

# A subalpine rangeland bird community before and after fire: prescribed burning in the Eastern Pyrenees

Pere Pons

High mountain rangelands host important populations of threatened bird species, but can be affected by extensive changes in land use. I studied the breeding bird community of two shrubland plots at 1,850–2,100 m a.s.l. in the Pyrenees. Breeding territories were mapped for four years, before and after the prescribed burning, the aim of which was to increase the grazing value of the study area. The most abundant species (reaching  $\geq 3$  breeding pairs/10 ha in at least one plot and one year) were Dunnock *Prunella modularis*, Dartford Warbler *Sylvia undata*, Stonechat *Saxicola torquatus*, Rock Bunting *Emberiza cia* and Ortolan Bunting *E. hortulana*. The open-shrubland plot contained a similar number of breeding species (10 vs. 9), but a lower overall density (23 vs. 28 breeding pairs/10 ha) than the dense-shrubland plot. Most breeding species also occurred in winter. After fire, the number of bird species, overall density and conservation value (an index that takes into account all species' densities and their categories of conservation concern in Europe) decreased, but tended to recover afterwards. These results may help understand the composition and dynamics of bird assemblages in managed mountain areas.

Key words: mountain shrublands, grassland management, territory mapping, breeding bird densities, conservation value

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In Europe different landscape dynamics are at work in mountains and lowlands. In general, mountainous areas are less affected by urban growth and by the development of large infrastructures. Nevertheless, the effects of global warming are especially noticeable in mountain habitats, and indeed habitats may shift in altitude (Peñuelas & Boada 2003), thereby leading to changes in the distribution of animal species. The most accessible extensive livestock-raising areas are threatened by intensification and overgrazing. On less accessible slopes, grazing is being abandoned, which is followed by shrub encroachment and spontaneous afforestation (Roura-Pascual *et al.* 2005). In order to reverse this trend, large areas of montane and subalpine shrubland are currently managed to reduce shrub cover and improve their grazing value for live-

stock in summer. Prescribed burning is a widely used management tool and is extensively employed in the Pyrenees and other Mediterranean mountain areas (Lambert & Parmain 1990).

The avifauna of low altitude burned forests in the Mediterranean has received considerable attention. For example, the impact of post-fire management on birds has been a topic of substantial research in Catalonia in recent years (Anton *et al.* 2009, Herrando *et al.* 2009, Rost *et al.* 2010). However, post-fire studies at high altitude (1,500–3,000 m a.s.l.) are still scarce in the Mediterranean Basin. Yet, this avifauna possesses a particular combination of species that live in a hostile environment and face the specific threats mentioned above. Furthermore, Mediterranean mountains harbour important populations of bird species which have unfavourable conserva-

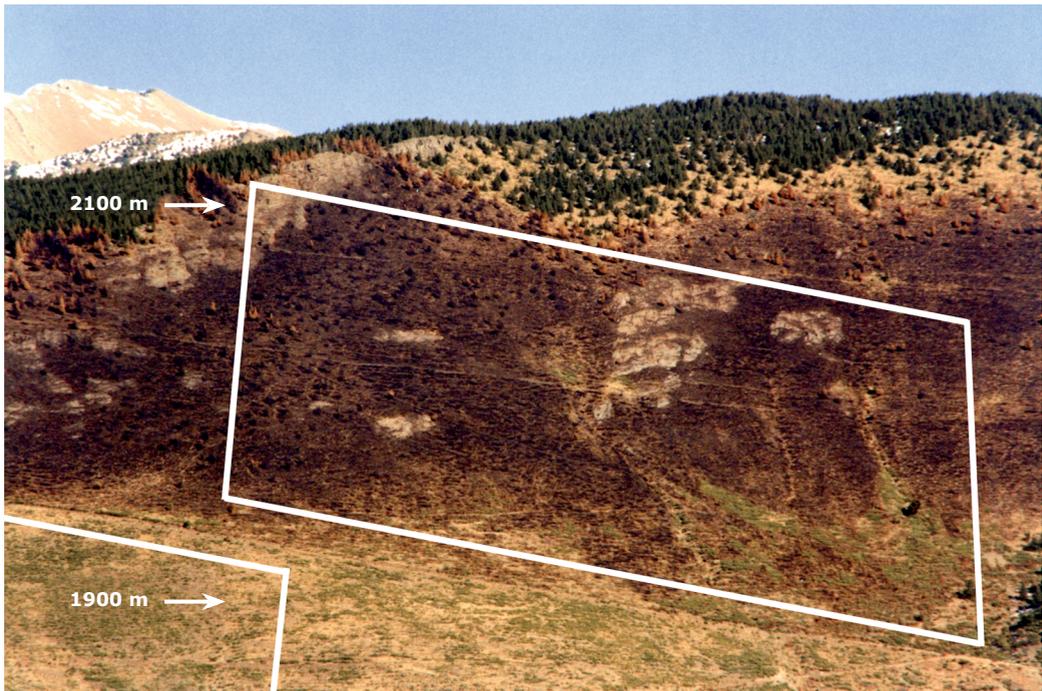
tion status in Europe (Tucker & Evans 1997). Available publications, concerning the Pyrenees and the Sierra Nevada, highlight the value of burned rangelands for bird conservation (Pons *et al.* 2003), reveal that the short-term impact of fire on birds depends on its severity (Pons & Clavero 2010), demonstrate that logging burned trees can be detrimental to avifauna (Castro *et al.* 2010), and suggest that avian communities in upland areas recover more slowly after fire than those in lowland areas (Pons & Clavero 2010).

