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Research Article

The Mesola red deer: present numbers and conservation perspectives

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Abstract

Most likely, the red deer *Cervus elaphus* of the Mesola Wood (about 1000 ha; NE Italy) are the only native red deer of peninsular Italy and are a national conservation priority. This population shows morphological and genetic peculiarities and is threatened because of its very small distribution range, low numbers, reduced genetic variability and interspecific competition with allochtonous fallow deer *Dama dama*.

In this paper an assessment is provided of red deer numbers and of relative densities of fallow deer, to evaluate the effects of conservation actions during the last 15 years (e.g. culling of fallow deer, supplementary feeding) on the status of the former. Between July and October 2010, 148 red deer were counted, with a balanced sex-ratio. Red deer productivity was low: the birth rate in 2010 was 0.28 and the post-winter-recruitment in 2011 was 0.21 calves/adult female. Apart from calves, yearlings were about 10% of individuals, in both sexes. Red deer were concentrated in the small (ca. 100 ha) sector of the study area where supplementary feeding is provided. By contrast, fallow deer showed a greater productivity (0.52 fawns/female) and a relatively more homogeneous distribution in the study area than the red deer. The monthly spatial overlap between red deer and fallow deer was almost complete (Pianka index > 0.92) across sectors where no supplemental feeding is provided, suggesting a great potential for competition between our study species.

In the last decade, the Mesola red deer have more than doubled, suggesting the favourable effect of management measures on their conservation status. The gradual decline of both productivity and the annual finite rate of increase may indicate that the population is close to the carrying capacity of the Reserve. The culling of fallow deer should go on to decrease the impact of this deer on natural food resources of red deer and to reduce the dependence of the latter from supplementary feeding.

Introduction

Most likely, the red deer *Cervus elaphus* living in the Natural Reserve "Bosco della Mesola" (BMNR; central northern Italy) are the only native red deer of peninsular Italy (Castelli, 1941; Mattioli, 1990; Mattioli et al., 2001) and constitute a population of great relevance for zoogeography, ecology, conservation and local cultural perspectives (Lovari and Nobili, 2010). In the Italian Peninsula only this population of

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red deer may have survived deforestation and persecution by man, living in a small forest in the Po delta area (Mattioli et al., 2003). These deer show some morphological peculiarities: small body size, reduced sexual dimorphism, persistent spotting in the summer coat, small antlers of simplified design, low reproductive performance (Mattioli, 1990, 1993a,b; Mattioli et al., 2003, 2001).

The Mesola red deer have been defined as "maintenance dwarfs with paedomorphic antlers" (Geist, 1998) and their small body size, their low sexual dimorphism and their simple antlers are thought to be related to the scarsely productive coastal submediterranean woodland on sandy soil (Mattioli, 1993a; Mattioli et al., 2003). In addition, the population shows a mitochondrial DNA genotype with a sequence significantly different from those of all other populations of red deer (Hmwe et al., 2006; Lorenzini et al., 2005), suggesting that it represents an independent unit of conservation (Moritz, 1994), which deserves conservation measures (Zachos and Hartl, 2011).

