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LONG-TERM MONITORING OF PYRENEAN CHAMOIS IN A PROTECTED AREA REVEALS A FLUCTUATING POPULATION

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RIASSUNTO - ***Monitoraggio a lungo termine del camoscio dei Pirenei in una zona protetta: fluttuazione della popolazione***. Tra il 1993 ed il 2009, la popolazione di camoscio pirenaico *Rupicapra p. pyrenaica* del Parco Nazionale d'Aigüestortes e Estany de Sant Maurici (14119 ha, Catalogna, Spagna) è stata monitorata periodicamente. Nel periodo post-riproduttivo (luglio), i censimenti sono stati condotti lungo 20 percorsi supraforestali fissi, con l'obiettivo di stimare le variazioni nelle dimensioni, rapporto sessi, struttura e produttività della popolazione nell'area protetta. La densità media è risultata pari a 6,7 camosci km^{-2}, il rapporto sessi circa 1:3 in favore delle femmine, mentre la produttività è stata pari a 0,6 juvenes per femmina adulta.
La proporzione di animali indeterminati durante i conteggi è diminuita significativamente nel tempo, probabilmente in seguito al progressivo *training* degli operatori. Nel periodo di studio, le dimensioni della popolazione sono fluttuate significativamente. Sebbene le cause di tali variazioni siano ancora da approfondire, le successive epidemie di cheratocongiuntivite infettiva e Pestivirus che hanno colpito la popolazione hanno probabilmente svolto un ruolo determinante. Si raccomanda di sviluppare un piano di gestione dell'intero massiccio montuoso, che includa regolari monitoraggi sanitari e conteggi autunnali.

Parole chiave: Cheratocongiuntivite infettiva, *Mycoplasma conjunctivae*, Pestivirus, *Rupicapra p. pyrenaica*

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The Pyrenean chamois *Rupicapra p. pyrenaica* is a mountain ungulate, endemic to the Pyrenees (Cabrera, 1914). In recent decades, populations have increased dramatically in response to changes in hunting regulations, rural abandonment, reductions in livestock and, to a lesser extent, the recent increase in the number of protected areas in Spain (from 80 in the 1980s to >1500 in the 2000s; De Lucio, 2006). Currently the main population consists of at least 53,000 animals (Herrero *et al*., 2004) that occupy almost the whole potential range. The population exhibits variable productivity (50-90%), high mortality rates (40-50%) of juveniles and yearlings, high

survival of adults (~90%) and an adult sex ratio skewed towards females (Canut and García-Ferré, 1994; Garin and Herrero, 1997; Crampe, 1997; Loison *et al*., 1999). The IUCN considers *Rupicapra pyrenaica* a species of Least Concern (LC) (Herrero *et al*., 2008) and it is the only big-game species in the Pyrenees that is included in Annex V of the European Directive, which obliges member states to monitor and report on its population trends. The vast majority of the subpopulations are hunted (Naudí and Riba, 2004; Herrero *et al*., 2004, Berducou *et al*., 2004, Padrós i Selma *et al*., 2004), which has some social and economic importance. Periodical outbreaks of Infectious Keratoconjunctivitis (IKC) by *Mycoplasma conjunctivae* and Pestivirus (Sánchez and Martínez, 1982; Marco *et al*., 2007) and, secondarily, predation by Golden eagles *Aquila chrysaetos* and dogs *Canis familiaris* contribute to natural mortality.

Chamois move seasonally from supraforestal pastures, where they occur mainly in summer, to forests, where they winter (Herrero *et al*., 1996; Pepin *et al*., 1997). As a consequence, individuals (and subpopulations) may move between areas where they can be hunted and areas where they are protected legally and, therefore, be affected by differing management practices. For that reason, the use of management units was recommended, which were implemented in some Pyrenean areas (Berducou *et al*., 2004; Herrero *et al*., 2004).

The objectives of our study were to assess changes in population size, sex-ratio, age structure and productivity of Pyrenean chamois living in a protected non-huntable area, and identify ways to improve the management and monitoring of the population.

The Aigüestortes i Estany de Sant Maurici National Park, Catalonia, Spain (42º 34' 14'' N, 0º 56' 25'' E), covers an area of 14119 ha in the south-central portion of the Pyrenees. Inside the Park hunting is prohibited while it is permitted in a surrounding 26733 ha large buffer zone. Most of the park is above 1600 m a.s.l., the highest elevation being 3033 m a.s.l. (Fig. 1; see Carrillo and Afonso, 1999, for more details about the Park).

In the park, predominant habitats include fir *Abies alba* and mountain pine *Pinus uncinata* forests, lakes, and rocky areas.