The general aim of this work was to study the breeding bird community of a subalpine rangeland in the Pyrenees. Thus, I mapped bird territories and measured vegetation structure in two plots, one with high and the other with low shrub density, for four years. Both plots were managed by prescribed burning and grazed during the study period. The specific objectives were to contrast bird density and vegetation volume, and to describe the composition and conservation value of the bird community before

and after the fires. In addition, due to the lack of available studies at this altitude, I also verified which species occurred in winter.

## Study Area

The study area at Err (42°27'N, 2°4'E) is located on the Puigmal massif (2,913 m a.s.l.) in the French Pyrenees. These south-west-facing slopes are used for summer grazing and managed by local shepherds and the SUAMME (*Service d'Utilité Agricole Montagne Méditerranéenne et Elevage* in Prada de Conflent). Two plots (A and B), each of 10 ha (300 x 333 m), were established in spring 1997 in subalpine shrublands dominated by Pyrenean Broom *Cytisus balansae* and a grass, *Festuca paniculata*. The plots were 30 m apart at their corners (Figure 1) and divided into a grid of 50 x 50 m using 1.5-m high stakes planted in the ground. Plots and their surroundings were affected by prescribed burning during



**Figure 1.** Location and altitude above sea level of the Err study plots in the Pyrenees. The photograph was taken a few days after the prescribed burning of Plot A in November 1997. The corner of plot B is shown in the bottom left-hand corner of the picture.

*Ubicació i altitud sobre el nivell del mar de les parcel·les d'estudi d'Err, als Pirineus. La fotografia va ser presa pocs dies després de la crema prescrita de la parcel·la A, el novembre de 1997. La cantonada de la parcel·la B s'observa a la part inferior esquerra de la imatge.*

the first (plot A) and the second (plot B) winters after the beginning of the study. These fires were part of a long-term programme run by SUAMME aimed at controlling shrub encroachment in stock-breeding areas in the Eastern Pyrenees.

Plot A was located at 1,900–2,100 m a.s.l. and consisted of a one-meter high dense shrubland, containing 138 young Mountain Pines *Pinus uncinata*, mostly in the highest part. Its vegetation was 35 years old in 1997, the last wildfire having occurred in 1962–63 (B. Lambert pers. comm. based on aerial photographs). An intense fire set on 28 November 1997 burnt 88% of the plot area (Figure 1) and only seven pines survived this prescribed burning. The plot had been grazed infrequently by cattle and wild ungulates (*Cervus elaphus* and *Rupicapra pyrenaica*) before the fire. Afterwards, grazing intensity increased. Plot B was a 7-year-old open shrubland with grassland at 1,850–2,000 m a.s.l. (prescribed burning took place in winter 1989–90, the last wildfire also having occurred in 1962–63). There were < 10 pines in this plot, but there were also some old junipers *Juniperus communis*, that mostly survived the prescribed burning. In all, 78% of the plot area was burnt by a relatively mild fire on 11 March 1999. The plot was quite intensively grazed by horses and cattle both before and after the fire. After fire, a detailed map of burned and unburned vegetation was drawn for both plots and used in both the bird and vegetation studies.