The Mesola red deer is seriously threatened (Lorenzini et al., 1998; Lovari and Nobili, 2010; Mattioli et al., 2003; Zachos et al., 2009; Zachos and Hartl, 2011). Its very restricted distribution range (1058 ha), small numbers (67 individuals in 1999, Mattioli et al. 2003; 120 individuals in 2006, Mattioli et al. 2007) and its low birth and recruitment rates (0.27-0.37 and 0.17-0.35 calves/adult female in 1994-1998, respectively, Mattioli et al. 2003) make this deer vulnerable to stochastic events (e.g. catastrophic episodes like floodings, fires, diseases; Zachos et al. 2009). Reproductive isolation, persistence at small numbers (Mattioli et al., 2003), bottlenecks and genetic drift contributed to determining a very low genetic variability (Lorenzini et al., 1998), which exposes the population to risks of inbreeding depression (Zachos et al., 2009). In addition, since the end of the Renaissance, the Mesola red deer have been almost uninterruptedly coexisting with the fallow deer *Dama dama*. Interspecific competition with fallow deer is considered to be a great threat for the survival of the Mesola red deer: in 1980-1999, while the population of the latter neared extinction, the population of the former fluctuated between 300 and 1000 individuals, with densities of 32-105 ind/100 ha (Mattioli et al., 2003). In 2008, despite a yearly removal of about 250-300 fallow deer, the population of this deer has been estimated at approximately 900 head (Lovari and Nobili, 2010). This considerable biomass of competitors has presumably exploited the food resources used by red deer, with the depletion of ground flora and of the understorey shrub layer (Mattioli et al., 2003).

In the last 15 years, conservation measures have been implemented (e.g. culling of fallow deer, recurrent mowing in the pastures, reseeding of pastures and winter supplementary feeding; Mattioli et al. 2003), which has led to some encouraging results: between 1994 and 1999, the population size of Mesola red deer increased, their physical conditions improved, calf and adult mortality declined and a few cases of antlers with bez tine or crown were reported after four decades of absence (Mattioli et al., 2003).

More recently, a National Conservation Plan for the Mesola red deer has been promoted under the aegis of the Italian National Forestry Service and the Italian Ministry of Environment (Lovari and Nobili, 2010) to assess threats for the survival of this population and to suggest urgent conservation measures (e.g. creation of alternative populations through reintroductions, intensive culling of fallow deer, habitat improvements in the BMNR).

A new assessment of population size and structure of Mesola red deer was needed, to evaluate possible effects of management actions implemented recently (e.g. fallow deer reduction by culling, improvement of pastures and supplementary feeding; Lovari and Nobili 2010). The aims of our study have been: (i) to assess minimum numbers, population structure and reproductive rates of the Mesola red deer and to compare them with the demographic parameters of 1999 (cf. Mattioli et al. 2003); (ii) to estimate relative densities of both the red deer and the fallow deer, both to investigate the spatial variation of densities of the two species and to obtain abundance indices useful as reference values for future monitoring.

Table 1 – Size of sectors partitioning the study area. Two out of 6 sectors allowed movements of deer, thus were pooled together.

Sector	Area (ha)
A	116.7
B	226.5
C	134.0
D	354.4
E (“Elciola”)	104.8
Total	936.4

Methods

Study Area

The BMNR (1058 ha) is an enclosed area managed by the Italian National Forestry Service. Our study has been carried out in a large part of the study area (936 ha) accessible to both deer species. This area is composed of woodland (93%, mainly holm oak *Quercus ilex* with manna ash *Fraxinus ornus*, hornbeam *Carpinus* spp., Caucasian ash *Fraxinus oxycarpa*, pedunculate oak *Quercus robur*, aspen *Populus* spp. and elm *Ulmus* spp.), wetland (4%) and grassland (3%: dry and wet meadows, glades and artificial pastures; Mattioli et al. 2003). Fallow deer were introduced first in the 16th century and again between 1957 and 1965, after having been exterminated during World War II (Mattioli et al., 2003). Between 2000 and 2004, the BMNR has been divided into 6 sectors (Tab. 1) by temporary wire fences 2-2.5 m high to facilitate culling of fallow deer. Fences were present during all the study period and will be removed after culling operations will be completed. Culling has been concentrated in single areas, which hopefully will progressively be freed from fallow deer and will be made accessible only to the red deer (Lovari and Nobili, 2010). Presently, culling takes place between mid-September and March. Five sectors are almost completely wooded, while sector E (“Elciola”) has a wood cover of 76%, with meadows extending to 16.5% and an artificial lake on 7.5% of its surface. From November to April and sometimes also in July and August, supplemental feeding is provided daily to red deer in three artificial stations in sector E (Lovari and Nobili, 2010). Except for periodic mowing in the pastures to increase food availability for red deer, no habitat modification occurred in the BMNR in the last 15 years (Lovari and Nobili, 2010; Mattioli et al., 2003).

