Note

Responses of Heather Moorland and Mediterranean Mouflon Foraging to Prescribed-Burning and Cutting

MARJORIE CAZAU, *Office National de la Chasse et de la Faune Sauvage, Centre National d'Étude et de Recherche Appliquée Faune de Montagne, 147 route de Lodève, 34990 Juvignac, France*

MATHIEU GAREL,[1] *Office National de la Chasse et de la Faune Sauvage, Centre National d'Étude et de Recherche Appliquée Faune de Montagne, 5 Allée de Bethléem, Z.I. Mayencin, 38610, Gières, France*

DANIEL MAILLARD, *Office National de la Chasse et de la Faune Sauvage, Centre National d'Étude et de Recherche Appliquée Faune de Montagne, 147 route de Lodève, 34990 Juvignac, France*

ABSTRACT We assessed the effects of prescribed burning and cutting on mouflon (*Ovis gmelini musimon* × *Ovis* sp.) spring habitat using an experimental design (17.28 ha) of 2 burned, 2 cut, and 2 untreated plots within a homogeneous stand dominated by heather (*Erica cinerea* and *Calluna vulgaris*). Overall, we found a shift in treated plots from ligneous species to herbaceous species with high digestive and energetic values for mouflon. We also found a consistently higher number of mouflon feeding on these treated habitats compared to untreated plots. Such effects were still apparent 4 years after habitat modifications. Our approaches could be used by managers to improve and maintain the range of mouflon populations experiencing habitat loss (e.g., woody plant encroachment) and for which the condition of an animal has often a high economical value through trophy hunting.

KEY WORDS diet forage quality, habitat improvement, mechanical cutting, open-landscape restoration, *Ovis gmelini musimon* × *Ovis* sp., mouflon, prescribed burning, scan sampling.

During the past century, changes in land use, including abandonment of pastoralism and suppression of controlled burning and wildfire, have caused many habitats to be overgrown with shrubs and forests (Wakelyn 1987). Because wild sheep are grazers that select large open areas dominated by grass-rich vegetation and high-visibility habitats near escape terrain, this loss of suitable habitat constitutes a major threat to wild sheep populations (Risenhoover and Bailey 1985, Wakelyn 1987).

Prescribed burning and cutting have been proposed as management tools for improving and maintaining wild sheep ranges (e.g., Smith et al. 1999). In grasslands and shrublands, burning has been found to lead to short-term increases in net primary productivity (Van Dyke and Darragh 2007, Borghesio 2009). As a consequence, ungulates preferentially use burned areas for their forage and nutrient values (Pearson et al. 1995, Smith et al. 1999, Van Dyke and Darragh 2007). In bighorn sheep, cutting has also been reported to increase site fidelity of animals through positive effects on habitat visibility (Smith et al. 1999).

We studied the effects of prescribed burning and cutting as tools for improving the habitat of a Mediterranean mouflon (*Ovis gmelini musimon* × *Ovis* sp.) population inhabiting the Caroux-Espinouse massif, southern France. Open areas decreased 50% over the last 50 years (Garel et al. 2007). Probably in relation to this loss of open areas, mouflon have changed the composition of their diet by including a higher proportion of ligneous species than herbaceous species (Cransac et al. 1997). This diet shift also probably contributed with selective hunting to the decline in body mass and trophy quality reported for this population (Garel et al. 2007). Because trophy hunting generates a large local income in mouflon populations (Whitfield 2003; our population: Garel et al. 2007), habitat improvement is a major management issue.

During 6 years (2003–2008), we monitored an experimental design to assess the lasting effects of prescribed burning and cutting on spring forage composition and quality in relation to the number of mouflon seen feeding on each treatment. Few studies have assessed concurrently the effects of these 2 methods on grazers' habitat and few have evaluated simultaneously changes in plant communities following habitat modifications and differences in treatment use by animals (Smith et al. 1999, Van Dyke and Darragh 2007); to our knowledge, none has performed both approaches.

