POPULATION DYNAMICS OF MOUFLON IN A PROTECTED AREA OF THE ITALIAN ALPS

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Abstract - In this paper we analyse the demography of the mouflon colony inside the Orsiera-Rocciavré Natural Park. Starting from 1986, mouflon counts have been carried out, usually twice a year by the Park wardens. The population increased regularly from 115 animals in 1986 to 294 animals in 1994, with a mean annual growth rate of 12.5%. After 1994 the population decreased rapidly to 85 animals in 1998, with a mean annual decrease of 26.7%. The sex-ratio showed a constant tendency to be balanced throughout the study period, and ranged from 0.9 to 1.1. Natality ranged from 0.42 to 0.71 and was inversely correlated with the density in the previous year.
In 1995 the Park started a program for the limitation of the mouflons inside the protected area. The animals actually culled were only 25, thus the control program can not be considered the only responsible for the decrease in the population after 1994. A density dependent effect on the fecundity of females may have contributed to the decrease. Wolf predation and climatic factors may also be responsible for this decline, although our data do not point out these effects. Our results are not consistent with the hypothesis of a detrimental effect of the mouflons on Alpine chamois in the study area.

Résumé - Dynamique des populations de mouflon dans une zone protégée des Alpes Italiennes. La démographie des mouflons dans le Parc Naturel Orsiera-Rocciavré a été analysée. Dès 1986, des dénombrements de mouflons ont été effectués deux fois par an par les gardes du Parc. La population a augmenté régulièrement de 115 animaux en 1986 à 294 animaux en 1994, avec un taux d'accroissement annuel moyen de 12.5%. Après 1994, la population a chuté rapidement à 85 animaux en 1998, avec un taux de décroissance annuel moyen de 26.7%. Le sex-ratio est resté constant pendant toute la période d'étude, variant de 0.9 à 1.1. La natalité variait de 0.42 à 0.71 et était inversement corrélée avec la densité de l'année précédante.
En 1995, la direction du Parc a commençé un programme de limitation du mouflon dans l'aire protégée. Avec seulement 25 animaux abattus, le programme de contrôle ne peut pas être considéré comme seul responsable de la diminution de la population après 1994. Un effet sur la fécondité des femelles, dépendant de la densité, peut avoir contribué à cette diminution. La prédation par les loups et les facteurs climatiques peuvent aussi être responsables de cette chute, toutefois nos données ne montrent pas ces effets. Nos résultats infirment l'hypothèse d'un effet négatif des mouflons sur le chamois alpin dans l'aire étudiée.

Key-words: Mouflon, *Ovis (Orientalis) musimon*, Alps, Protected area, Population dynamic, Density dependent effect
Mots clés: Mouflon, *Ovis (Orientalis) musimon*, Alpes, Aire protégée, Dynamique de population, Effet dépendant de la densité.

Ibex J. Mt. Ecol. 5: 205-212
Anthropozoologica 31: 205-212

1. Introduction

The introduction of game species in new habitats is a practice started thousands of years ago and increased in the last centuries (Lever, 1985 and 1994). Only recently, with a better comprehension of the mechanism that governs the ecosystem, we begin to understand the magnitude of the threat

posed by these actions (Williamson, 1996; Meffe *et al.*, 1997).

The mouflon, *Ovis* [*orientalis*] *musimon,* originated in the late Neolithic (5000 b.p.), from domestic sheep introduced in Corsica and Sardinia at the beginning of the Neolithic (7000 b.p.) (Vigne, 1992). Since the XVIII century, the mouflon was introduced in many countries in Europe and outside the continent (Pfeffer, 1967; Cassola, 1985; Lever, 1985). In Italy the species is present with many colonies in the Alps and Apennines (Apollonio & Meneguz, *in press*; Bertolino *et al.*, 1998). The introduction of the mouflon in the Italian Alps started in 1962, with the first release in the Albergian Hunting Reserve (Rossi *et al.*, 1988; Bertolino *et al.*, 1998). The Reserve is located in the Chisone Valley (Western Alps), mainly on the right side of the river. Until 1995, the colony originated from this introduction was the greatest in the Italian Alps (Bertolino *et al.*, 1998). In 1980 a Natural Park was established by the Piedmont Region in the Orsiera-Rocciavré Massif, neighbouring with the Reserve on the left side of the valley. In those years a small nucleus of mouflons was seasonally present in the park area, due to the expansion of the colony (IPLA, 1982). Since 1986, the Park wardens have monitored the ungulates through regular censuses. In this paper we analyse the data available on the demography of the mouflons inside the protected area and compare it with the dynamics of the Alpine chamois population in the same area, in order to stress on the possible reciprocal influences.