Deer counts

In the BMNR, red deer are used to human presence. Thus it is easy to observe and count them (Mattioli, 1990; Mattioli et al., 2003). Both red and fallow deer were counted from a vehicle along fixed itineraries, at dawn and dusk (Mattioli, 1990; Mattioli et al., 2003). Itineraries (total length = 39.2 km) covered homogeneously each sector of the BMNR (0.04-0.05 km/ha). Counts were replicated 2 times/month between July and October 2010 (once at dawn and once at dusk), for a total of 8 sessions/sector. During each session, number, sex and age class was recorded for both red and fallow deer. Size and shape of antlers of Mesola red deer males differ greatly among individuals (Mattioli et al., 2003): size, shape and number of tines of antlers were noted down, to allow individual recognition of red deer stags (Mattioli et al., 2003). For both deer species, age classes were defined as: adults ($>$ 4 years old), subadults (2-4 years old), yearlings (1 year old), for males; adults ($\geq$ 2 years old) and yearlings (1 year old) for females; calves or fawns (0 year old). Age classes were estimated by considering body size, body shape and proportions, as well as antler size and structure (Mattioli, 1990, 1992; Mattioli et al., 2003). Particular attention was paid to avoid double counts, e.g. by conducting counts in the same day in sectors not impermeable or counting as 1 individual those red deer males with similar antler shape and size, observed in different days in different, not impermeable, sectors.

Minimum numbers of red deer were estimated by considering the maximum number of individuals observed in the same session, for each sex or age class/sector. For both deer species, population structure was estimated. For the red deer, minimum birth rates (i.e. the ratio between the maximum number of calves observed at the same time to the maximum number of adult females) were also estimated. Since fallow deer were culled in the months preceding data collection, they were frequently scared by the observer and it was often difficult to reliably distinguish adult and yearling females. Thus, for the fallow deer, the birth rate was estimated by the ratio of the number of fawns to the number of all females, including 1-year old individuals. We estimated this ratio for red deer also, to compare it to that of fallow deer. For the red deer, the mean annual finite rate of increase ($\lambda = e^r$; Caughley 1977) was calculated by comparing the population size during this study with past figures (1997-1999, i.e. after the beginning of fallow deer culling , Mattioli et al. 2003; 1999-2006, Mattioli et al. 2007), to assess the population dynamics and the productivity of the population of Mesola red deer in the last decade.

For both deer species, relative densities were assessed in each sector, through a kilometric index of abundance (KAI; Acevedo et al. 2008; Maillard et al. 2001; Meriggi 1989), where: deer density = maximum number of individuals observed in the same session / km driven in the sector. When itineraries were at the boundary of a sector, thus allowing a view of only one side of them, the half of their length was considered in formulas. Monthly KAI values were also estimated at the study area scale, with: deer density = sum of individuals observed in each sector / sum of km driven in each sector. Interspecific comparisons of KAI of red deer and fallow deer are not advisable, as both the mobility and detectability are different between species (e.g. influenced by culling, for the fallow deer, or by supplementary feeding, for the red deer).

Between July and October, we estimated the monthly spatial overlap between the fallow deer and the red deer across sectors where no supplemental food is provided, through the Pianka index (Pianka, 1974):

$$O_{FR} = \frac{\sum_{i=1}^{N} O_{iF} O_{iR}}{\sqrt{\sum_{i=1}^{N} O_{iF}^2 \sum_{i=1}^{N} O_{iR}^2}} \quad (1)$$

where N is the number of sectors, O_{iF} and O_{iR} denote the proportion of fallow deer and red deer individuals observed in the i^{th} sector, excluding the "Elciola" sector.

