., 2010), is attracted by protected areas (Pedrotti *et al*., 2007). In addition, the absence of risks to be shot while in open areas encouraged deer to use grasslands, as is also suggested by the fact that the distance from forest edge had a limited effect on forage losses. In fact, losses decreased with increasing distance in 2008 but not in 2010, most likely as a result of a progressive habituation by deer to using open areas. This might be an important implication, because other studies, which were conducted in proximity of forest edges, suggested that forage consumption by deer was higher in plots closer to cover (Trdan and Vidrih, 2008; Wilson *et al*., 2009; Kamei *et al*., 2010). Another reason for the high losses is the continuous presence of deer throughout summer. In general, in mountain areas red deer use meadows in early spring, at the beginning of grass re-growth, but then, with the advancing of summer, migrate to higher elevations where forage quality is better (Pettorelli *et al*., 2005; Luccarini *et al*., 2006; Bocci *et al*., 2010). However, in Cansiglio the density of deer is constant, or even growing, from late spring to autumn, probably because the second cut of the meadows maintains an offer of good quality forage provided by the grass re-growth (Mearns *et al*., 2007).

This study demonstrates also that red deer grazing, in addition to reducing the production of forage, might have a negative impact on its quality. The chemical composition of grass, especially for CP content, was slightly better than that observed in previous studies in the same area (Andrighetto and Ramanzin, 1987; Xiccato *et al*., 1998), but was significantly affected by deer grazing. In fact, there were no differences in CP content between the samples collected inside and outside the cages when CP content inside was around 12-13% DM, but the reduction in CP content outside reached an average of around 5% DM when CP content inside was around 20-25% (Figure 4). This effect most probably reflects a selective feeding of deer on plant species and/or morphological parts that are richer in CP content. To this regard, an increase in the proportion of grasses as respect to that of legumes in the samples collected outside the cages might explain why in these samples CP decreased while NDF did not change, since grasses are poorer in CP than legumes, while are richer in NDF. In this study the botanical and morphological compositions of the samples collected inside and outside the cages were not compared. However, based on the feeding behaviour of other deer species grazing pastures of different quality (Bryant *et al*., 1981; Weckerly, 1994), it is plausible to hypothesize that red deer in Cansiglio were able to feed more selectively when sward was younger and richer in leaves.

The results obtained in this study have also important management implications. In the most severely damaged plots, the farmers might decide to shift to pasture after the first instead than the second cut, because its labour and mechanisation costs would not be compensated by the low residual production. In addition, the loss in protein content increases the costs of forage supplementation, and might again discourage the farmers from investing in management practices designed to improve forage quality. The losses in quantity and quality of the forage produced on farm are especially negative for the organic farmers, who might be unable to fulfil the share of the forage budget that must be produced on farm as required by organic regulations (EU Regulation N. 834/2007), and, in any case, have to face higher costs when purchasing forage and supplements from the market.

Conclusions

This study confirms that high densities of red deer seriously impact on forage production by mountain meadows. In addition, demonstrates that this heavy grazing might negatively influence the crude protein content of the residual forage, most likely as a result of selective feeding by deer. These damages increase substantially production costs for the local dairy farms, and might require adjustments in management practices of meadows and in feeding strategies. The magnitude of the effects observed in this study is likely the result of a series of combined circumstances: the study area is protected and therefore attracts high densities of the species, the intensive management to which meadows are subjected maintains an offer of good quality forage throughout summer, and the forest surrounding grasslands provides cover when needed. Therefore, the findings of this study cannot be generalised to other areas where deer density is lower and human disturbance is stronger. However, red deer is rapidly expanding in many European Countries, and this, in combination with the abandoning of agriculture and the depopulation of mountain regions, will increase the presence of the species into rural areas. Hence, the occurrence of conflicts with agriculture will also increase. Finally, the study concentrated on the damages to meadows, but it is also important to stress that this problem must be addressed with an ecosystem and holistic approach. The co-existence of deer and cattle in the same meadows might cause cross-transmission of etiological agents and have sanitary implications (Gortazár *et al*., 2007). To avoid any actual and potential conflict, meadows could be fenced to exclude deer. However, this practice could be too expensive for large areas, and could not be acceptable in a Nature 2000 site because of potential impacts on other species. In addition, it would concentrate all feeding by deer in the forest, where the impacts on biodiversity are already high. Red deer culling might reduce population density, and provide an additional source of income to the local communities, but it would also reduce the touristic appeal of the area, which is now often visited especially for deer-watching, and would be strongly contrasted by part of the public opinion. In conclusion, this paper is also an example of how, in marginal areas, farming will increasingly need to be integrated into a multi-purpose ecosystem management.

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