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MESOLA RED DEER: PHYSICAL CHARACTERISTICS, POPULATION DYNAMICS AND CONSERVATION PERSPECTIVES

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ABSTRACT - The biometry, demography and genetics of red deer *Cervus elaphus* of Mesola Wood (NE Italy), are presented and discussed in relation to the conservation of this population. Modest body size, low stature, oversimplified antlers and a low reproductive performance characterise red deer from Mesola Wood. The mitochondrial genome showed a private haplotype, different from other red deer in Italy and central Europe. The uniqueness of this nucleus and its biogeographic importance make a long-term conservation plan particularly urgent. Management measures such as fallow deer reduction, winter feeding and pasture mowing were tested, giving promising results. The physical condition of the animals improved, calf and adult mortality declined, and a few cases of antlers with bez tine or crown were reported in this study after four decades.

Key words: Red deer, conservation, population dynamics, body size, genetic variability, NE Italy.

RIASSUNTO - ***Il Cervo della Mesola: caratteristiche fisiche, dinamica di popolazione e prospettive di conservazione***. La biometria, la demografia e la genetica del cervo *Cervus elaphus* del Gran Bosco della Mesola (Italia nord-orientale), vengono presentate e discusse in relazione alla salvaguardia di questa popolazione. Il cervo della Mesola risulta caratterizzato dalle modeste dimensioni corporee, dalla struttura semplificata dei palchi e da un basso rendimento riproduttivo. L'analisi del genoma mitocondriale ha evidenziato un aplotipo privato, diverso da quello degli altri cervi italiani e centroeuropei. L'unicità di questo nucleo e la sua importanza biogeografia rendono particolarmente urgente un piano di conservazione a lungo termine. Sono stati verificati interventi gestionali quali la riduzione numerica dei daini, il foraggiamento invernale e lo sfalcio delle superfici a pascolo, con risultati promettenti. Le condizioni fisiche degli animali sono migliorate, la mortalità tra i piccoli e gli adulti è diminuita, e sono stati registrati alcuni casi di palchi dotati di ago o corona per la prima volta dopo quattro decenni.

Parole chiave: Cervo della Mesola, conservazione, dinamica di popolazione, biometria, variabilità genetica

INTRODUCTION

The "Gran Bosco della Mesola" Natural Reserve, near the Po delta, harbours the only native population of red deer *Cervus elaphus* in the Italian peninsula (Castelli, 1941; Mattioli, 1990; Mattioli *et al.*, 2001). More than five hundred years ago, red deer were found in four forests along the coast of the Adriatic Sea, from the Po river southwards to the city of Ravenna. During the 17th century, deforestation, drainage, and persecution by man forced the species to withdraw into a small area of the forest which belonged to the Abbey of Pomposa. This area was surrounded on three sides by malarial swamps and on one side by the sea. After World War II, red deer of Mesola Wood became almost extinct as the population was reduced to only ten animals (Mattioli, 1990). In 1970 the population amounted to approximately 40 head, which grew to 120 in 1980, and then decreased to 48 in 1992 (Mattioli, 1990; Lorenzini *et al.*, 1998).

Previous research identified some peculiarities of this deer population: modest body size, persistent spotting in the summer coat, oversimplified antlers and a low reproductive performance (Mattioli, 1990; 1993 a and b). In 1994 a more extensive study was undertaken to identify the causes of decline and to monitor in greater depth the population, collecting data on biometry, eco-ethology, genetic structure and health conditions of the animals in order to select and test viable management options. The present study is part of this research programme.

STUDY AREA

The Natural Reserve, managed by the Italian Forest Service, covers an area of 1058 ha, 950 of which are accessible to ungulates. Woodland accounts for 93% of the territory, while grasslands occupies 3%, and wetland 4%. The holm oak *Quercus ilex* is the dominant tree species, present in two different forest communities, the sub-mediterranean xerophilic wood of the oldest sand dunes (with *Fraxinus ornus*) and the mesophilic wood (with *Carpinus*). The hygrophilic forest community, with *Fraxinus oxycarpa*, *Quercus robur*, *Populus* and *Ulmus*, grows in the intradunal depressions. Grassland is represented by dry and wet meadows, glades and artificial pastures.