STUDY AREA

Our study site was situated on the southern border of the Massif Central, in southern France. The massif hosts a population of Mediterranean mouflon introduced between 1956 and 1960 (for details on population characteristics, see

Received: 2 September 2009; Accepted: 5 August 2010

Additional Supporting Information may be found in the online version of this article.

[1]*E-mail: mathieu.garel@oncfs.gouv.fr*

Garel et al. 2005*a*). We studied mouflon habitat on the Caroux plateau, located on the southern edge of the massif (1,090 m above sea level, 43.60 °N, 2.99 °E).

We studied a homogeneous stand covering 17.28 ha on the eastern part of the plateau and consisting of a duplicate of 6 plots, each 360 m long and 80 m wide (Fig. 1). This stand was the largest homogeneous stand available on our study site and for which habitat treatments were allowed by land owners. The stand was an old moorland (>40 years without habitat modification) dominated by heather (*Erica cinerea* and *Calluna vulgaris*), with presence of broom (*Genista pilosa*, *G. anglica*, *Cytisus oromediterraneus*, and *C. scoparius*), pill sedge (*Carex pilulifera*), and grassy areas (*Festuca rubra*, *Agrostis canina*).

METHODS

In spring 2004, 2 plots of the experimental area (Fig. 1) were cut (C1 and C4 in Mar), two were burned (B3 and B6 in Apr), and two were left untreated (U2 and U5). Cutting was performed using a tractor (Landini, Saint-Dizier, France) fitted with a hammer-mill (Desvoys, Landivy, France). Average cut height was 5 cm. Cutting does not kill the plants but reduces their growth. Weather conditions during burning were favorable, with wind speed of 12 km/hr and 16 km/hr, air temperatures of 13.8 °C and 14.6 °C, and atmospheric humidity of 41% and 45% for B3 and B6, respectively. The highest temperatures reached during burning were 900 °C for the 2 burned plots.

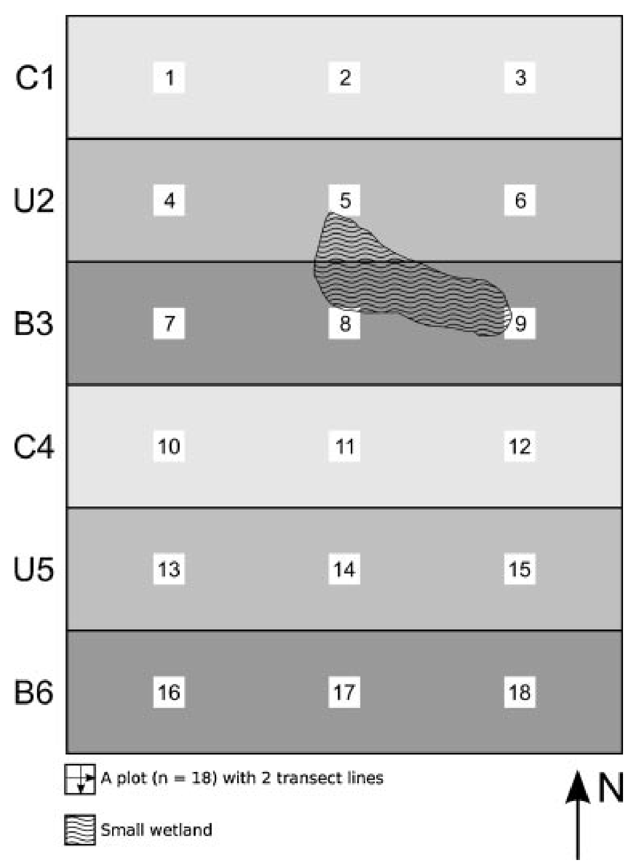

Figure 1. Experimental design (6 plots of 360 m × 80 m) we used to assess the effects of prescribed burning (B3 and B6) and cutting (C1 and C4) as management tools for improving mouflon habitat on the Caroux plateau, southern France, 2003–2008. U2 and U5 are untreated plots (control). White squares are 20-m × 20-m plots within which we monitored 2 vegetation transects using the point intercept protocol.

