Impact of red deer (*Cervus elaphus*) on forage crops in a protected area

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Abstract

During the last decades in Italy red deer (*Cervus elaphus*) density has locally reached very high values, with consequent serious problems due to the interaction with human activities, especially in protected areas. This study aims at quantifying the impact of red deer on herbaceous crops for forage production in a protected area in Northern Italy, that has been recently colonized by this species. To this aim, 14 exclusion enclosures on maize destined for whole plant silage production and 24 exclusion enclosures (not grazed, NG) on permanent meadows were established. For each of these sample plots (2x2 m), an adjacent control plot of identical surface area was established, freely available to red deer (grazed, G). Maize was harvested in September, whereas three grass cuts were harvested on meadows (May, July and August) and biomass production was weighed. Grass samples were collected, both in NG and in G plots, for chemical analysis. Red deer number was monthly estimated by night counts along fixed paths, using spotlights. The analysis of deer distribution allowed the distinction between two areas: High Density (HD: Northern area, with lower human disturbance, abundance of sheltered areas and an estimated deer density of 14-30 heads/km^2) and Low Density (LD: Central and Southern areas, with an estimated deer density of 0-1.6 heads/km^2). The percentage of maize plots with deer damage was significantly higher in HD than in LD area (83.3 vs 12.5%, respectively; $P<0.05$). In HD, red deer impact on maize crop was significant on plant height (NG= 250.75±47.58 *vs* G=136.87±87.90 cm; $P<0.05$) and biomass production/plant (NG=0.87±0.42 *vs* G=0.37±0.39 kg/4 m^2; $P<0.05$), whereas no significant effect was observed in LD. The percentage of plots of permanent meadows with deer damage did not differ between HD and LD areas. Significant losses were observed only in the second cut in the HD area for DM production, which was reduced by almost 14%.

The chemical composition of the meadow forages showed only slight differences between G and NG plots (CP and NDF content significantly lower in G plots). The results obtained indicate that a high

red deer density has an impact on the economic activity of farmers, particularly in term of maize losses (with estimated economic losses higher than € 20,000/farm/year), and suggest that appropriate management strategies, such as fencing of the crops at risk, are highly advisable.

Keywords: permanent meadows, maize, yield loss, crop damage, red deer.

Introduction

During the last decades in Italy red deer (*Cervus elaphus*) number has been increasing, mainly due to landscape changes and to an increased awareness and attention of people towards conservation policies, that lead to a more severe regulation of hunting activities and to a proliferation of protected areas, together with frequent interventions of restocking. The estimated red deer number stated in the last official national report (referred to 2010) was more than 67,700 heads, and in some areas local densities reached very high values (Raganella Pelliccioni et al., 2013). A similar growth in red deer number has been reported also in other European countries and in North America (Putman and Moore, 1998; Milner et al., 2006; Apollonio et al., 2010).

Due to the large body mass of this species and to its high capacity of adapting to different environments, high population densities may have serious impacts on the ecosystems and also raise problems due to the interaction with human activities, especially in protected areas, where hunting is banned and deer population control is therefore particularly difficult (Marchiori et al., 2012).

Negative effects of high deer densities have been recorded on other animal species, including both mammals (e.g. rodents, roe deer, chamois; Pedrotti and Bragalanti, 2008; Muñoz et al., 2009) and birds (e.g. capercaillie, rufous hummingbird, song and fox sparrow; Pedrotti and Bragalanti, 2008; Martin et al., 2011). Damage has also been observed on forestry and plantation woodlands (Pedrotti and Bragalanti, 2008; Rao, 2017; White et al., 2004) and natural shrubs (Martin et al., 2011).

However, what is probably perceived by man as the most negative effect of high deer densities is the impact on cultivated lands, that may have severly negative economic consequences (Delger et al., 2011; White et al., 2004). A serious impact of red deer on alpine meadows (Catorci et al., 2016) and on yield and quality of agricultural crops and of forage from permenent meadows has been documented by several authors in Italy (Pedrotti and Bragalanti, 2008; Marchiori et al., 2012) and elsewhere (Bleier et al., 2017; Trdan and Vidrih, 2008; Wilson et al., 2009). The attractiveness of cultivated fields for deer (*Rusa unicolor* and *Muntiacus muntjac*) has been confirmed also in Bhutan by Thinley et al. (2017). Furthermore, several authors report severe economic losses due to deer damage to maize (Gildorf et al., 2004; Delger et al., 2011), wheat crops (Springer et al., 2013), oats and canola crops (Sorensen et al., 2015). The intensity of damage seems to be related mainly to deer density, but partly also to other factors, such as the length of forest edge, and the proportion of cultivated fields (Bleier et al., 2012).