## Methods

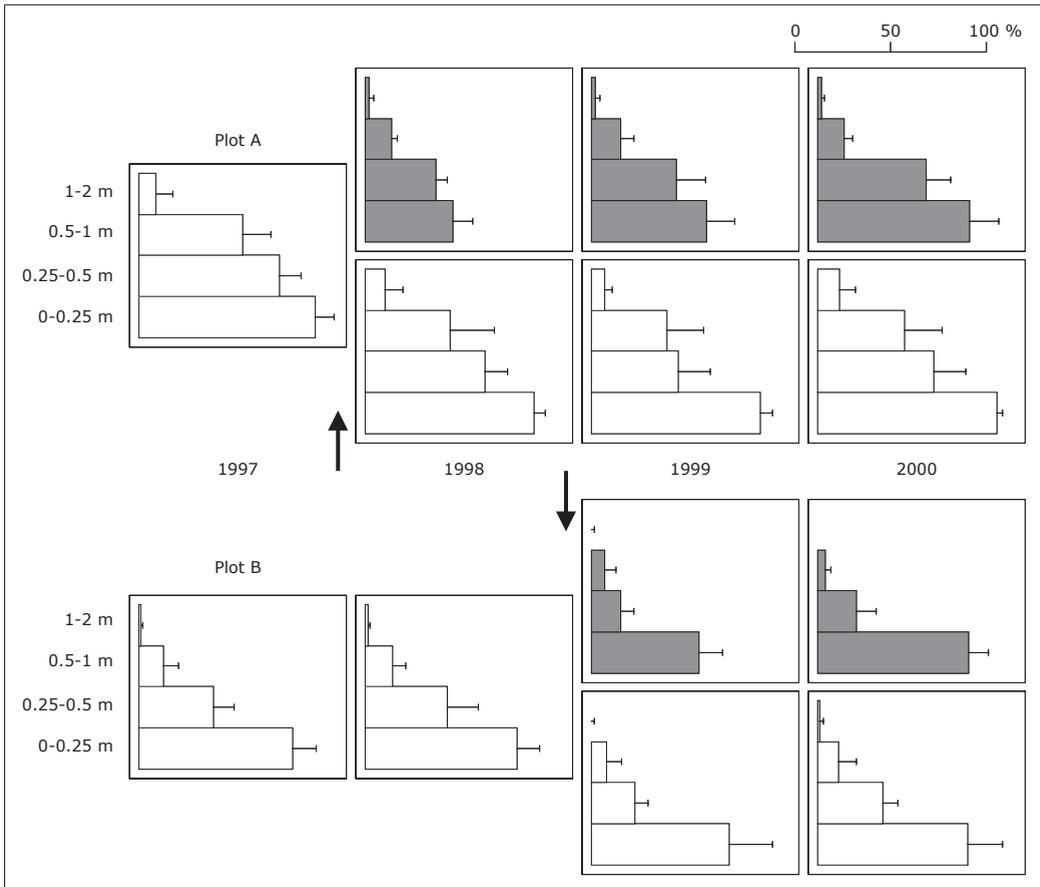
Vegetation and birds were studied in June 1997–2000, the main period of bird song in the Pyrenees. Vegetation structure was measured once a year before the fire in each plot at 13 fixed sampling stations, regularly distributed at ~100-m intervals. After the fire in each plot 10 stations were selected in well-burned areas and eight in areas containing unburned patches. Each sampling station covered an area of ~1,200 m<sup>2</sup>, in which the foliage cover (in %) of six vegetation layers (0–0.25 m, 0.25–0.5 m, 0.5–1 m, 1–2 m, 2–4 m and 4–8 m) was estimated by comparison with a template (Prodon & Lebreton 1981). A vegetation volume index was then constructed by multiplying cover values by the height of the layer and then summing up the products. After the fire, volume was calculated separately for

burned and unburned vegetation, weighted by their corresponding areas, and then pooled to calculate a global index for each plot.