We placed 3 sampling units including 2 transects 20 m long on each plot (Fig. 1). We oriented transects north–south and west–east. Within plots U2 and B3 (plots 5, 8, and 9), we excluded a small wetland composed of bracken (*Pteridium aquilinum*), aspen (*Populus trembula*), and common tormentil (*Potentilla erecta*) from analysis, as it departed from the general floristic composition of the stand.

We focused our study on plant and mouflon surveys we performed during spring when energetic demands for reproduction require high food availability and quality to be met and when large groups occur in open areas (Bon et al. 1990). For each year, we used vegetation data we collected in June (the only spring month for which vegetation data is available each year) and mouflon observations we made during April–June (the only period for which observations are available each year). We performed the floristic composition survey from 2003 onwards, whereas we only performed the forage quality and mouflon survey from spring 2004 onwards (i.e., after burning and cutting). Therefore, in addition to spatial comparisons between treated and untreated plots, floristic data available in 2003 allowed us to temporally assess the effects of treatments on the floristic composition.

We monitored the floristic composition on each transect by using a specific protocol based on the point intercept method (e.g., Jonasson 1988). Fifty points were evenly spaced 40 cm apart along each transect. We vertically lowered a stick of 120 cm at each point. As compared to standard methodology, observers ($n = 5$) only recorded the presence or absence of contact between plants and the stick (Jonasson 1988). We expressed the result as the total number of contacts over a given transect.

We monitored estimated forage quality by cutting vegetation from a 0.25-m^2 (50 cm × 50 cm) quadrat drawn randomly within each plot. In 2004 and 2005, we took between 4 and 5 quadrat samples within each plot. From 2006 to 2008, we took between 2 and 3, and between 2 and 4 quadrat samples on untreated and treated plots, respectively, to reduce field effort. We dried parts of plants edible for mouflon (i.e., green stems of small diameter, leaves, and flowers; see Cransac et al. 1997) for 72 hr at 60 °C and then crushed them for analysis using Near Infrared Spectroscopy (NIRS). This technique was successfully used to measure several components of animal feed (e.g., protein, carbon fiber, and digestibility; Lyons and Stuth 1992). We measured 4 parameters: nitrogen materials (MAT), corresponding to indirect digestibility; lignin (ADL), indicating quality of fibers; solubility of organic matter (SMO); and dry matter (SMS), corresponding to in vitro digestibility (i.e., proportion of energy available for animals). We calibrated the NIRS equation against chemical reference analyses in laboratory (Kjeldahl method for nitrogen and Van Soest method for fibers; see Van Soest 1994). Coefficients of determination between predictions from NIRS equations and reference values obtained from chemical analyses range between 0.95 and 0.97, indicating that MAT, ADL, SMO, and SMS can be accurately predicted from NIRS analysis (Mark et al. 2002).

To assess attractiveness treatments to mouflon, we monitored the number of mouflon seen on each plot using the scan sampling method (see Altmann 1974). We made visual observations during the period of maximal feeding activity of mouflon (i.e., 2 hr after sunrise and 2 hr before sunset). From 2005 onwards, observations were limited to sunset scans because we detected no difference in the number of mouflon seen in 2004 between sunrise and sunset observations. Each scan sampling period lasted 2 hr, with a scan every 20 min ($n = 7$ scans). We recorded sex and age, activity (e.g., feeding, resting), and plot use of all individuals.

We pooled intercept points of each plant species we recorded using the point intercept protocol into 5 categories according to the mouflon diet (Cransac et al. 1997): herbaceous species (HR), heather species (two categories: *Erica cinerea* [EC] and *Calluna vulgaris* [CV]), sedges (SD), and other woody plants (WP). The data consisted of a contingency table where each row corresponded to the sum of the intercept points for each plant category (in columns) for a given transect, a given plot, a given treatment, and year ($n = 180$ rows). We performed a factorial correspondence analysis (FCA) on this contingency table and then used a between-class analysis to assess treatment-year-specific differences in floristic composition. We computed the variance interclass (class = treatment-year) and assessed its significance using a permutation test. We applied a similar approach to forage quality data where each row corresponded to forage variables (MAT, ADL, SMS, and SMO in columns) for a given quadrat sample, a given treatment, and year ($n = 107$ rows). Because forage variables were quantitative we used a principal component analysis (PCA) instead of FCA.