In Italy, the damage to agricultural land caused by wild animals has been dramatically increasing during the last years, mainly related to the progressive expansion of wild ungulate populations. According to last official national records, in Italy in 2004 the estimated damage due to wild ungulates was at least 10,300,000 € (Carnevali et al., 2009). In Lumbardy region, red deer alone was responsible for an estimated damage of 17,902 € in 2004, that raised to 48.729 € in 2011 and then declined to 29.139 € in 2012. However, for some provinces (e.g. Sondrio) the amount paid represents only a fraction of the real damage, due to limited fund availability (data provided from Lumbardy region, General Directory of Agriculture). In fact, the requests for crop damage compensations are becoming more and more difficult to be met by public administrations, and this in turn generates conflicts between farmers, managers of protected areas, and hunters. A deep knowledge of the phenomenon and of the relative risks and the identification of cost-effectiveness parameters are therefore highly required, in order to ensure greater effectiveness of public actions (Cozzi et al., 2015).

This study was carried out with the aim of quantifying the impact of red deer on herbaceous crops for fodder and maize silage production in a protected area recently colonized by the species, in order to provide objective data that can be used to support management strategies.

2. Methods

2.1 Study area

The study was conducted in the "Riserva Naturale Pian di Spagna-Lago di Mezzola", a protected area located between the provinces of Como and Sondrio, in Lumbardy region (Northern Italy). This natural Reserve was established in 1985, following its inclusion in Natura 2000 Network, in order to protect many important migratory and nesting wild bird species. It is located at the bottom of a plain alpine valley (average altitude: 200 m a.s.l.) and has a surface area of about 1,586 hectares. The mean annual temperature is 12°C (with minimum temperatures of about -10°C recorded in December-January and maximum temperatures above 36°C recorded in July-August), and precipitations range from 1,000 to 1,500 mm/year (data provided by ARPA, Regional Agency for the Protection of the Environment, 2014).

The landscape is composed of four main types of environment: water environment (open waters, i.e. Mezzola lake, and inner waters, i.e. ponds and canals, with *Ninphaea alba* and *Nuphar luteum* as prevalent plant species); wetlands (reeds, with high prevalence of *Phragmites australis*, and areas populated by *Carex spp*.); small hygrophilic woods (characterized by the presence of *Salix alba*, *Alnus glutinosa*, *Populus nigra* and *Fraxinus excelsior*); and farmlands. These agricultural areas are mainly destined for the production of forage crops and maize silage for dairy and beef cattle. Polyphite permanent meadows are mainly composed by *Achillea millefolium*, *Anthoxanthum odoratum*, *Pimpinella major*, *Plantago lanceolata*, *Poa pratensis*, *Poa trivialis*, *Ranunculus acris*, *Taraxacum officinale*, *Trifolium pratense*, and *Bromus hordeaceus*. These meadows are cut 3-4 times/year from May to September, yielding an average production of 10 tons of dry matter (DM)/hectare. Maize for silage production is harvested once a year, in September, with an average yield of 15-20 tons DM/hectare.

Wild fauna in the Reserve is represented by a wide variety of birds (mainly water fowls, partly nesting in the area and partly using it only as a resting place during migrations), reptiles (e.g. *Hyla* *intermedia*, *Tritus carnifex*, *Bufo bufo*, *Rana synklepton*), small carnivores (mainly *Vulpes vulpes*, *Meles meles*, *Martes foina*), and some small rodent species. The only important large mammal is the red deer, whose presence in the Reserve has been occasionally recorded since the beginning of this century and has become a permanent presence since 2004-2005. This species has been recently increasing in number in the Reserve, raising from a total estimated number of 25 heads in 2011 to 75 in 2014 (year in which this study was carried out).

Increasing agricultural damage by wild fauna has been recorded in the area, with consequent increasing compensation costs (from 2,377 € in 2005 to 20,000 € in 2013).

2.2 Red deer counts

Red deer number was monthly estimated from May to September by night counts (from 22:30 to 24:00 h), using strong spotlights from two off-road vehicles simultaneously driving slowly along fixed paths (Fig. 1) (Tsukada et al., 2013). Spotlight counts were carried out with the kind support of the local police of Como and Sondrio provinces.

Three census units were identified in the Reserve: North (2.92 km^2, 9.7 km traveled), Centre (1.92 km^2, 5.3 km traveled), and South (5.14 km^2, 15.0 km traveled). These three units are separated by roads with intense car traffic, that do not allow easy movements of deer from one unit to another.

2.3 Forage impact assessment

Squared exclusion enclosures of 4 m^2 (2 x 2 m), made of wire mesh, were placed in May 2014 on maize fields destined for whole plant silage production (n=14) and on permanent meadows (n=24). In order to compare the production inside and outside the exclusion enclosures, for each sample plot in enclosures (not grazed, NG) we established an adjacent control plot of identical surface area, freely available to red deer for grazing (grazed, G). Sample plots were chosen in order to be representative of the three census units, paying special attention to their location with respect to the distance from sheltered areas (reeds and woods) and from anthropic disturbance (roads and buildings) (Tables 1 and 2). We used a threshold of 120 metres to classify the distance from shelter ("close": distance < 120 metres; "far": distance > 120 metres) or from a source of anthropic disturbance ("disturbed": distance <120 metres; "undisturbed": distance >120 metres).

