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Assessment of carrying capacity of *Cistus* spp. shrublands for red deer (*Cervus elaphus* L.) management in Monfragüe Natural Park (SW Spain)

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RESUME – *"Evaluation de la capacité de charge des maquis de* Cistus *ssp. pour la gestion de cerf (*Cervus elaphus *L.) dans le Parc Naturel de Monfragüe (SO Espagne)". Trois types de maquis de* Cistus *ssp. ont été classifiés avec le programme TWINSPAN. Le premier type (L) est dominé pour* Cistus ladanifer*. Le second (S) pour* Cistus salvifolius *et le troisième type (T) est la transition de les autres deux. Le facteur d' usage de chacun des pâturages de cistes a été calculé pour la taux d'utilisation de la ressource (% de coups de dents) et le nombre des déjections pour transept. Dans chaque communauté la couverture des cistes et sa densité, la valeur nutritionnelle et la capacité de charge (CC) ont été estimé. Pour le type L la CC fut 0,03 ± 0,025 cerfs ha $^{-1}$. Pour le type S fut 0,070 ± 0,074 cerfs ha^{-1} et pour le T 0,017 ± 0,011 cerfs ha^{-1}. Malgré les maquis de* Cistus *sont 60% des communautés végétaux de la région de Extremadura, leur CC est très faible, c'est dû à sa faible acceptation pour les cerfs, probablement pour son grand teneur en substances toxiques.*

Mots-clés: *Cerf, maquis de cistes, capacité de charge, Extremadura.*

Introduction

The Monfragüe Natural Park is the best preserved area of Mediterranean forests in the region of Extremadura (Herrera, 1984; Rivas-Martínez, 1987). The surroundings of the Park is formed by "dehesa" (open evergreen forest with grasslands) under livestock management. Inside the Park the Mediterranean shrublands and forest are dominant. In this area, livestock is forbidden and the range is only used by red deer (*Cervus elaphus* L.) (Paton *et al*., 1999). Red deer use shrublands mainly in late spring and summer, when the annual grasslands are parched. This use is important for females since it coincides with the final gestation period (Azócar *et al.,* 1991) and for males because it is before the rutting season. Shrublands used in summer can be between 29.6-72.1% of diet content (Rodríguez-Berrocal, 1993). *Cistus* spp. is 35% of shrublands and in certain areas are dominant. In the shrubland ecosystems the determination of appropriate carrying capacity is relevant for sustainable deer management (Papachristou *et al*., 1997; Robles and Passera, 1995). *Cistus*, species show low acceptabilities by deer due to their high toxicity (tannins and flavonoids) (Ballesteros *et al*., 1982).

Material and methods

Study area

Monfragüe Natural Park is located in Cáceres province (Southwestern Spain) (between 39º45' and 40º00' North latitude and 5º45' and 6º00' West longit ude). Average altitude is 360 m a.s.l. Soils have a low organic matter and phosphoric content, scarce deep and permeability (Devesa, 1995). Climate is sub-humid Mediterranean and the annual rainfall is 791 mm (Rivas-Martínez, 1987).

Sampling methods

During the springs of 1997 to 2000, botanical composition was determined by lineal cover transects of 50 m. Point-centred quarter method (Cottan and Curtis, 1956; Morisita, 1954) based on transects of 10 x 2 m^2 was used for the analysis of sizes and covers (Paton *et al.*, 1999; Robles, 1990). Total sampling surface was 2600 m^2 (130 transects).

Forage biomass of each plant was handled clipped (Azócar *et al.*, 1991; Mac Cracken and Van Ballenberghe, 1993; McCall *et al.*, 1997) in shrubs under 2.3 m of height as this is the browsing limit for the biggest deer (Paton *et al.*, 1999). The forage biomass was dried in a MEMERT stove to 65℃ during 72 h. Dry matter (DM) was weighed in an AND electronic balance with a precision level of ± 0.001 g.

Nutritional analysis

Six samples, 3 from small plants and 3 from big plants, were used for nutritional analysis. Ash was determined in a NEURTEK HD-230 electric oven. Crude protein (CP) was determined by Kjeldahl and acid detergent fibre (ADF) by Van Soest (AOAC, 1990). Metabolizable energy (ME) was calculated by a previous multivariate model based on CP, ADF and *in vitro* organic matter digestibility (IVOMD) (Paton, 2002).

Statistical analysis

Differentiation of the three types of *Cistus* shrublands was realised with TWINSPAN (Hill, 1994). Size-forage biomass relationships used for the analysis of productivity in each community were determined by log-log regressions (Paton *et al.*, 2002). These equations were applied to the metric data of each plant in each transect. DM of the whole plants of each species in the transect was added and the obtained productivity was transfered to kg/ha. Both productivity (DM) and nutritional parameters (CP, ADF and ME) were determined in each community and the differences tested by Kolmogorov-Smirnov test (Sokal and Rohlf, 1984).

Carrying capacity

Requirements in ME of deer are based on according Rodríguez-Berrocal (1993). We consider three types of animals in terms of energy: non-pregnant females, pregnant females and adult males and a population structure of 12%, 38% and 50% respectively. This population structure is considered the most suitable for deer management in the Park (Carranza, 1991). Therefore, the carrying capacity refers to a standard animal with an average energy requirements between the different groups. Use factor was calculated with the browsing indexes according to the methodology of Martínez (2002).

Results and discussion

The TWINSPAN programme shows three types of shrublands: with dominance in *Cistus ladanifer*, with dominance in *Cistus salvifolius* and a mixed shrubland with different species of *Cistus* and other shrubs (*Cytisus* spp. and *Genista* spp.). In Table 1 the average of density, cover, DM, browsing percentage, faecal remains, CP, ADF, ME and CC are shown.

Only the CP was significant ($P < 0.05$) different in the *Cistus salvifolius* community. Also the TWINSPAN differentiates three communities in terms of carrying capacity only exists two: *C. salvifolius* and the rest. With regard to the other communities (black heathers, etc.) in the Park, *Cistus* areas show very low carrying capacity (Paton *et al.*, 1999). These results should be explained by the high toxicity (tannins, flavonoids, terpenns, etc.) in *Cistus* (Chaves, 1994). The carrying capacities obtained show that from the point of view of range management, the ecosystems are not economically interesting for deer exploitation.

Table 1. Carrying capacity (CC) in the three communities and related parameters: plant density, plant cover, use factor by browsing index and faecal density, forage biomass, crude protein (CP) and metabolizable energy (EM)

Communities	C.ladanifer	Mixed	C.salvifolius
Density (plants/m^2)	0.53 ± 0.65	1.17 ± 2.02	0.48 ± 0.80
Cover (%)	37.34	57.21	50.96
DM (kg/ha)	1689.72 ± 1343.31	960.86 ± 654.32	1146.18 ± 569.20
% browsing	31.43 ± 36.04	22.79 ± 31.34	28.66 ± 36.12
Faecal remains	5.73 ± 5.89	4.13 ± 4.51	1.75 ± 2.87
CP (%)	8.77± 1.54	10.10 ± 1.21	12.23 ± 0.97
ADF (%)	46.43 ± 17.71	46.31 ± 16.12	46.03 ± 15.01
ME (kJ/kg)	6.59 ± 1.03	7.29 ± 0.84	7.70 ± 1.68
CC (deer ha^{-1})	0.03 ± 0.03	0.017 ± 0.01	0.07 ± 0.074

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