2. Study area and methods

The Orsiera-Rocciavré Park is situated in the Western Alps (44°75'N - 6°90'E), and includes mountain areas of the Chisone, Sangone and Susa valleys. The study area is located on the left mountain side of the Chisone valley, with a south exposure, and on the upper part of the north slope of the Susa valley. The area is characterised by extensive meadows alternating with shrubs, prevalently *Rhododendron ferrugineum* and *Vaccinium* spp. At lower altitudes we have extensive forest formations of larch *Larix decidua* and Scots pine *Pinus sylvestris.* Other ungulates present in the Park are: Alpine chamois *Rupicapra rupicapra*, Red deer *Cervus elaphus*, Roe deer *Capreolus capreolus*, and Wild board *Sus scrofa*. A reintroduction program of Alpine ibex *Capra ibex* started in 1995. During the summer season the presence of domestic sheep and cows is remarkable.

Starting from 1986, counts of ungulates within the park area have been carried out by the Park wardens, except in 1990 and 1992. Counts are made at least once a year, but usually twice: the first in June for the mouflon and in July for the chamois, at the end of the respective lambing season, and the second at October-November. The results of the two censuses of the years were correlated between them ($R^2 = 0.72$; $p<0.05$). During the censuses, the size and the structure (age/sex classes) of the population were determined by direct observations.

We analysed the dynamics of mouflon and Alpine chamois populations using simple linear regression. We used the highest value of the yearly censuses for the abundance analysis. Due to the lack of data for some years, the mean annual growth (or decrease) rate between periods was calculated using the "compound increase formula"(Frè, 1989):

Growth rate = $\left(\sqrt[n]{N_{i+n}/N_i} - 1\right) \times 100$

where n is the total number of years considered, N_i is the number of individuals counted in the year i and N_{i+n} is the number of individuals counted after n years. This formula, usually used by economists, accounts for the compound effect, and thus better describes the mean population increase in cases like this in which some years are missing.

The natality (lambs/females ratio) was evaluated using the data from the spring censuses, when the differences in body size between lambs and yearlings reduced the possibility of error in the discrimination between the two age

classes. For this reason data for 1993, when only an autumn census had been carried out, was not considered.
Simple linear regression was computed to evaluate the influence of snow depth and lenght of persistence on demographic parameters.Data on snow depth and days of persistence were obtained from a meteorological station located at Pragelato, in the same valley and approximately the same altitude of the study area.

3. Results

The mouflon population increased regularly from 115 animals in 1986 to 294 animals in 1994 ($R^2 = 0.62$; $p<0.05$) (Fig. 1). During this 9-year period the overall growth rate was of about 156%, with a mean annual growth rate of 12.5%. After 1994 the population showed a negative trend ($R^2 = 0.92$; $p<0.01$), with a rapid decrease, especially after 1996 (Fig. 1); in 1998 only 85 animals were counted. The mean annual decrease was of 26.7%, with the highest values in the last two years (42% between 1996 and 1997, and 35% the next year).
The sex-ratio showed a constant tendency to be balanced throughout the study period, and ranged from 0.9 to 1.1 (Fig. 2). Mean yearly natality was 0.56, but there were great fluctuations, with a minimum value of 0.42 and a maximum of 0.71. Natality was inversely correlated with the total number of animals counted in the previous year ($R^2 = 0.7$; $p<0.05$) (Fig. 3). The relations between number of mouflons and snow depth and days of snow persistence in the previous winter were not significant (Depth: $R^2 = 0.22$, $p = 0.17$; Persistence: $R^2 = 0.16$, $p = 0.25$).
The population trend of Alpine chamois increased regularly during all years considered in this study ($R^2=0.93$; $p<0.0001$) (Fig. 1).