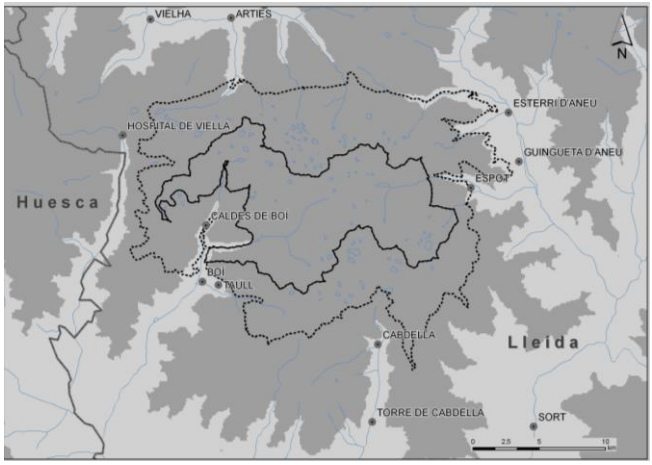

Figure 1 - Study area. Borders of the Aigüestortes i Estany de Sant Maurici National Park (black line) and the surrounding Buffer Zone (dotted line). Surface over 1600 m a.s.l. is light grey.

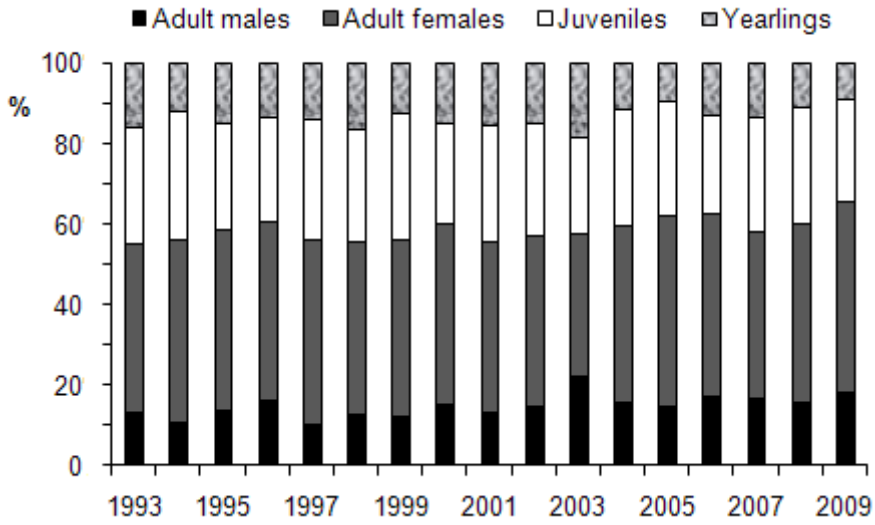

Figure 2 - Age-structure of the chamois population. Each column shows the % contribution of each class for each year.

Mixed forests of *Betula pendula*, *Quercus humilis,* and *Quercus petraea*, *Populus tremula*, *Fagus sylvatica* and *Pinus sylvestris* occupy the valley-bottoms. The climate is mountainous and Atlantic with annual precipitation >2000 mm at the highest elevations. Other (non-monitored) ungulates in the park are fallow deer *Dama dama*, roe deer *Capreolus capreolus*, wild boar *Sus scrofa,* and, recently, red deer *Cervus elaphus*. In summer 2008, domestic livestock included cows (771), sheep (5911), and horses (34). In 1990, there was an outbreak of Infectious Keratocojunctivitis (IKC, Canut and García-Ferré, 1994).

Every July between 1993 and 2009, chamois were counted along 20 fixed itineraries walked by two rangers, equipped with binoculars, spotting scopes, and *ad hoc* maps. Individuals were identified as adult males or adult females (over 3 yr), juveniles (< 1 yr), yearlings (1-2 yr), or indeterminate chamois. Annual population density was calculated by dividing the number of chamois observed by the total area surveyed.

To allow for sound comparisons of yearly data, the study focused on 11 out of 20 itineraries (10230 ha). In some cases, missing data (9 surveys out of total 340) were estimated by interpolating a linear regression. The statistical significance of trends was assessed by Poisson's regressions using R free software (R Development Core Team, 2009).