We discarded observations (35 scans among 686) made in unfavorable conditions (e.g., human disturbance, fog, and rain) and restricted analyses to sunset scans to be consistent throughout the study period. We only used data for individuals that we observed feeding, as we expected habitat treatments to provide better foraging conditions for mouflon. We used a hurdle model because many scans led to zero observations (90%), which cannot be accounted for by a Poisson model (Martin et al. 2005). The hurdle model is a 2-component model that fits zeros separately from non-zero observations using a binomial model. For the non-zero observations, we used a truncated (i.e., left truncated at $y = 1$) negative binomial distribution with a log-link because counts are most often overdispersed (Martin et al. 2005; present study: $\bar{x} = 3.0$, variance = 5.9). We used the logarithm of the area of each plot visible from the observation point as an offset variable. We then accounted for effects of temperature, plot, and year both in the hurdle and in the count components of the model. Temperature has been shown to negatively affect the number of mouflon seen (Garel et al. 2005*b*). We assessed the significance of each effect using likelihood ratio-tests.

The data were partly non-independent for a given scan sampling period due to the short time interval between each scan. In addition, one animal can also be repeatedly seen over several days or years. This pseudo-replication may bias parameter estimates. We partly evaluated such bias by randomly drawing for each plot 1 observation among the 7 observations obtained during a scan sampling and by replicating this procedure 1,000 times. When fitting a model with a plot effect to such data, we did not find any difference between bootstrap estimates obtained from these 1,000 subsamples and maximum likelihood estimates obtained on the whole data set (results not presented here). We performed all statistical analyses using R (R version 2.11.1, R Development Core Team 2007; http://www.r-project.org/, accessed 31 May 2010) with the ade4 (Chessel et al. 2004) and pscl (Zeileis et al. 2008) packages.

RESULTS

We found treatment-year-specific differences both in floristic composition (inter-class variance = 72.5%, $P < 0.001$) and forage quality (inter-class variance = 53.2%, $P < 0.001$). We expected the highest inter-annual variation for floristic composition because floristic data were available before habitat improvements (i.e., in 2003, Fig. 2a). Most of the floristic composition (75.1%) and forage quality (72.4%) structure was accounted for by the first axis of multivariate analyses, opposing transects composed of lignified species against transects composed of HR (Fig. 2a), and quadrat samples with a high proportion of low digestibility lignin against quadrat samples with high quality forage (Fig. 2b). The second axis was characterized by transects with presence of SD (variance explained = 17.5%, Fig. 2a) and quadrat samples with a high proportion of nutrients (20.9%, Fig. 2b) for floristic and forage analyses, respectively.

From the floristic composition analysis, we found in 2003 a consistent homogeneity among all plots dominated by heather. Compared to treated plots and the reference year (2003), floristic composition of transects monitored on untreated plots varied little during the study period, being lastingly dominated by heather. In 2004, 3 months after burning and 2 months after cutting, we found a shift in floristic composition from heather to HR in B3, B6, C1, and to a lower extent in C4. These changes were still present during the following 4 years of monitoring.

In vitro digestibility (SMS–SMO) decreased with increasing lignin (ADL; see correlation circle, Fig. 2b). The highest levels of nutrients in the vegetation was reached in 2004 on B3 and B6 and decreased the following years. Compared to untreated plots where samples had high levels of lignin, solubility of organic and dry matter remained high during the monitoring period on B3, B6, and C1 whereas C4 occupied an intermediate position. These results consistently reflected the difference in floristic composition between plots (e.g., dominance of heather on U2 and U5, and dominance of HR on B3, B6, and C1; see Fig. 2a).