4. Discussion

During the 13-year period the mouflon population in the Orsiera-Rocciavré showed an opposite trend: an increase from 1986 to 1994 was followed by a rapid decrease. The demographic increase occurred in the first phase, led to an expansion of the area occupied

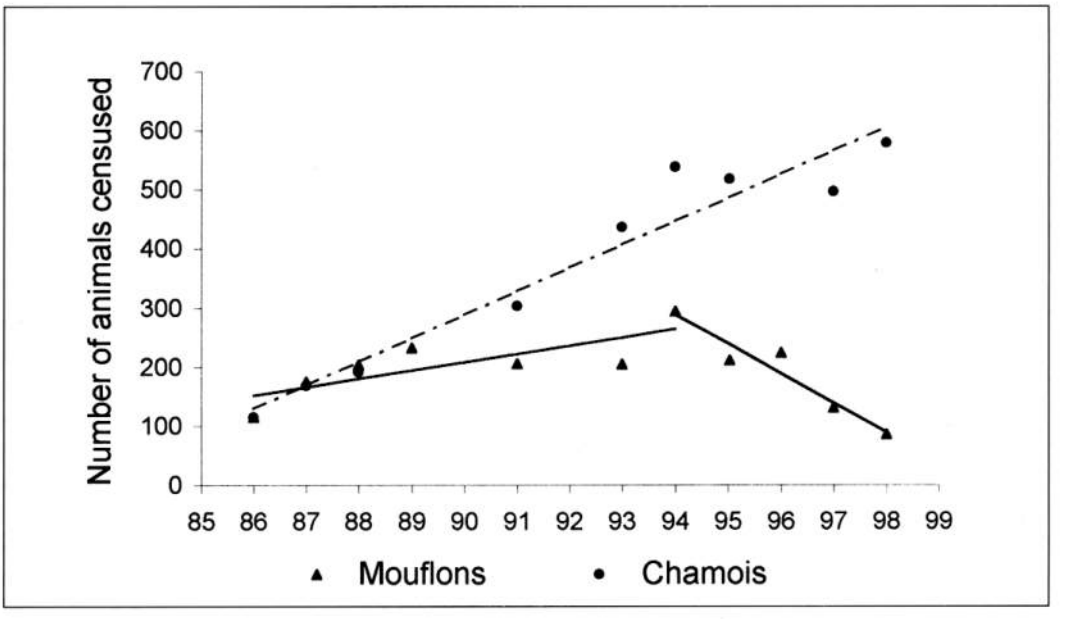

Fig. 1 - Chamois and mouflon population trends in the Orsiera-Rocciavrè Natural Park in 1986-1998.

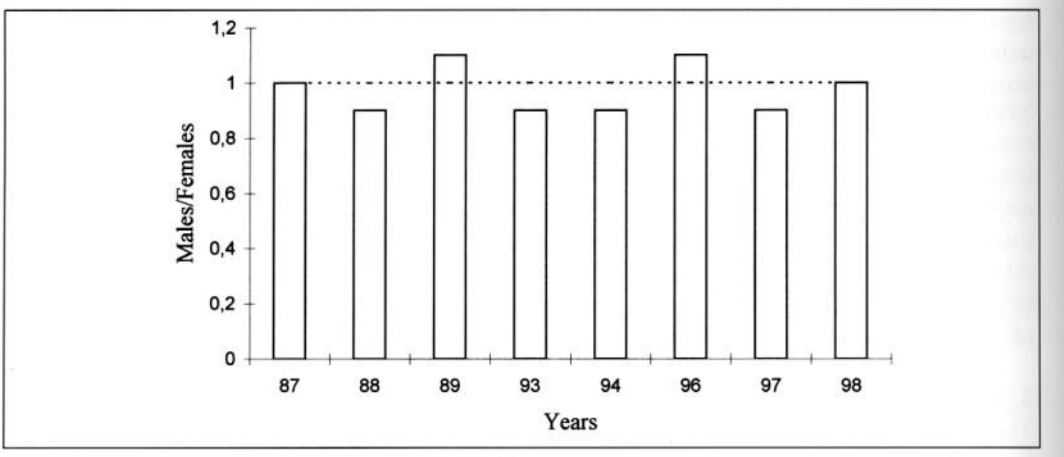

Fig. 2 - Sex-ratio of the mouflon population in the Orsiera-Rocciavré Natural Park. Dotted line= sex-ratio 1:1.