For maize, the exclusion enclosures were placed just after seeding. In order to avoid damage due to ravens, anti-bird protection nets were posed both in G and NG plots to protect the young plants during the initial growth phase (until they were 10-15 cm heigth). The whole plants were harvested in early September, at early dough stage. The cut was made at 20 cm from the ground. Before harvesting, the average height of the plants in the sample plots was measured and the number of plants was counted.

For permanent meadows, three cuts (May, July and August) were harvested and the biomass was weighed for each G and NG plot and samples (300 g) were collected. The grass samples were dried in a ventilated oven at 55°C until constant weight. After drying, the samples were ground through a 1-mm screen (Pulverisette 19, Fritsch). Samples were analysed for the concentrations of DM (method 945.15; AOAC International, 2005), ash (method 942.05; AOAC International, 2005), CP (method 984.13; AOAC International, 2005), NDF corrected for insoluble ash and with the addition of α-amylase (aNDFom; Mertens, 2002) and ADF (Van Soest et al., 1991), using the Ankom 200 fiber apparatus (Ankom Technology Corp., Fairport, NY).

The quality of meadows between G and NG plots was evaluated considering the difference in CP, ADF, NDF and ashes concentrations.

2.4 Statistical analysis

Due to a delay in the initial set up of the exclusion enclosures, data from the first cut of permanent meadows were not analysed.

The presence of damage was defined as a production loss of G plots higher than 10% as compared to NG plots. The frequency of plots with/without damage in High density and Low density areas (see paragraph *Red deer counts*) was compared by Fisher's exact test.

The considered variables were checked for normality of distribution using the Kolmogorov-Smirnov test and, as all variables presented a normal distribution ($P>0.05$), parametric statistics were used for data analysis. The difference between NG and G plots for both production and chemical analysis was compared by matched-pairs t test, both in High and Low deer density areas.

Furthermore, in order to test also the effect of other factors that may affect plot production, the ratio of biomass production between G and NG plots was analysed using a General Linear Model (GLM) with 3 fixed factors: deer density (2 levels: high *vs* low), anthropic disturbance (2 levels: disturbed *vs* undisturbed), distance from shelter (2 levels: far *vs* close), and the interactions between deer density and the last two factors (Proc GLM, SAS Inst. Inc., Cary, NC).

Results and discussion

Red deer counts

Red deer were present with low numbers in the Centre and South units, but they were present with high numbers and densities in the North unit (Table 3). Deer density in the North unit was very high (from a minimum of 14.0 in July up to 29.8 heads/km^2 in September), and far above the recommended densities: for example, the Provinces of Como and Sondrio suggest that densities should be below 3-6 heads/km^2. Other authors consider that, in mixed wooded and agricultural lands, deer density should not exceed 2.5 heads/km^2 (Tosi e Toso, 1992). Furthermore, the guidelines from the National Institute for Environmental Protection and Research (ISPRA)

recommend that a minimum density of 1.5 heads/km^2 should be reached before a culling plan can be allowed, and consider 10 heads/km^2 as a maximum tolerable density (Raganella Pelliccioni et al., 2013), whereas the target densities in Stelvio National Park are around 9-10 heads/km^2 (Pedrotti and Bragalanti, 2008). In the North unit of Pian di Spagna, deer density was always far above these recommended values and reached a peak of almost 30 deer/km^2 in September, at the beginning of the hunting season, when deer move to Pian di Spagna in order to find protection from hunters and use the Reserve as mating ground. The preference of deer for the North unit, rather than for the other units, is probably due to a lower human disturbance in this unit and to its proximity to the Mezzola lake, whose shores are rich in reeds, that provide a good shelter for the animals and play a protective role similar to that observed for woods in other areas (Pompilio and Meriggi, 2001).
The results of our censuses represent the minimum certain number of animals that were actually counted during night counts and should therefore be considered only as estimates. Nonetheless, the differences between the North unit and the other two units were so marked (Table 3) that they allowed to class the units as "Low density" (LD) area (including the Centre and South units, which had very similar low deer densities), and "High density" (HD) area (the North unit, with high densities). These classes were then used for subsequent analysis of deer impact.