Red deer are separated in two subpopulations, one restricted to a fenced area named "Elciola".

Fallow deer *Dama dama*, present in the area since Renaissance, were introduced once again in the Reserve between 1957 and 1965 and have since outnumbered red deer. From 1980 to 1999 fallow deer numbers ranged from a minimum of 300 to a maximum of 1,000 head (32-105 animals per km^2). Assuming a mean daily intake of 4.5 kg of green forage per fallow deer, this meant an additional daily consumption of about 1.6-4.5 tons of vegetation. The extensive over-grazing by fallow deer in open areas resulted in the heavy depletion of the turf with an increase of less palatable grasses. Moreover, the over-browsing by fallow deer in the wood has removed most of the ground flora and the understorey shrub layer, suppressing tree regeneration.

MATERIAL AND METHODS

CENSUSES AND DEMOGRAPHY

Every year three censuses were carried out in the Reserve, in April, July and

September, amounting to a total of 16 between 1994 and 1999. Each one consisted of a total count of animals done from car along fixed routes covering the whole Reserve: all deer could be recognised through ear tags, skin markings, scars and/or antler design.
The yearly changes in population size are expressed as annual finite annual rate of increase λ (= e^r) (Caughley, 1977). The number of calves per adult hind observed in summer represents the birth rate, while the number of calves per adult hind sighted in the following spring represent the post-winter recruitment. The repeated counts of recognisable animals permitted also to reconstruct mortality rates.

CAPTURE AND DATA COLLECTION

Deer were captured from January 1995 to April 1999, resulting in a total of 58 captures and recaptures. Fourty-eight individuals (28 females and 20 males) were captured with a dart gun and marked with coloured ear tags. At the end of 1995 tagged animals represented 52.5% of the total population of the Reserve (32 out of 61 red deer) and at the beginning of 1999 represented 47.8% (32 out of 67).
Captured deer were weighed with a spring scale fixed to a portable tripod. Linear measurements were recorded according to Langvatn (1977 and 1986).
The age of animals was estimated by examining their teeth (Wagenknecht, 1984). Samples of blood and skeletal muscle were collected by jugular puncture and biopsies respectively, and used for serological and genetic analysis.

MANAGEMENT

Due to the evident decline of red deer population, the following management measures were adopted in 1994:
- supplementary feeding during winter
- recurrent mowing in the pastures (18 hectares, at least twice a year)
- reseeding of sample areas
- removing fallow deer by capture and culling (250 head were removed during the winter 1996-1997, 150 head in 1997-1998 and 200 head in 1998-1999).

STATISTICAL ANALYSIS

Data on antler points before and after the management interventions were tested for normality and after negative response were analysed by non-parametric tests. Changes in the proportion of antlerless yearlings were assessed by the Fisher's exact probability test, due to the scanty numbers; since we hypothesised a directional response, the one-tailed test was chosen. Changes in demographic parameters were analysed by Mann-Whitney U test.

RESULTS

BIOMETRY

Sexual size dimorphism is undetectable in calves and yearlings, and reduced in adults. On average, adult stags have 10% longer linear dimensions and 49% greater body mass than females (Tabs. 1 and 2) (usually European red deer stags are 12-15% larger and 70-90% heavier than females; cf. Raesfeld and Reulecke, 1988). Body growth is slow; yearling stags 18-22 months old reach 44% of the adult mass, against a standard of about 65%; yearling hinds achieve 64.5% of the adult weight, against a standard of about 85%.
Mesola red deer are of low stature. The adult height at withers is about 58% of

Table 1 - Linear measurements (mean ± SD) of adult stags (≥ 5 years old) and adult hinds (≥ 2 years old); n = sample size.

	Stags	Hinds
Head-trunk length	183.9 ± 7.6 n=6	167 ± 7.9 n=22
Tail length	13.8 ± 0.9 n=6	12.8 ± 1.2 n=22
Shoulder height	107.9 ± 1.9 n=6	95.0 ± 2.4 n=22
Thoracic circumference	113.5 ± 4.2 n=6	101.2 ± 3.8 n=22
Hindleg length	48.8 ± 0.8 n=6	45.2 ± 1.2 n=22
Ear length	17.7 ± 0.5 n=7	16.5 ± 0.5 n=21

head-trunk length, against a standard of about 62-64% (Mattioli, unpublished data from red deer of alpine origin; cf. Langvatn, 1986).