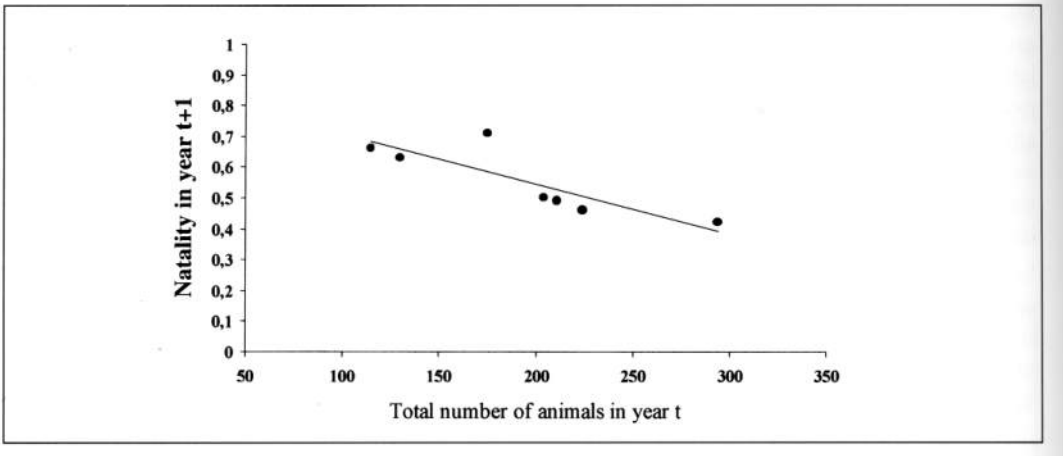

Fig. 3 - Relation between natality (lambs/females ratio) and total number of animals in the previous years.

by the species. In those years, the area occupied by the mouflon passed from 1014 ha to 2400 ha, with an increase of 137% (Bertolino, 1989; Bassano & Bertolino, 1997). The seasonal pattern of space use in the Orsiera-Rocciavré population seems to be influenced by climatic factors and the seasonal distribution of feeding resources: mouflons migrated from the winter range located at the bottom of the valley, prevalently outside the protected area, to the summer range in the high altitude alpine meadows (Bassano & Bertolino, 1997).

A mouflon population limitation plan, started by the Orsiera-Rocciavré Natural Park in 1995, predicted an harvest equivalent to the annual increase (about 30%), corresponding at that time to 70 animals a year. Despite of this plan, the animals actually culled were only 25 (13 females and 12 males) in 1996. The following years no other animals were culled inside the protected area. Due to the little number of culled animals, the control program can not be considered responsible for the decrease in the population that started in 1995 and continued in the successive

years. Also the high percentage of females culled every year starting in 1990, inside the neighboring Albergian Hunting Reserve (Meneguz & Apollonio, 1997) can not be considered responsible for that decrease. Meneguz and Apollonio (1997) pointed out that the population in the Reserve did not decrease from 1988 to 1995; a decrease in 1996 was ascribed to the high snow cover in winter. The natality rate that has been recorded attests the high fertility of the species. Our values are similar to those reported for colonies in the Eastern Alps (Brugnoli, 1994) and Pyrenees (Bon *et al.*, 1991), and higher than what is known for Corsica (Dubray & Roux, 1990) (Tab. 1). The negative relationship we found among the total number of animals counted in the previous year and natality, may indicate density dependent effects on fecundity. Also if the Orsiera-Rocciavré mouflon population is expanding it's range, the increase of the surface occupied by the population corresponded to an expansion of the summer range, while the winter range remained stable (Bertolino, 1989; Bassano & Bertolino, 1997), probably because of a shortage of suitable wintering areas. Thus high population densities during winter, when feeding resources are limited, may have an effect on natality. Besides direct effects on the fecundity of individuals, the mechanism which might cause the reduction in the number of lambs per female at high densities, is a delay in the age of first reproduction, as shown in bighorn sheep *Ovis canadensis* (Festa-Bianchet *et al.*, 1995) and in some species of cervids as also in donkeys *Equus asinus* (for a review see: Gailard *et al.*, 1998). Data on individual life histories of marked females would be required to verify this hypothesis in the Orsiera-Rocciavré mouflon population. Interspecific competition between mouflon and chamois has been hypothesised by different authors, but it is generally considered detrimental to the latter (Pfeffer, 1967; Pfeffer & Settimo, 1973; Gonzales, 1984; Lanfranchi *et al.*, 1991). In the Orsiera-Rocciavré Natural Park, the chamois population increased regularly from 1986 to 1998 and seemed not to be affected by the presence of the mouflon, even before 1994. Anyway it is necessary to consider that the initial situation was that of two nuclei in expansion colonising the park, starting with a few animals. If the two species are in competition, it's likely that such a competition appears only in condition of high density and food shortage.