Both the probability of seeing mouflon and the number of mouflon seen were negatively affected by increasing temperature (binomial model: slope [logit scale] = -0.470, SE = 0.114, $P < 0.001$; truncated negative binomial model: slope [log scale] = -0.297, SE = 0.150, $P = 0.047$).

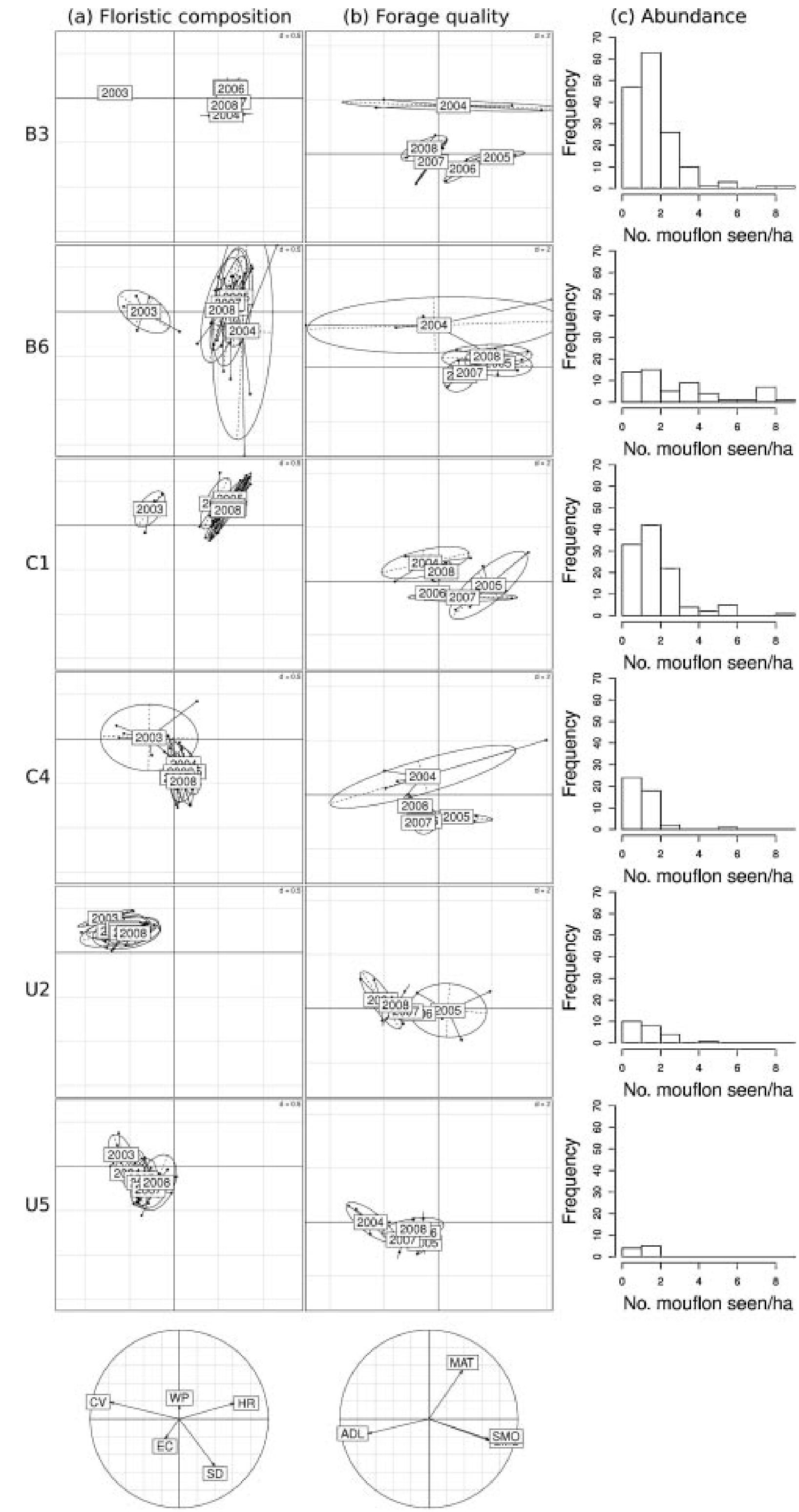

Figure 2. Statistical analyses of data collected in spring on each plot to assess a) floristic composition, b) forage quality, and c) mouflon abundance, on the Caroux plateau, southern France, 2003–2008. B3 and B6 were prescribed burn plots, C1 and C4 were cut plots and U2 and U5 were untreated plots. a) Between-class analysis (structured by year and plot) on a FCA: projection of the transects monitored to assess floristic composition of each plot on the first (horizontal) and second (vertical) axes (variance explained 92.6%) and correlation circle. HR, herbaceous species; EC, *Erica cinerea*; CV, *Calluna vulgaris*; SD, sedges; and WP, other woody plants. b) Between-class analysis (structured by year and plot) on a PCA: projection of the vegetation samples analyzed to assess forage quality of each plot on the first (horizontal) and second (vertical) axes (variance explained 93.3%) and correlation circle. MAT, nitrogen material; ADL, lignin; SMO, solubility of the organic matter; SMS, solubility of dry matter. Note that SMO and SMS labels were overlapped. c) Frequency of animals seen (excluding zero observations) by scan and by hectare from 2004 to 2008.

Probability of seeing mouflon during scans varied among years and plots (binomial models; years + plots vs. years × plots: df = 20, $\chi^2 = 44.3$, $P < 0.001$), whereas we only found differences among plots when modeling non-zero observations (truncated negative binomial models; year effect: df = 4, $\chi^2 = 4.77$, $P = 0.31$; plot effect: df = 5, $\chi^2 = 27.08$, $P < 0.001$). We observed more mouflon on B3, B6, and C1 than on control plots, with C4 still in an intermediate position (Fig. 2c, Table 1). These results were consistent with our floristic composition and forage quality findings when assessing between-plot differences (Fig. 2a,b). No forage quality data were available in 2003 so only spatial references (i.e., U2 and U5), and no temporal references (i.e., 2003), were available. For all plots (except B6) we observed the most mouflon in 2004 (2006 in B6), when burning and cutting were performed; the number of mouflon we