Counts were repeated in February, March and May 2011, to assess the minimum number of red deer calves surviving throughout the winter (i.e. the maximum number of calves observed at the same time) and the recruitment rate of red deer (i.e. the maximum number of calves observed at the same time / the maximum number of adult females).

Results

Red deer numbers

Between July and October 2010, 148 red deer were counted (55 males, 74 females, 19 calves). In 1999-2010, the mean annual finite rate of increase was 7.4% (λ = 1.074). The average annual increase was 8.7% in 1999-2006, and 5.4% in 2006-2010 (cf. Mattioli et al. 2003, 2007).

Table 2 – Population structure of Mesola red deer (N = 148 individuals; July-October 2010). Subadult individuals were considered only for males.

	Males	Females
Calves	19	
Yearlings	6	6
Subadults	18	
Adults	31	68

In 2010, the minimum birth ratio was 0.28 calves/adult female and the sex ratio (males : females) was 1 : 1.3. Fifty-six percent of males were adults, 33% were subadults and 11% were yearlings (Tab. 2). Ninety-two percent of females were adults and 8% were yearlings (Tab. 2). Neither the sex ratio nor the birth rate differed significantly between "Elciola" and the other sectors pooled (Chi-square test: χ^2 = 1.453, df = 1, p = 0.228, for the sex ratio; χ^2 = 0.647, df = 1, p = 0.421, for the birth rate). In February-May 2011, 14 individuals < 1 year old were counted, indicating a minimum survival rate of 0.74 for calves and a recruitment rate of 0.21 calves/adult female.

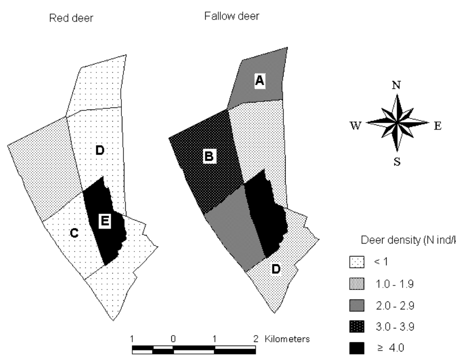

Figure 1 – Spatial variation of relative densities (N ind/km) of Mesola red deer and fallow deer, in sectors partitioning the BMNR, estimated by direct counts: mean values of monthly estimates (July-October 2010).

Relative densities were the greatest in the sector E ("Elciola": monthly KAI values were 16-84 times greater than those recorded in the other sectors; Figg. 1-2). In each session, 82-94% of red deer sightings occurred in the "Elciola" sector. In particular, in each session, 90%-100% of female sightings and 56-91% of male sightings occurred in this area (Fig. 3), respectively, suggesting that especially red deer

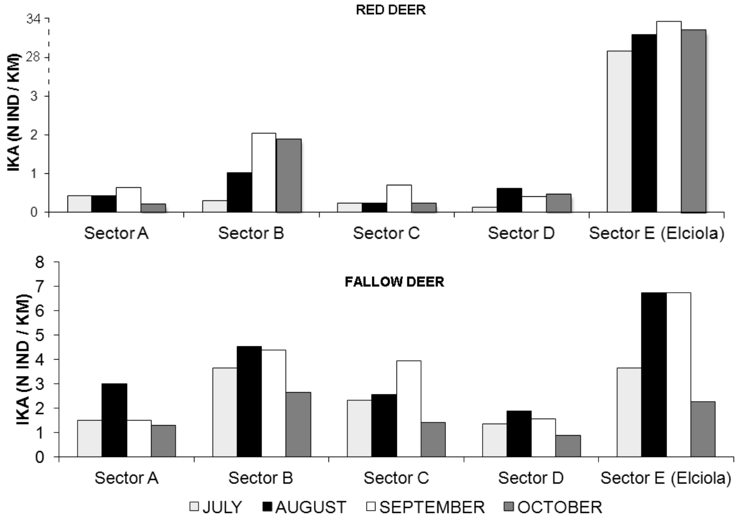

Figure 2 – Monthly variation of relative densities (N ind/km) of Mesola red deer and fallow deer, in sectors partitioning the BMNR, estimated by direct counts (July-October 2010).

hinds aggregated at patches where supplementary food was provided.