GENETIC VARIABILITY AND DIFFERENTIATION

Red deer population from Mesola Wood was investigated for genetic variability at the nuclear level by electrophoresis of allozymes. The values of average expected heterozygosity and mean proportion of polymorphic loci revealed by the survey were low but consistent with those reported for other populations of red deer (Lorenzini *et al.*, 1998). DNA variation was assessed by restriction fragment length polymorphism of four PCR-amplified segments in the mitochondrial genome.
Comparison of seven red deer populations (the subspecies *C. e. corsicanus,* five populations of alpine origin, and one population from central Europe) showed that Mesola red deer were monomorphic for one single "private haplotype", different from those found in the Italian and central European populations studied (Lorenzini *et al.*, in prep.).

DEMOGRAPHY

During the study period spring red deer population increased from 59 to 67, with an average annual increase of 2.6% (λ = 1.02575) (Tab. 3). However, between 1994-1996 on average population size decreased annually by 4.3%, whereas between 1997-1999 it increased annually by 10.4%. The Elciola subpulation formed 78% of the total. Sex ratio, which was rather biased in 1994 (1:2.4) gradually rebalanced to 1:1.3 in 1999.

RESULTS OF THE MANAGEMENT MEASURES

As a result of implemented management strategies, nutritional conditions

Table 2 - Live body weights (mean ± SD), data from 1995 to 1999; n = sample size.

Age and sex class	Mean ± SD
Calves (6-10 months old)	35.0 ± 8.5 n=6
Yearling stags	47.9 ± 12.6 n=8
Subadult stags (2-4 years old)	71.8 ± 8.1 n=7
Adult stags (≥ 5 years old)	109.9 ± 11.6 n=8
Yearling hinds	47.7 ± 2.5 n=3
Adult hinds (≥ 2 years old)	74.0 ± 7.4 n=23

of red deer improved significantly. Female mean weights increased by 5.8 kg (+ 7.5%) between 1995 and 1996-1998 period.

The quality of antlers also improved. From 1993 to 1999 in Elciola 108 pairs of cranial appendages (true antlers, bony buttons and fur-covered knobs) were observed, belonging to 40 different individuals. On average stags exhibited delayed antler development, with full maturation only after 9 years of age. Mean values of number of total tines in adults and subadults (Tab. 4) were similar to those reported in a previous study (Mattioli, 1993 a) and did not differ between the periods 1993-96 and 1997-99. But antlerless yearlings decreased from 66.7% to 18.2% (Fisher's exact probability test: p = 0.04, one-tailed). And for the first time in 40 years, in 2 individuals out of 5 stags > 9 yers old, antlers with bez tine and/or rudimentary crown were observed in 1997 (cf. Mattioli, 1993 a).

Table 3 - Changes in population size of Mesola red deer from 1994 to 1999 (spring census numbers).

Year	Elciola	Out of Elciola	Mesola
1994	46	13	59
1995	47	13	60
1996	39	11	50
1997	42	13	55
1998	46	13	59
1999	51	16	67

Table 4 - Number of tines per antler pair (mean ± SD) in subadult and adult stags of Elciola and comparison between the two periods (n = sample size).

	Subadults	Adults
1993-1999	3.03 ± 1.87 n=36	6.12 ± 1.38 n=52
1993-1996	2.57 ± 1.75 n=21	6.00 ± 1.00 n=21
1997-1999	3.67 ± 1.92 n=15	6.19 ± 1.60 n=31

The calving rate and post-winter recruitment increased in the last two years (Tabs 5 and 6), but the difference was statistically not significant (Mann-Whitney U test; π = -1.732 and -1.777, p = 0.083 and 0.076 respectively). The reproductive performance continued to be modest, coherent with the average for 1983-1991 (cf. Mattioli, 1993 b).