Table 1. Predicted number of feeding mouflon from the hurdle model fitted to scan sampling observations on the Caroux plateau, southern France, 2003–2008. We made predictions for a given year and plot for 100 scans, at average temperature (15.3 °C) and for 1 ha.

		Year						
Treatments	**Plots**	**2004**	**2005**	**2006**	**2007**	**2008**	**Total**	**Average**
Burning	B3	91	47	39	39	36	252	178.5
	B6	15	13	41	19	17	105	
Cutting	C1	61	34	24	46	31	196	133.0
	C4	31	7	11	6	15	70	
Untreated	U2	26	7	4	0	4	41	26.5
	U5	4	1	2	2	3	12	

observed then markedly decreased in 2005 and remained roughly stable until the end of the monitoring (Table 1). Groups feeding on B6 were on average larger than groups seen on B3 and C1 (Fig. 2c). Overall, spring vegetation and mouflon surveys showed consistent patterns across treatments (e.g., significant habitat improvement on treated plots was related to more mouflon seen feeding).

DISCUSSION

We found a positive effect of prescribed burning on forage characteristics in terms of digestibility and energy content for mouflon (see also Hobbs and Spowart 1984). Accordingly, we observed more individuals feeding on burned areas compared to untreated plots as previously shown in bighorn sheep populations (Smith et al. 1999), and these differences were still present 4 years after treatments. Cutting also appeared to be effective in removing lignified species, such as *Calluna vulgaris*, and in restoring favorable mouflon habitat on 1 plot (C1), as did burning (Fig. 2, Table 1). For the other cut plot (C4), trophic quality of the cover after cut was much lower. This difference between cut plots most likely arose from a difference in cutting processing. Presence of stones on C4 often required a greater cut height, which resulted in a superficial cut of the moor that prevented development of HR.