Birds were studied by a mapping method which allows detailed maps of the breeding territories found in a given plot to be generated (Bibby *et al.* 1997). Using this method, I concentrated on simultaneous songs in order to distinguish neighbouring territorial males. Observations from daily visits were cumulated until there was very little doubt about the precise location of territorial boundaries. The number of visits ranged from eight to 10 per year. These visits lasted on average five hours (including mornings and sometimes afternoons); both plots were mapped every day. Specific densities (breeding pairs/10 ha) were calculated by taking into account not only the territories totally included in the plots, but also the within-plot proportion (0.25–0.5–0.75) of edge territories (i.e. those also extending outside the plot). In addition, global density (total number of breeding pairs/10 ha), bird species richness (number of breeding species) and conservation value were calculated for every plot and year. The conservation value was calculated following the index in Pons *et al.* (2003), which takes into account the European conservation status or SPEC (BirdLife International 2004) and the log-transformed density (abundance in the original index) of the bird species recorded in the plot. As well, the structure of the bird community was described using a Correspondence Analysis (CA) performed on bird species' densities per plot-year. The CA was focused on inter-species distances and was performed with Canoco (ter Braak & Smilauer 1998). Finally, five visits to the plots in November 1997 to February 1998 were used to confirm the occurrence of breeding species in the cold season.

## Results

Plot A had the densest cover before the fire and as a result the fire here was more severe than in Plot B. Prescribed burning noticeably affected the four vegetation layers from the ground to two meters in height in plot A. Moreover, cover values of burned areas did not reach those of unburned areas during the study (Figure 2). By contrast, cover values of burned areas in plot B



**Figure 2.** Mean vegetation structure (% foliage cover of four vegetation layers) of unburned (open bars) and burned areas (grey bars) in the Err study plots. Error bars show standard deviation. Arrows show the fire date in each plot.

*Estructura vegetal mitjana (% de recobriments foliar de quatre estrats de vegetació) d'àrees no cremades (barres blanques) i cremades (barres grises) a les parcel·les d'estudi d'Err. Les barres d'error mostren la desviació estàndard. Les fletxes indiquen la data de foc a cada parcel·la.*

were similar to those of unburned areas by the second year after the fire.

The most abundant species of both plots was the Dunnock *Prunella modularis*, which reached its highest density (14.5 b.p./10 ha) in the dense shrubland of plot A before the fire (Table 1). Other species present in high densities ( $\geq 3.0$  b.p./10 ha) in particular plots and years were Dartford Warbler *Sylvia undata*, Stonechat *Saxicola torquatus*, Rock Bunting *Emberiza cia* and Ortolan Bunting *E. hortulana*. Nests were found or behaviour indicating nest construction, nest defence or feeding young were observed for all the commonest breeding species. Over-

all bird density ranged between 13.2 and 28.0 b.p./10 ha and the number of breeding species varied between seven and 11, while the bird conservation value varied between 10.0 and 21.4. All these community variables decreased in the first year after fire, especially in plot A, although tended to return to former values in the following years. Furthermore, there was a remarkable similarity between changes in overall bird density and changes in vegetation volume in both plots (Figure 3).

The first and second axes of the CA accounted for 55.7% and 20.9%, respectively, of the variance of the dataset. The first axis

separates the two plots and appears to be related from right to left to increasing vegetation cover. This is supported by species position (e.g. Dartford Warbler to the left and Skylark *Alauda arvensis* to the right), but also by changes in plot coordinates after the fires (Figure 4). The second axis seems mainly to be related from bottom to top with increasing herbaceous cover in areas with sparse trees, burned or otherwise, in plot A. This interpretation is supported by the position on the graphic of Tree Pipit *Anthus trivialis* and Whinchat *Saxicola rubetra* (Figure 4).

If we exclude long distance migrants, most species also occurred in winter, the most important exception being the Dunnock (Table 1). In complete contrast, the Dartford Warbler, a

Mediterranean species, was present even after snowfall. Other species that did not breed in the plots but occurred in winter (some of them also in spring) were Meadow Pipit *Anthus pratensis*, Goldfinch *Carduelis carduelis*, Chaffinch *Fringilla coelebs*, Coal Tit *Periparus ater*, Crested Tit *Lophophanes cristatus*, Alpine accentor *Prunella collaris*, Citril Finch *Carduelis citrinella* and Mistle Thrush *Turdus viscivorus*.