In all sectors, monthly KAI values increased in September and tended to decrease in October, but for the sector D (Fig. 2). At the study area scale, monthly KAI values were the greatest in September (2.95 ind/km) and the lowest in July (2.20 ind/km; Tab. 3).

Table 3 – Relative densities (N individuals/km) of Mesola red deer and fallow deer in the BMNR between July and October 2010.

	Jul.	Aug.	Sept.	Oct.
Red deer	2.20	2.65	2.95	2.77
Fallow deer	2.19	3.15	2.95	1.49

Fallow deer numbers and overlap with red deer

In July-October, a nearly balanced sex ratio was found (1 : 1.1, without fawns). Fawns were 21% of all individuals and the ratio among number of fawns and number of females (including 1-year old females) was 0.51. This ratio was approximately two times greater than that red deer (0.26 calves/female), but this difference only approached significance (Chi-square test: χ^2 = 3.194, df = 1, p = 0.074). Among males (minimum N = 50), 34.8% were adults, 32.6% were subadults and 32.6% were yearlings.

As for the red deer, relative densities were the highest in the “Elciola” sector (Figg. 1-2). Monthly KAI values tended to increase in August-September and to decrease in October, after the start of culling (Fig. 2). At the study area scale, monthly KAI values were the highest in August (3.15 ind/km) and the lowest in October (1.49 ind/km; Tab. 3). Out of the “Elciola” sector, the monthly spatial overlap with the red deer was almost complete (Pianka index: O_{FR} = 0.923, July; O_{FR} = 0.963, August; O_{FR} = 0.948, September; O_{FR} = 0.956, October).

Discussion

In the last decade, the population size of Mesola red deer of the BMNR have increased at least by 121%, from minimum 67 (1999: Mattioli et al. 2003) to minimum 148 individuals (2010: present study). In the late summer 2011, 30 calves were observed in the “Elciola” sector (G. Nobili, *pers. comm.*). In December 2007-February 2008, 12 individuals were moved to a small (ca. 110 ha), fenced part of the BMNR (G. Nobili, *pers. comm.*), not included in this study. These individuals were taken from “Elciola” (N = 1) and from another enclosure, which contained only these individuals, originating from founders born in “Elciola”. This small group

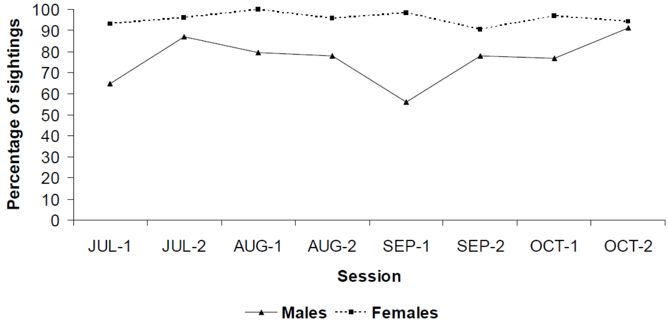

Figure 3 – Percentage of sightings of Mesola red deer males and females in the sector E (Elciola), during each session of counts.