Spatio-temporal differences in the number of mouflon seen feeding on B3 versus B6 and on U2 versus U5 cannot be linked to variation in floristic composition or forage quality. These differences most likely originated from the spatial arrangement of our experiment (Fig. 1) and from the partial failure of treatment on C4. Therefore, untreated plot U2 benefited during the first year from mouflon using B3 and C1, whereas B6 was spatially isolated from B3 and C1, the 2 most used plots. In addition, a culture of grasses, cereals, and vegetables (approx. 2.5 ha) frequently used by mouflon (122 mouflon/100 scans per ha) was present northeast of C1, thereby attracting part of the local population close to C1 and B3.

In 2004, a few months after treatments, we observed the highest number of feeding mouflon for all plots (Table 1), with more mouflon on U2 than on B6, probably due to an increasing use of the plots neighboring U2 compared to B6 (see above). This greater use of the whole experiment suggests a global attractiveness of the stand shortly after treatments and before animals preferentially chose treated plots.

Prescribed burning released ashes on the ground, whereas cutting left plant residuals. Consequently, mineral fertilization of the soil should be faster on burned plots than on cut plots, which may explain the higher nutrient quality (MAT) on burned treatments than on C1 only a few months after habitat treatment (Fig. 2b). This change following burning is consistent with the short-term increase in net primary productivity reported in previous studies (Van Dyke and Darragh 2007, Borghesio 2009).

Management Implications

Burning and cutting by creating herbaceous areas attractive to foraging mouflon might be effective for improving spring mouflon feeding areas and subsequently improving animal condition. Burning and cutting are therefore worthwhile considerations for mouflon habitat management, as mouflon generate large incomes through local economic activity focused on trophy hunting (e.g., Whitfield 2003). Furthermore, creating attractive areas for wild sheep at specific locations could allow limitation of damage on commercial forests and vineyards, 2 other important local sources of incomes.

Habitat treatments should be performed at a larger scale (e.g., 200–300 ha, consistent with the home range size of mouflon) to allow assessment of demographic responses of the population. When planning habitat treatments at a larger scale, the choice between cutting and prescribed burning, as well as the frequency at which each method should be used, will depend on cost, topography (e.g., slope), weather conditions (e.g., rainy and windy), and soil condition (e.g., potential for erosion, which could be exacerbated by burning; Fernández et al. 2008). Our results also emphasize similar treatments might incur different results (C1 vs. C4, B3 vs. B6) and we strongly suggest that particular attention be paid to how such methods are performed in the field (e.g. cut height for the cutting method). Untreated habitats that contributed to the creation of a mosaic of vegetation could also be maintained to prevent loss of biodiversity and long-term results might be obtained by combining habitat modification with increasing herbivore grazing (Pons et al. 2003, Borghesio 2009).

Acknowledgments

We thank P. Bonnel and J.-L. Durand of Groupement d'Intérêt Environnemental et Cynégétique, the city and ACCA of Rosis, and the Cellule de Brûlage Dirigé de Béziers for their technical support for cutting and prescribed burning. We are grateful to the trainee and intern of Office National de la Chasse et de la Faune Sauvage for collecting vegetation and mouflon data, especially C. Guilliot, S.-P. Babski, J. Duhayer, and E. Marty. A special thanks to M. Tronchot for her unvaluable help and considerable involvement in this project. We thank J.-M. Cugnasse for his ideas and advices, D. Bastianelli and L. Bonnal of CIRAD for providing NIRS data, A. Bernard-Laurent and J.-M. Gaillard for their corrections on a previous version of this manuscript, and C. Carter for correcting the English.

LITERATURE CITED

Altmann, J. 1974. Observational study of behavior: sampling methods. Behaviour 49:227–267.

Bon, R., G. Gonzales, S. Im, and J. Badia. 1990. Seasonal grouping in female mouflons in relation to food availability. Ethology 86:224–236.

Borghesio, L. 2009. Effects of fire on the vegetation of a lowland heathland in north-western Italy. Plant Ecology 201:723–731.

Chessel, D., A.-B. Dufour, and J. Thioulouse. 2004. The ade4 package – I: one table methods. R News 4:5–10.