Impact on maize

The percentage of maize plots with deer damage (production losses >10%) was significantly higher in HD than in LD area (83.3 vs 12.5%, respectively; $P<0.05$; Fig. 2). In HD area, the only plot without damage is plot n. 1, which is located far from sheltered areas and close to a railway and a concrete road with intense car traffic. These two conditions probably create an unsuitable environment for red deer. On the contrary, in LD area most of the plots were undamaged, except for plot n. 13, that had no anthropic disturbance and was close to sheltered areas (Table 1). These characteristics favoured red deer presence, thus intensifying the browsing activity on maize. This is in agreement with findings from a research carried out in Hungary, which demonstrated how damage due to wild ungulates in maize fields is usually correlated with the extension of their contact area with shelters (woods) (Bleier et al., 2012) and with their distance from cover (Bleier et al., 2017). Hinton et al. (2017) report similar results in Mississippi, where a reduced height of soybean plants close to forested field borders was observed. This may be explained by the preference of deer, as well as of other ungulate species, for the presence of sheltered areas (Pompilio and Meriggi, 2001). The effect of anthropic disturbance and distance from shelter, and of their interaction with deer density, on the ratio of biomass production between G and NG plots could not be statistically confirmed by GLM analysis, probably due to the low sample size (N=14). However, GLM clearly confirmed a highly significant effect of deer density, with lower ratios in HD than in LD areas (38.73%±9.52 *vs* 92.06%±13.83% in HD and LD areas, respectively: $P<0.01$). Particularly low ratios of biomass production between G and NG plots were observed in HD areas, especially in plots located close to shelter (27.32%±13.46 vs 50.13%±13.46 in plots close and far from shelter, respectively), although these differences were not statistically significant.

The impact of deer in the HD area is also confirmed by the significant difference between NG and G plots in terms of plant height, total biomass production and biomass/plant. In the LD area the difference between NG and G plots for plant height and biomass/plant was not significant (Table 4). However, also for this area, the total biomass production was significantly lower in G than in NG plots. This could possibly be due to some browsing effect (that reduced plant heigth, although not significantly), but also to the lower number of plants in G plots (24.9±3.1 in NG plots; 21.4±4.9 in G plots) that was assumed to be randomly distributed and not a consequence of deer browsing.

As to the type of damage, some differences were observed between HD and LD areas. In the LD area, deer damage on G plot n. 13 occurred between August and September, and was directed mainly to maize ears without compromising the development of the plants. These observations are in agreement with the progressive change in the type of damage recorded in presence of medium deer density (4.5 heads/km^2) by Bleier et al. (2017), who reported maize ear damage as the most important damage that appeared in the last part of the plant cycle, whereas in the initial phases only some browsing and tramping were observed. By contrast, in the HD area, the type of deer damage was different: deer intensively browsed maize leaves starting from the early vegetative phases (June): although this did not lead to the death of the plants, it definitively compromised their development, causing a reduced growth of the organs and, most of all, the lack of maize ear production (Fig. 3). Therefore, there was no direct deer damage on the ears, because the very high deer density in our study area did not allow the development of the ears. This resulted in the impossibility for the farmers of using the crop for silage production and eventually led to a complete loss of production in the damaged field. Maize silage is the main forage crop used in the diet of cows in plain areas (Pirondini et al., 2012), but its use is becoming progressively more and more common also in alpine areas. Alpine dairy farming changed substantially during the last 50 years from traditional, small scale, forage based dairying towards larger and more specialised dairy systems with severely reduced pasture utilization and a strong increase of maize silage and concentrate supplementation levels (Horn et al., 2013). For example, a study of Penati et al. (2009) in an alpine area of Sondrio province reports that about 77% of farms (24 out of 31 surveyed farms) used self-produced maize silage with an amount ranging from 5 to 28 kg/cow/day. Similarly, Guerci et al. (2014) report an average total land area of 77 ha for farms located in lowland alpine areas (Sondrio province); in these farms, the surface cultivated with maize was on average 11.1 ha. Assuming an economical value of maize silage of € 46/t (Clal, 2017) and an average maize silage yield of 40 t/ha, in HD areas the annual loss would exceed € 20,000 per farm.

Impact on permanent meadows

The production of permanent meadows showed a great range of variability among plots, probably due to different floristic composition and to environmental conditions (e.g. presence of shadow provided by the surrounding trees).

The percentage of plots of permanent meadows with deer damage (production losses >10%) did not differ between HD and LD area, neither in the second (14.3 vs 23.1%, respectively) nor in the third cut (33.3 vs 23.1%, respectively).