Another possible limiting factor is predation. Until some years ago, the Golden eagle *Aquila chrysaetos* and the Red fox *Vulpes vulpes* were the only potential predators of the mouflon in the Alps, but their impact on the species can be considered negligible (Geist, 1971; Hadjisterkotis, 1990; Apollonio & Meneguz, *in press*). More significant could be the predation carried out by stray dogs (Apollonio & Meneguz, *in press*). On the other hand, the recent reappearance of the wolf *Canis lupus* in the Western Alps (Breitenmoser, 1998), might have a remarkable influence on the dynamics of the mouflon population. The presence of the wolf in Val Chisone has been reported starting from 1996 (Ottino & Pulzoni, 1998); successful reproduction attempts by the species in neighbouring areas have also been reported, indicating the presence of a settled nucleus (Ottino & Pulzoni, 1998). Mouflons are a primary prey of the wolf where present (Poulle *et al.*, 1997). Mouflons originated from a Mediterranean island and are probably not well adapted to locomotion with high snow cover, making them an easy prey. Furthermore, the original population of mouflons has not been in contact with a large predator as the wolf for thousands of years, and thus it is probable that selective pressures for anti-predator behaviours were relaxed in this species. At present there are no factors for attributing the considerable decrease of the number of mouflons in the park area to the predatory effect. Park wardens have never found animal carcasses whose death may be ascribed to wolf predation. Anyway, it is necessary to consider that the

recovery of carcasses is not an easy task and that the predation could take place mostly in winter, when the mouflons are in the winter range, outside the park borders.

Winter climatic conditions are an important limiting factor for the mouflon, able to influence the choice of the habitat and to cause seasonal migrations towards lower altitudes (Pfeffer, 1967; Cruveille & Tuffery, 1981; Gonzales, 1984; Bon *et al.*, 1991; Laurent, 1981; Bassano & Bertolino, 1997). In very harsh years there can be a considerable mortality of animals (ONC, 1985; Bon, 1991; Boussès *et al.*, 1994). Although we did not found any significant correlation between the number of mouflons and snow cover, we must point out that the influence of weather condition on the demography of alpine ungulates are probably evident only in situation with high density (Portier *et al.*, 1998), while we could analyse only few years in such a situation. Furthermore, mortality due to snow cover could be very high in lambs (Cugnasse, 1982; ONC, 1985; Bon *et al.* 1991), but our data were not suitable to analyse the survival of lambs during their first winter.

The sex-ratio remained balanced throught the study period and did not change after the decrease phase. Mortality was thus not biased toward adult males as found in other situations (Boussès *et al.*, 1991; Clutton-Brock *et al.*, 1991) indicating probably a reduced mortality of adults. These results suggest that the decrease in the population was caused by a reduction in natality and lamb survival more than by adult mortality, in accordance with results found for other ungulates (Gaillard *et al.*, 1998).

In conclusion, the present study documented a strong decrease in a population of mouflons expanding its summer range. The density dependent effects found on the lambs/females ratio suggest that limited resources in winter at high local densities may cause a strong instability in this mouflon population, not being this species adapted to the harsh alpine environment. Wolf predation and climatic factors may also be involved in the population dynamics of this species in the Orsiera-Rocciavré Natural Park, but our data were probably not suitable to point out these effects. In order to completely understand the dynamics of this population, a long term study on individually marked subjects would be required.

5. Acknowledgements

We are grateful to all the Park wardens that have realized the censuses. We thank Denis

Tab. 1 - Mean natality (lambs/females ratio) in different European mouflon populations.

DISTRICT	STUDY AREA	YEARS	MEAN	± S.E.	REFERENCE
Western Alps	Orsiera-Rocciavré (I)	1986-98	0.56	0.03	This Study
Eastern Alps	Fassa (I)	1990-93	0.62	0.005	Brugnoli, 1994
	Stenico (I)	1990-93	0.60	0.03	Brugnoli, 1994
Eastern Pyrenées	Carlit (F)	1981-86	0.56	0.07	Bon *et al.*, 1991
Hérault	Caroux (F)	1977-83	0.78	0.02	Bon *et al.*, 1991
Corsica	Asco (F)	1977-89	0.45	0.02	Dubray & Roux, 1990

Réale for useful and interesting comments on the manuscript. Part of the writing up was done while A. v. H. was at the Département de Biologie, Université de Sherbrooke (Canada), supported by a scholarship from the University of Pavia (Italy).

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