Cransac, N., G. Valet, J.-M. Cugnasse, and J. Rech. 1997. Seasonal diet of mouflon (*Ovis gmelini*): comparison of populations sub-units and sex-age classes. Revue d'Ecologie-La Terre et la Vie 52:21–36.

Fernández, C., J. A. Vega, T. Fonturbel, E. Jiménez, and J. R. Pérez. 2008. Immediate effects of prescribed burning, chopping and clearing on runoff, infiltration and erosion in a shrubland area in Galicia (NW Spain). Land Degradation and Development 19:502–515.

Garel, M., J.-M. Cugnasse, J.-M. Gaillard, A. Loison, P. Gibert, P. Douvre, and D. Dubray. 2005a. Reproductive output of female mouflon (*Ovis gmelini musimon*×*Ovis* sp.): a comparative analysis. Journal of Zoology (London) 266:65–71.

Garel, M., J.-M. Cugnasse, A. Loison, J.-M. Gaillard, C. Vuiton, and D. Maillard. 2005b. Monitoring the abundance of mouflon in South France. European Journal of Wildlife Research 51:69–76.

Garel, M., J.-M. Cugnasse, D. Maillard, J.-M. Gaillard, A. J. M. Hewison, and D. Dubray. 2007. Selective harvesting and habitat loss produce long-term life history changes in a mouflon population. Ecological Applications 17:1607–1618.

Hobbs, N. T., and R. A. Spowart. 1984. Effects of prescribed fire on nutrition of mountain sheep and mule deer during winter and spring. Journal of Wildlife Management 48:551–560.

Jonasson, S. 1988. Evaluation of the point intercept method for the estimation of plant biomass. Oikos 52:101–106.

Lyons, R. K., and J. W. Stuth. 1992. Fecal NIRS equations for predicting diet quality of free-ranging cattle. Journal of Range Management 45:238–244.

Mark, H., G. E. Ritchie, R. B. Roller, E. W. Ciurczak, C. Tso, and S. A. MacDonald. 2002. Validation of a near-infrared transmission spectroscopic procedure, part A: validation protocols. Journal of Pharmaceutical and Biomedical Analysis 28:251–260.

Martin, T. G., B. A. Wintle, J. R. Rhodes, P. M. Kuhnert, S. A. Field, S. J. Low-Choy, A. J. Tyre, and H. P. Possingham. 2005. Zero tolerance ecology: improving ecological inference by modelling the source of zero observations. Ecology Letters 8:1235–1246.

Pearson, S. M., M. G. Turner, L. L. Wallace, and W. H. Romme. 1995. Winter habitat use by large ungulates following fire in northern Yellowstone national park. Ecological Applications 5:744–755.

Pons, P., B. Lambert, R. Rigolot, and R. Prodon. 2003. The effects of grassland management using fire on habitat occupancy and conservation of birds in a mosaic landscape. Biodiversity and Conservation 12:1843–1860.

R Development Core Team. 2007. R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Risenhoover, K. L., and J. A. Bailey. 1985. Foraging ecology of mountain sheep: implications for habitat management. Journal of Wildlife Management 49:797–804.

Smith, T. S., P. J. Hardin, and J. T. Flinders. 1999. Response of bighorn sheep to clear-cut logging and prescribed burning. Wildlife Society Bulletin 27:840–845.

Van Dyke, F., and J. A. Darragh. 2007. Response of elk to changes in plant production and nutrition following prescribed burning. Journal of Wildlife Management 71:23–29.

Van Soest, P. J. 1994. Nutritional ecology of the ruminant. Second Edition. Cornell University Press, Ithaca, New York, USA.

Wakelyn, L. A. 1987. Changing habitat conditions on bighorn sheep ranges in Colorado. Journal of Wildlife Management 51:904–912.

Whitfield, J. 2003. Sheep horns downsized by hunters' taste for trophies. Nature 426:595.

Zeileis, A., C. Kleiber, and S. Jackman. 2008. Regression models for count data in R. Journal of Statistical Software 27:1–125.

Associate Editor: David Euler.