Deer impact was less evident on permanent meadows than on maize crops and only partially dependent on deer density: no significant production differences between G and NG plots were recorded in the LD area in both cuts, nor in the HD area in the third cut (Table 5). Statistical analysis on the ratio of biomass production between G and NG plots in the two cuts confirmed the absence of significant differences depending on deer density, presence of anthropic disturbance, distance from cover, and on their interactions. However, significant production losses were observed in the second cut in the HD area for total DM production (Table 5), that was reduced by almost 14%. Similar losses (15%) were recorded in South-Western England as a consequence of red deer grazing (Wilson et al., 2009), and also in Quebec, where 12-18% of crop losses in hay fields were attributed to deer (Richer et al., 2005). A much higher impact of red deer was observed in Slovenia (average losses of about 50%, with peaks of 80%; Trdan and Vidrih, 2007), in a protected area in Como Province (Riserva Naturale Lago di Piano, where losses ranged from 10% in high quality meadows up to 50% in low quality meadows; Alghisio, 2009), in another protected area in North-Western Italy (Pian del Cansiglio, where production losses were 15-25% in the first cut and raised up to 25-50% in the second cut; Marchiori et al., 2012), and in the Italian Stelvio National Park (with losses ranging from 21% to 32%; Pedrotti and Bragalanti, 2008). In our study area, the low impact on meadows is probably due to the presence of alternative crops, such as maize, that can be browsed rather than grazed by red deer. In fact, according to Mátrai et al. (2013) the diet of red deer is dominated by browses.

According to Guerci et al. (2014), the average surface of permanent grassland in lowland alpine farms in Sondrio province (where the study area is located) is 18.3 ha. Considering both these values (grassland surface and average DM loss), the loss of grass due to deer grazing from permanent meadows would be about 300 kg DM/ha, which corresponds to a total annual loss of 5.5 t DM/farm. Given the average price of grass hay (€ 165/t; Borsa Granaria Milano, 2017), this corresponds to an economic annual loss of approximately € 1000/farm.

Deer grazing had almost no effect on meadow quality (Table 6), except for a significant reduction of the percentage of CP in the LD area in the second cut and of NDF in G plots of the LD area in the third cut. A reduction of the percentage of CP in grazed areas was observed also by Marchiori et al. (2012) but, contrarily to the results by these authors, in our case this reduction does not seem to be correlated with the CP content inside the exclusion encolsures. CP requirements are particularly high for hinds in early summer (June–July, corresponding to the time of the second cut), that in Italy for red deer corresponds to late pregnancy/early lactation stage (Mattiello et al., 2007). We can hypothesise that in LD area deer had the possibility to be more selective than in the HD area, thus choosing the most nutritious parts of plants, and this resulted in a lower CP content in G than in NG plots.

The lower NDF values recorded in the third cut of the LD area in G plots are not easy to explain. However, it is interesting to notice that a reduction of NDF in G plots, although not significant, was observed also in both cuts of the HD area. This was probably due to the effect of grazing, that favoured the regrowth of new grass, thus limiting the accumulation of fibrous material. Overall, it has to be underlined that the average quality of meadwos (in terms of CP and NDF) was comparable to that reported by Borreani et al. (2005) for grass hays collected in the same area (Sondrio province).

Conclusions

In Pian di Spagna Natural Reserve a high red deer density is the main factor affecting herbaceous crops for grass and maize silage production, particularly in term of maize damage, and this may lead to considerable economic losses for the farmers. As reported by Penati et al. (2013), enhancing feed self-sufficiency seems to be the best strategy to improve ecological performances of dairy farms while maintaining their profitability in alpine areas. Our results confirm that deer density can have a pronounced effect on maize crops, whereas the impact on permanent medows was always low and only partially dependent on deer density. Although some damage may occur on permanent meadows, this damage may be limited by the presence of more palatable crops, such as maize, that seem to be preferred by deer and whose presence is correlated with the volume of damage (Bleier et al., 2012). The scarce differences in quality parameters recorded between G and NG plots suggest also that the limited use of meadows is usually not highly selective, except when nutritional demands are particularly elevated. Overall, where possible, diets based on local forage resources (particularly permanent grassland) should be preferred to maintain the link with the territory.

The objective data provided by the present research highlight the need of setting up specific prevention plans and may serve as a useful support tool to guide management decisions. For example, electric fences can be effectively employed for the reduction of deer damage (Mori and Galardi, 2002; Johnson et al., 2014); however, fences can limit wildlife movements, and their installation could be quite expensive (Marchiori et al., 2012). In order to limit the disturbance to wildlife and to optimise the financial resources, according to our results, fencing might be focused mainly on the protection of maize fields, starting from their initial development phases, and should be concentrated on the fields close to sheltered areas and far from human disturbance. Such a fencing strategy could yield effective results, and may represent a viable alternative to culling plans that may not be well accepted by the general public in a protected area.

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Conflict of interest

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Table 1. Characteristics of maize sample plots, depending on anthropic disturbance and presence of shelter.

Sample plot	Census unit	Anthropic disturbance	Presence of shelter
1	North	yes, high	far
2	North	no	far
3	North	yes, low	far
4	North	no	close
5	North	no	close
6	North	yes, high	close
7	Central	yes, low	close
8	Central	yes, low	close
9	Central	yes, high	close
10	South	yes, low	far
11	South	no	close
12	South	yes, high	far
13	South	no	close
14	South	yes, high	far

*Anthropic disturbance: high = busy farm roads, concrete roads, railway; low = farm roads, buildings.