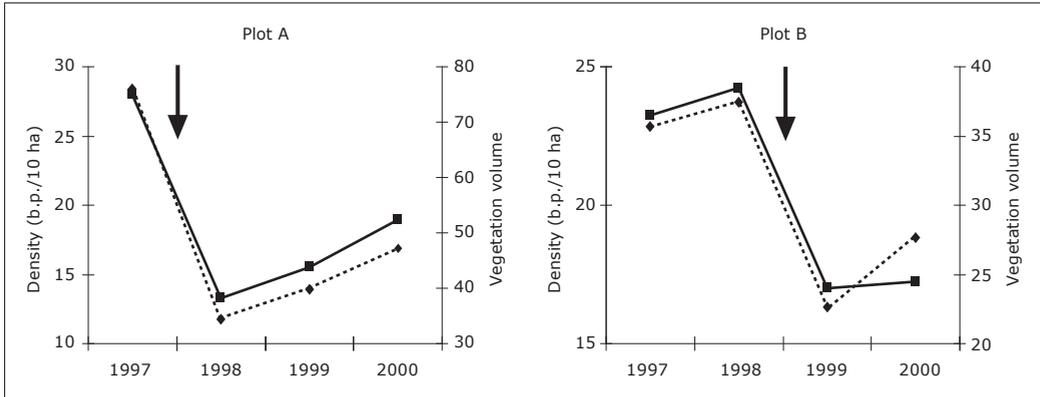
## Discussion

Density estimates derived from mapping methods have been used to assess the response of bird communities to disturbances such as timber

**Table 1.** The bird community before and after fire (arrow) at the two study plots at Err. Columns show breeding species, SPEC category (BirdLife International 2004), study years for both plots and occurrence in winter (LDM = long-distance migrant overwintering abroad). Rows show data for every species (including breeding densities in b.p./10 ha), number of breeding species, overall density (b.p./10 ha) and the conservation value index (Pons et al. 2003). Specific densities equal to or above 3 b.p./10 ha are shown in bold.

*Comunitat d'ocells abans i després del foc (fletxa) en les dues parcel·les d'estudi d'Err. Les columnes mostren les espècies nidificants, categories SPEC (BirdLife International 2004), anys d'estudi per a ambdues parcel·les i aparició durant l'hivern (LDM = migradors de llarga distància hivernant fora de Catalunya). Les files mostren les dades per a cada espècie (incloent-hi la densitat reproductora en parcel·les/10 ha), el nombre d'espècies nidificants, la densitat total (parcel·les/10 ha) i un índex de valor de conservació (Pons et al. 2003). Les densitats específiques iguals o superiors a 3 parcel·les/10 hectàrees s'assenyalen en negreta.*

Species	SPEC	Plot A				Plot B				Winter
		1997	1998	1999	2000	1997	1998	1999	2000	
<i>Alauda arvensis</i>	3	0	0	0	0	2.5	2	1.75	1.75	NO
<i>Alectoris rufa</i>	2	0	0	0	0	0	0	0	0.25	NO
<i>Anthus trivialis</i>	-	0	0	0.5	1	0.25	0	0	0	LDM
<i>Carduelis cannabina</i>	2	1.5	1	1	0.75	0.5	1	0.5	0.5	YES
<i>Coturnix coturnix</i>	3	0	0	0	0	0	1	0	0	LDM
<i>Emberiza cia</i>	3	0.75	2	2	<b>3.75</b>	2.5	2.25	<b>3.25</b>	2.25	YES
<i>Emberiza hortulana</i>	2	0	0	0	0.75	2.5	2.5	<b>3</b>	2.5	LDM
<i>Lanius collurio</i>	3	0	0.75	1	1	1	0.75	0.25	2.5	LDM
<i>Lullula arborea</i>	2	0	0	0	0.25	0.75	1	1.25	1.25	YES
<i>Prunella modularis</i>	E	<b>14.5</b>	<b>7.25</b>	<b>6</b>	<b>6.75</b>	<b>8.25</b>	<b>7.25</b>	<b>4.25</b>	2	NO
<i>Saxicola rubetra</i>	E	0.75	0.25	2	1.75	0	0	0	0	LDM
<i>Saxicola torquatus</i>	0	2.25	1	2	1.5	<b>4.75</b>	<b>4.5</b>	2	<b>3</b>	YES
<i>Sylvia communis</i>	E	2	0	0	0	0	0	0	0	LDM
<i>Sylvia undata</i>	2	<b>5</b>	1	1	1	0	1.5	0	0.5	YES
<i>Turdus merula</i>	E	1	0	0	0	0.25	0.5	0.75	0.75	YES
<i>Turdus torquatus</i>	E	0.25	0	0	0.5	0	0	0	0	YES
Number of species		9	7	8	11	10	11	9	11	
Overall density		28	13.25	15.5	19	23.25	24.25	17	17.25	
Conservation value		15.5	10.0	11.2	14.7	16.2	21.4	16.1	18.8	