is actually reproducing (2 calves, apart from 4 females and 2 males, were observed in October 2010, FF *pers. obs.*), which suggests that the total population size of Mesola red deer is approaching 200 individuals. Supplementary feeding and culling of fallow deer have presumably favoured the numerical increase of red deer (cf. Mattioli et al. 2003). However, the average rate of increase of the population of Mesola red deer has not been constant over years, and tended to decline in the last decade, being 10.4% in 1997-1999 (i.e. after the beginning of fallow deer culling, Mattioli et al. 2003), 8.7% in 1999-2006, and 5.4% in 2006-2010. Our results suggest that the increase of the population was relatively high after starting of management measures in 1994 (Mattioli et al., 2003), but it has gradually decreased throughout the years. Our counts give an estimate of minimum numbers of red deer, which could be an underestimate of actual population size as not all individuals may be counted. However, our aims were (1) to obtain an estimate of minimum numbers and of the population parameters of red deer, and (2) to compare our estimates with counts carried out in 1997-1999 and in 2006, through the same method (Mattioli et al., 2003, 2007). Thus, most likely, the method we have used did not affect our conclusions.

The fallow deer has a large feeding (Hofmann, 1989) and habitat flexibility (it may use open habitats, e.g. fields, pastures and open wood, but also dense Mediteranean scrubwood; Apollonio et al. 1998; Batcheler 1960; Ferretti et al. 2011a), high reproductive rates, which are apparently insensitive to density-dependence (Putman et al., 1996), does not seem to be affected by densities of other ungulates (Ferretti et al., 2011a,b; Imperio et al., 2012) and is gregarious (e.g. Apollonio et al. 1998). In addition, the fallow deer can show aggressiveness to other deer species, at feeding contexts (in captivity, to red deer: Bartoš et al. 1996 and to axis deer *Axis axis*: McGhee and Baccus 2006); in the wild, to roe deer *Capreolus capreolus*: Ferretti et al. 2011b and to white-tailed deer *Odocoileus virginianus*: Bartoš et al. 2002).

Overlap in diet and habitat use has been recorded with the red deer (e.g. Putman 1996) and with the roe deer (e.g. Ferretti et al. 2011a; Putman 1996). Negative relationships have been shown between the densities of fallow deer and those of roe deer (Ferretti et al., 2011b; Focardi et al., 2006; Putman and Sharma, 1987), as well as those of red deer (Carranza and Valencia, 1999). Not surprisingly, in the BMNR, the culling of 250-300 fallow deer/year in the last decade was accompanied by an increase in population size of Mesola red deer (Mattioli et al., 2003).

The present study confirms two concerns for the population of Mesola red deer (Mattioli, 1990; Mattioli et al., 2003). First, the birth and recruitment rates recorded in 2010-2011 were still low (0.28 and 0.21 calves/adult female, respectively) and were 25% and 39% lower than those recorded in 1997-1999, respectively (birth rate: 0.37; recruitment rate: 0.35; Mattioli et al. 2003). Accordingly, the proportion of young individuals is low (9% of 1-year old individuals, for males; 8% for females): these values fall in the range found by Mattioli (1990), in 1982-

1986 (4-17%, for males; Mattioli 1993b) and are lower than those suggested for stable populations of red deer (15%; Bubenik 1984, 1986). These results need to be confirmed by a long-term, standardized collection of data, even if birth rates may have also been low in 2009 (only 12 yearlings were counted in 2010, with a ratio of 0.18 yearlings/adult female). Second, the distribution of red deer in the BMNR is strongly influenced by the supplementary feeding: monthly relative densities were up to 84 times greater in the small "Elciola" sector (ca. 100 ha, where artificial feeding stations are placed) than in the other sectors, where the red deer shares natural food resources with the fallow deer. Mesola red deer clumped together where they found artificial food (even if population structure appeared not to differ between "Elciola" and the other sectors): there, with respect to 1997-1999, a density-dependent decrease in productivity may have occurred (Mattioli et al. 2003; cf. Clutton-Brock et al. 1982; Creel and Creel 2009), with a few dominant females monopolizing the access to food resources, thus growing enough to reproduce. In addition, the present density of red deer is high (> 15 ind/100 ha, in the whole BMNR; ca. 100 ind/100 ha, in the "Elciola" sector; cf. Mattioli 2003) and the number of red deer may be close to the carrying capacity of the BMNR, which could explain the reduction in population increase and productivity with respect to 1997-1999.