Table 2. Characteristics of permanent meadow sample plots, depending on anthropic disturbance and presence of shelter.

Sample plot	Census unit	Anthropic disturbance*	Presence of shelter
1	North	yes, high	far
2	North	yes, low	far
3	North	yes, high	far
4	North	no	far
5	North	yes, high	close
6	North	no	close
7	North	no	close
8	North	no	far
9	North	yes, low	close
10	North	yes, high	far
11	Central	yes, low	close
12	Central	yes, low	far
13	Central	no	far
14	Central	no	close
15	South	yes, high	close
16	South	no	close
17	South	yes, low	far
18	South	no	close
19	South	yes, low	close
20	South	no	close
21	South	no	close
22	South	yes, high	far
23	South	yes, high	close
24	South	no	close

*Anthropic disturbance: high = busy farm roads, concrete roads, railway; low = farm roads, buildings.

Table 3. Red deer numbers and densities per surface area (deer/km^2) and per traveled km (deer/km) obtained from night spotlight counts in each of the three census units.

	North (High density)			Centre (Low density)			South (Low density)		
	N. of animals	Deer/km^2	Deer/km	N. of animals	Deer/km^2	Deer/km	N. of animals	Deer/km^2	Deer/km
May	49	16.8	5.1	0	0	0	3	0.6	0.2
June	52	17.8	5.4	0	0	0	1	0.2	0.2
July	41	14.0	4.2	0	0	0	6	1.2	0.4
August	77	26.4	8	3	1.6	0.3	7	1.4	0.5
September	87	29.8	9	3	1.6	0.3	7	1.4	0.5

Table 4. Production variables for maize Not Grazed (NG) and Grazed (G) plots (4 m^2) in High density (HD) and Low density (LD) areas, difference between NG and G plots and relative significance level (matched-pairs t test).

Area	**Variable**	**NG plots**	**G plots**	**Difference NG – G plots**	**Signif.[a]**
HD (n=6)	Plant height (cm)	250.75±47.58	136.87±87.90	113.87±71.94	*
	Biomass production/plant (kg)	0.87±0.42	0.37±0.39	0.49±0.38	*
	Total biomass production/plot (kg)	20.00±9.63	6.75±6.10	13.25±8.92	**
LD (n=8)	Plant height (cm)	273.44±43.81	266.25±53.82	7.19±13.85	n.s.
	Biomass production/plant (kg)	0.88±0.44	0.86±0.45	0.02±0.04	n.s.
	Total biomass production/plot (kg)	22.12±11.00	18.60±9.46	3.52±2.57	**

[a] Significance level: n.s.=not significant; *=P<0.05; **=P<0.01.

Table 5. Biomass production (total production and DM production) in the second and third cut for permanent meadow Not Grazed (NG) and Grazed (G) plots (4 m^2) in High density (HD) and Low density (LD) areas, difference between NG and G plots and relative significance level (matched-pairs t test).

Area	**Variable**	**NG plots**	**G plots**	**Difference NG – G plots**	**Signif.[a]**
		Second cut			
HD (n=7)	Biomass production/plot (kg)	3.21±0.64	2.97±0.99	0.24±0.56	n.s.
	Biomass production/plot DM (kg)	0.86±0.17	0.74±0.21	0.12±0.12	*
LD (n=13)	Biomass production/plot (kg)	2.60±1.15	2.48±0.99	0.12±0.37	n.s.
	Biomass production/plot DM (kg)	0.66±0.30	0.65±0.30	0.01±0.07	n.s.
		Third cut			
HD (n=9)	Biomass production/plot (kg)	4.28±0.61	3.87±0.92	0.41±.059	n.s.
	Biomass production/plot DM (kg)	0.92±0.13	0.86±0.16	0.05±0.09	n.s.
LD (n=13)	Biomass production/plot (kg)	2.75±1.31	2.62±1.25	0.12±0.31	n.s.
	Biomass production/plot DM (kg)	0.60±0.29	0.56±0.25	0.04±0.09	n.s.

[a] Significance level: n.s.=not significant; *=P<0.05.

Table 6. Chemical compositon of the second and third cut of permanent meadows for Not Grazed (NG) and Grazed (G) plots (4 m^2) in High density (HD) and Low density (LD) areas, difference between NG and G plots and relative significance level (matched-pairs t test).