Mean calf mortality declined from 20.1% in the period summer 1994 - spring 1997 to 2.9% in the period summer 1997 - spring 1999. Mean annual adult mortality decreased from 11.8% in 1994-1997 to 5.9% during 1997-1999.

Table 5 - Comparison between mean birth rates in Elciola.

	calves per hind ≥ 2 years old
1994-1996	0.267
1997-1998	0.370

Table 6 - Comparison between mean post-winter recruitments in Elciola

	calves per hind ≥ 2 years old
1995-1997	0.173
1998-1999	0.348

DISCUSSION

Research confirmed the distinctiveness of this population both morphometrically and genetically. Mesola red deer have a slow growth rate, modest final body size, low stature, reduced sexual dimorphism and simplified antler structure. Compared with other European populations, Mesola red deer have on average adult body weight reduced by 30-35% (males) to 15-30% (females). Mean linear dimensions are reduced by 8-15% compared with Swiss, German or Norwegian populations (Buchli, 1979; Raesfeld and Reulecke, 1988; Drechsler, 1985; Langvatn, 1986).

It is an obvious case of ecotype typical of marginal and unproductive environments, developed as a result of isolation in coastal submediterranean woodland on sandy soil. During a warm period in the XIIIth century, mediterranean scrub and woods dominated by *Quercus ilex* spread northwards from southern Italy along the Adriatic coast up to Istria. Large sized red deer from the Po plain forests of *Quercus robur* colonised coastal woods and swamps adapting to live in less luxuriant environments. Poor quality habitat favoured small sized deer, more efficient competitors for restricted resources. Sexual dimorphism in size decreased as a consequence of the greater susceptibility of stags to food restrictions (Clutton-Brock *et al.*, 1982; Leberg and Smith, 1993; Ashley *et al.*,1998; LeBlanc *et al.*, 2001). Human manipulations, *i.e.* introduction of fallow deer, improper selvicoltural interventions and hunting pressure have possibly exacerbated the situation, further reducing body growth. The simple antler design may have been affected by the incorrect hunting practice during the early decades of the XXth century, when trophy stags were systematically removed (Mattioli, 1993 a; cf. Hartl *et al.*,1985). Geist (1998) defines Mesola red deer as maintenance dwarf with paedomorphic features, juvenile-like antlers and short limbs. Lower stature is at present difficult to interpret. It is not sufficiently clear if the slight shortening of limbs falls within the overall variability of the species, or if is a by-product of body size reduction or an adaptive change. Only more complete biometric data sets will permit to know intra- and inter-population variation of *Cervus elaphus*. And only detailed osteometric analysis of limb elements will suitably document the leg shrinking phenomenon.

Management measures experimented since 1994, have determined a general

improvement in the physical condition of the animals, halted population decline, and allowed reappearance of antler traits absent for decades. Particularly remarkable was the improvement in antler development and architecture: once again antlers proved to be an excellent condition index for a deer population (cf. Brown, 1990). Yearling stags were particularly reactive to the changes in food availability, increasing the proportion of antlered individuals (cf. Schmidt *et al*., 2001); the onset of the first antler set is related to the complete growth of pedicles, in turns strictly connected with the attainment of a threshold body mass (Suttie and Kay, 1983; Fennessy and Suttie, 1985). These relatively simple interventions must be continued, proceeding to more complex and ambitious plans. It is vital to increase resources available to deer through appropriate woodland management techniques (thinning, opening glades, exclosures, etc.). The uniqueness of this population and its biogeographical importance make Mesola red deer a national conservation priority. It is essential to continue periodic monitoring on population dynamics and health screening. It will be important to know whether once management is implemented the nucleus will consolidate itself. It will be crucial to understand reasons for the low reproductive rate observed. Once the population reaches more acceptable numbers (*ca.* 100 individuals) one basic issue will be the translocation of part of the stock, in order to reduce the risk of extinction and to maximise genetic variability (cf. McCullough *et al.*,1996).
This will call for a well-organised conservation strategy, requiring adequate funding and technical know-how. The long-term conservation of the only native red deer population of the Italian peninsula certainly deserves such attention.

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