The chamois population mainly consisted of adult females (44%) and their juveniles (28%), while adult males (15%) and yearlings (13%) were less common (Fig. 2). On average, 19.5% (range = 10-29% per year) of the individuals observed during surveys were not identified, although the proportion decreased significantly over time (Poisson regression, -3.08 annual decrease (-3.82 a -2.35), $p<0.00$, Tab. 1), reflecting the progressive training of surveyors. Average adult sex ratio was 0.3 males per female (range = 0.2-0.6), productivity was 0.6 juveniles / adult female (range = 0.5-0.7), and population density was 6.7 chamois km^{-2} (range = 4.7-9.2). On the whole, productivity showed limited inter-annual variation, while the decreasing proportion of yearlings in the population suggested differences in annual mortality (Crampe *et al.*, 2006).

Table 1 - Application of Poisson regression to the proportion of undetermined chamois (1993-09).

Yr (N)	Coeff. B= r	SE	Exp(B)=λ	Confidence limits 95%	P	% of annual variation (95%)
17	-0.0309	0.0038	0.969	0.962-0.976	<0.0001	-3.08 (-3.82 ÷-2.35)

In the study area, the demographic characteristics of the population of Pyrenean chamois were similar to those reported in other studies (Pérez-Barbería and García-González, 2004), although it would have been better to assess the sex ratio of the population in autumn, when adult males join rutting females (Gonzalez and Berducou, 1985; Herrero *et al*., 2004). Between 1993 and 2009, the size of the chamois population in the park fluctuated significantly, the best-fit curve being a polynomial one (Tab. 2, Fig. 3). Although the reasons for the long-term fluctuation in the population are not fully understood, these successive outbreaks of infectious diseases likely played a major role. In fact, during our study three infectious disease outbreaks occurred: (1) in 1996-1997, an outbreak of IKC was determined from visual detection; (2) in 2001-2002, an outbreak of Pestivirus occurred in the buffer zone surrounding the park (Marco *et al.* 2007); and (3) in 2004-2005, another IKC outbreak, determined from 16 chamois visually detected. Between 1993 and 2001, the population recovered from the IKC outbreak; between 2001 and 2005, IKC and Pestivirus outbreaks occurred; between 2005 and 2009, the population resumed it's recovery from the effects of the infectious diseases (Tab. 2, Fig. 3).

Additional detailed data are needed to clearly understand these phenomena and the factors influencing the demography of the chamois population in the Pyrenees. Monitoring programs should include a sanitary survey. A routine collection/record of dead animals and the hunting bags of the whole mountain massif should be carried out. The seasonal altitudinal migration of the population exposes the chamois to hunting from autumn to spring in areas outside the park, thus, variation in hunting management (N of individuals that can be legally hunted) may influence population dynamics. To better analyze the population trend of this species and develop adequate management for all the wild ungulates dwelling in the area, it is necessary to develop a management plan which considers the whole mountain massif as a unique management unit and which includes regular autumn surveys.

Table 2 - Application of Poisson's regression to the number of chamois observed between 1993 and 2009.

Periods	Yr (n)	Coeff. B= r	SE	Exp(B)=λ	Confidence limits 95%	P	% of annual variation (95%)
1993-09	17	-0.0151	0.0016	0.985	0.982-0.988	<0.0001	-1.5 (-1.82÷-1.19)
1993-01	9	0.03829	0.0041	1.039	1.031-1.047	<0.0001	3.9 (3.07÷4.74)
2001-05	5	-0.1469	0.0103	0.863	0.846-0.881	<0.0001	-13.7 (-15.4÷-11.9)
2005-09	5	0.0501	0.0117	1.051	1.027-1.076	<0.0001	5.1 (2.7÷7.6)

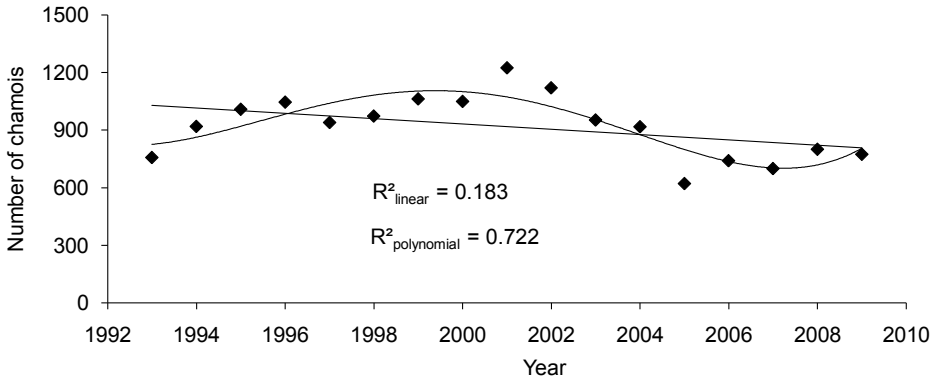

Figure 3 - Chamois population trend (1993-09) and it's adjustment to both a linear and polynomial function.

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