Area	Variable	NG plots	G plots	Difference NG – G plots	Signif.[a]
		Second cut			
HD (n=7)	CP (% on DM)	13.10±1.53	13.61±1.39	-0.51±1.32	n.s.
	ADF (% on DM)	38.43±1.15	38.49±1.51	-0.06±1.51	n.s.
	NDF (% on DM)	58.02±5.39	56.97±5.10	1.05±3.82	n.s.
	Ashes (% on DM)	10.61±1.09	9.76±0.66	0.85±1.33	n.s.
LD (n=13)	CP (% on DM)	13.74±1.51	12.94±1.55	0.79±1.67	*
	ADF (% on DM)	40.32±2.72	40.06±2.81	0.25±1.28	n.s.
	NDF (% on DM)	58.89±5.28	59.34±4.27	-0.45±2.96	n.s.
	Ashes (% on DM)	10.69±1.56	10.10±1.63	0.59±0.96	n.s.
		Third cut			
HD (n=9)	CP (% on DM)	16.43±2.05	16.22±2.82	0.21±2.06	n.s.
	ADF (% on DM)	37.99±2.36	38.20±3.19	-0.21±2.92	n.s.
	NDF (% on DM)	58.49±2.85	56.83±2.82	1.66±3.69	n.s.
	Ashes (% on DM)	12.06±1.90	13.07±1.93	-1.00±1.89	n.s.
LD (n=13)	CP (% on DM)	16.61±2.55	15.48±2.76	1.13±2.65	n.s.
	ADF (% on DM)	37.94±1.57	37.11±2.22	0.83±1.85	n.s.
	NDF (% on DM)	59.29±4.11	56.86±4.54	2.43±1.67	***
	Ashes (% on DM)	11.96±2.60	12.51±2.02	-0.55±2.25	n.s.

[a] Significance level: n.s.=not significant; *=P<0.05; ***=P<0.001.

Figure 1. Location of fixed paths used for spotlight counts in the three census units (North, Centre and South), within the Pian di Spagna-Lago di Mezzola Natural Reserve.