**Figure 3.** Overall breeding bird density (solid line) and vegetation volume (dashed line) in the Err study plots. Arrows show the fire date in each plot.

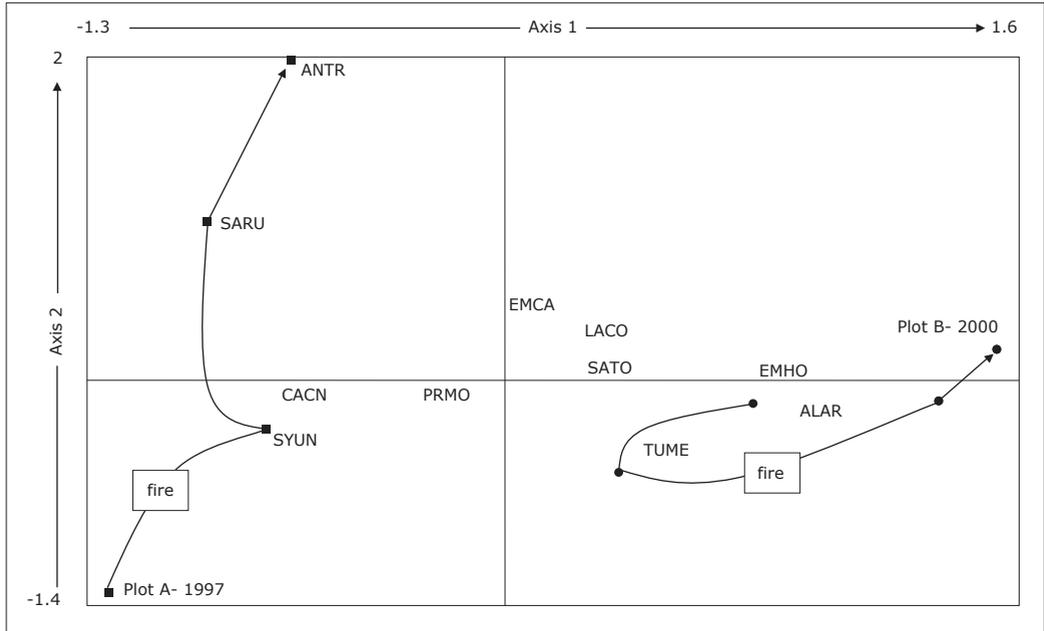
*Densitat global d'ocells reproductors (línia contínua) i volum de la vegetació (línia discontinua) a les parcel·les d'estudi d'Err. Les fletxes indiquen la data de foc a cada parcel·la.*

harvesting (Sallabanks *et al.* 2000, Moorman & Guynn 2001, Fink *et al.* 2006), coppicing (Fuller & Moreton 1987), farming practices (Genghini *et al.* 2006), grassland management (Gottschalk *et al.* 2007) and building development (Jokimaki & Suhonen 1993). However, standard mapping method produces a single density value per plot and year, and plot replication is very time consuming. In the present study, density figures for those species that sing mostly in flight or have large territories in relation to plot size (basically Skylark, Woodlark *Lullula arborea* and Red-legged Partridge *Alectoris rufa*), are probably only coarse estimates. Density estimation is also a coarse approximation for semi-colonial and for polygamous species (Bibby *et al.* 1997, Sutherland *et al.* 2004). This is the case of the semi-colonial Linnet *Carduelis cannabina* (Drachmann *et al.* 2002), which often moved around in small groups in the Err plots, and the Dunnock, which has a highly variable mating system that includes monogamy and different forms of polygamy. In a 10-year study in Britain, there were 21% more males than female Dunnocks in a population (Davies 1992). If this proportion were applied to the Err populations before the fire, the number of females and of potential nests would be smaller. For example, the 14.5 male territories/10 ha in plot A before the fire would potentially correspond to 12 nests. It is possible that this figure could be a more reliable estimator of the density of reproductive units for this species, although it would not change the marked dominance of

the Dunnock in this rangeland bird community.