So far, no study could demonstrate the existence of competition between the fallow deer and the red deer. We found an almost complete spatial overlap between fallow deer and red deer across sectors where no supplemental feeding is provided, also in summer months (i.e. the limiting season, in Mediterranean areas, cf. Massei et al. 1997), which suggests a great potential for competition between them. One may expect that the former (c. 900 ind in c. 900 ha, in 2008, Lovari and Nobili 2010) could have a negative impact on food resources of the latter (Mattioli et al., 2003). Through grazing and browsing, fallow deer could deplete the turf, in grassland, and remove most of the ground flora and the understorey shrub layer, suppressing tree regeneration, in wood (Mattioli et al., 2003). Assuming a mean daily intake of 4.5 kg of green forage per fallow deer (Mattioli et al., 2003), a daily consumption of about 4 tons of vegetation could be estimated. The great spatial overlap recorded between fallow deer and red deer in sectors where no supplementary feeding is provided, the observed high productivity of fallow deer and their potential rate of increase of about 20% / year make urgent the implementation of their removal plan. The numerical reduction of fallow deer will decrease its competitive pressure on Mesola red deer, that could use all the Reserve and reduce their dependence from supplementary feeding. By contrast, the effects of environmental improvements (e.g. mowing in the pastures, reseeding, opening of clearings in the wood) are expected to vanish under the impact of high densities of fallow deer (ca. 100 ind/100 ha still in 2008; Lovari and Nobili 2010). Any benefit of environmental improvements for the red deer will be ineffectual, without the concurrent significant decrease (possibly, demise) of fallow deer numbers.

In the BMNR, yearly counts of both deer species will help evaluating the effects of management actions on the status of red deer. As red deer are used to human presence, in the BMNR, and it is easy to observe them (Mattioli, 1990; Mattioli et al., 2003), counts through fixed itineraries are a cheap method to estimate their minimum numbers, which could be compared with past values (cf. Mattioli et al. 2003, 2007). The use of alternative, additional methods (e.g. mark-recapture, pellet group counts, distance sampling) should follow an assessment of their reliability (i.e. through the comparison with estimates obtained through direct counts). Counts should be carried out between August and October and in late winter-early spring (cf. Mattioli et al. 2003), to assess numbers, population structure, birth and recruitment rates of Mesola red deer, and between August and September (i.e. after births and before the beginning of culling operations). These counts could also be used to estimate relative densities of fallow deer. Drive counts can also be carried out in sample areas, to obtain estimates of absolute numbers of fallow deer (Lovari and Nobili, 2010).

The existence of a single population puts the Mesola red deer at a great risk of extinction because of catastrophic events (Zachos et al., 2009). After decades of conservation efforts (Lovari and Nobili, 2010), Mesola red deer have reached high densities, with presumably 160-200 individuals living in a small (1058 ha), fenced area. Accordingly, the productivity of this population has decreased in the last decade, suggesting that its absolute numbers could not further increase without continuous supplementary feeding. The conservation of these deer should not be based only on *in situ* strategies. The foundation of other wild populations in 1-2 suitable, protected areas should be considered as a high priority for the conservation of the Mesola red deer (Lovari and Nobili, 2010; Mattioli et al., 2003; Zachos et al., 2009; Zachos and Hartl, 2011). Counts suggest that now the population of red deer could stand the removal of 20-40 individuals for translocations to 1-2 areas (Lovari and Nobili, 2010). Translocations should follow the assessment of genetically suitable individuals (Lorenzini et al., 2005) and the identification of 1-2 areas suitable (i.e. with environmental features similar to the Mesola wood, without fallow deer and sufficiently far from the distribution range of other red deer populations; cf. Lovari and Nobili 2010). This measure will increase greatly the probabilities of long-term survival of this ancient deer of Peninsular Italy.

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