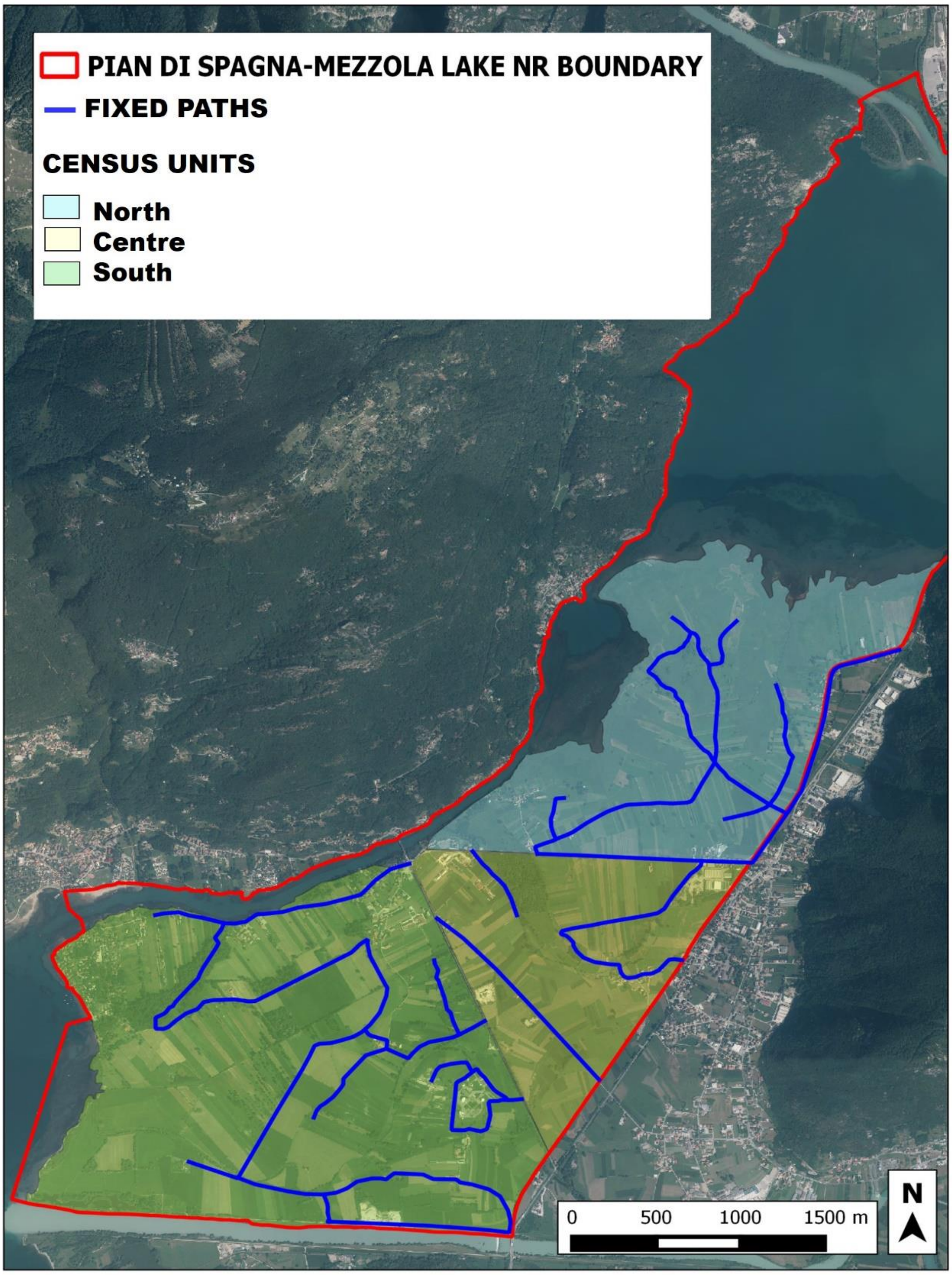

Figure 2. Location of the damaged and undamaged maize sampling plots in areas with high and low deer density, within the Pian di Spagna-Lago di Mezzola Natural Reserve.

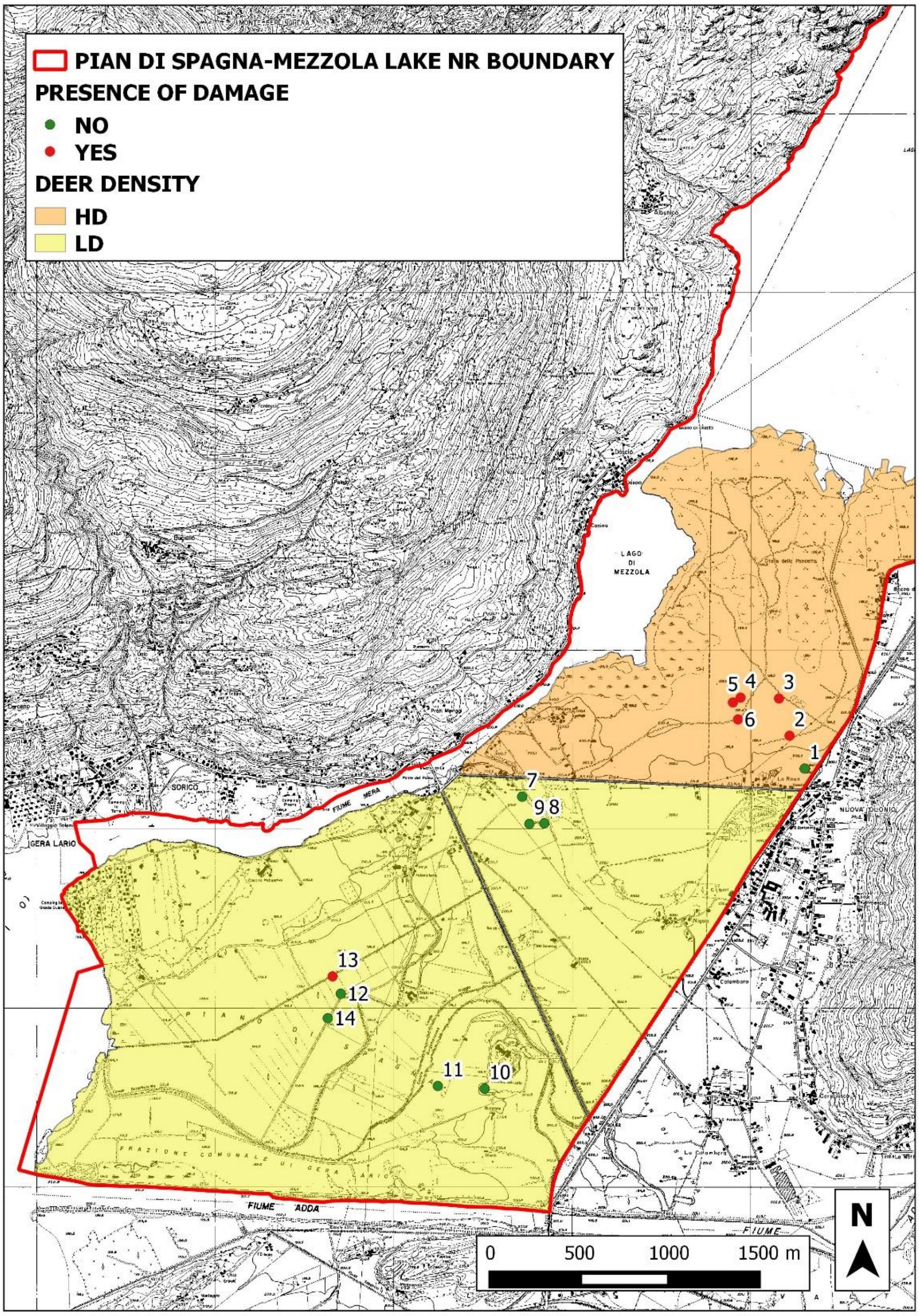

Figure 3. Example of deer damage in the high density area: deer intensively browsed maize leaves starting from the early vegetative phases and definitively compromised their development, causing a reduced growth of the organs and the lack of maize ear yield.