The avifauna of the subalpine rangelands studied was composed of a large number of temperate and boreal species, with the addition of a few Mediterranean elements such as Red-legged Partridge and Dartford Warbler. Most breeding species also occurred in winter. The Err plots lay a few kilometres from the edge of the study area of the Catalan Winter Bird Atlas (Herrando *et al.* 2011) and three species were found at even higher altitudes than the maximum recorded in this atlas: Dartford Warbler was observed during the five 'winter' visits to the plots (reaching 2,020 m a.s.l. on 23-11-1997), Stonechat was recorded at 1,900 and 1,780 m a.s.l. on 22-11-1997 and 16-1-1998, respectively, and Meadow Pipit was found at 1,900 m a.s.l. on 28-11-1997. The mild microclimate of this southwest-facing hillside, where the snow does not last long (B. Lambert pers. comm.), may help explain this pattern. In severe weather (cold snaps, high wind, heavy snowfall) birds can temporarily descend in altitude to feed and avoid cold stress (Senar & Borras 2004). In the eastern Pyrenees these movements can be sudden, due to the high elevation gradient and to the proximity of Mediterranean-climate lowlands.

Both plots had suffered previous fires and were grazed by livestock. However, the more recent fire and the higher grazing pressure in plot B may explain why this plot was covered by a very open shrubland in contrast to the dense shrubland of plot A. Bird species composition



**Figure 4.** Graphic of the first two axes of the Correspondence Analysis including the 12 commonest bird species and eight plot-years. Four-letter acronyms show species (ALAR: *Alauda arvensis* + *Lullula arborea*, ANTR: *Anthus trivialis*, CACN: *Carduelis cannabina*, EMCA: *Emberiza cia*, EMHO: *Emberiza hortulana*, LACO: *Lanius collurio*, PRMO: *Prunella modularis*, SARU: *Saxicola rubetra*, SATO: *Saxicola torquatus*, SYUN: *Sylvia undata*, TUME: *Turdus merula*). Squares and dots are plots A and B, respectively, and their trajectories from 1997 to 2000 are shown with arrows.

Gràfic dels dos primers eixos de l'anàlisi de correspondències de les 12 espècies d'ocells més comunes i 8 mostres (anys-parcel·la). Els acrònims de quatre lletres indiquen les espècies (ALAR: *Alauda arvensis* + *Lullula arborea*, ANTR: *Anthus trivialis*, CACN: *Carduelis cannabina*, EMCA: *Emberiza cia*, EMHO: *Emberiza hortulana*, LACO: *Lanius collurio*, PRMO: *Prunella modularis*, SARU: *Saxicola rubetra*, SATO: *Saxicola torquatus*, SYUN: *Sylvia undata*, TUME: *Turdus merula*). Els quadrats representen la parcel·la A i els punts la B, i la seva trajectòria des del 1997 fins al 2000 es mostra amb fletxes.

was therefore different and only five (Linnet, Rock Bunting, Dunnock, Stonechat and Black-bird *Turdus merula*) out of 14 species were shared between plots. The nine exclusive species were linked to grassland habitats (five species) in plot B and mostly to shrubland (four species) in plot A. The trend towards an increase in bird species as shrub encroaches in mountain rangelands (Laiolo *et al.* 2004) does not seem to be fulfilled when comparing before the fire plot A with plot B. This is probably because plot B consisted of a mosaic of shrub and grass patches that favours a higher beta diversity of birds.

Grass, shrub and tree layers in plot A were severely affected by fire and did not reach their former values for three years after the fire, although the cover below 50 cm was already important at the end of the study. As a consequence, shrubland bird species disappeared

or severely reduced their densities (the case of the Whitethroat *Sylvia communis*), whereas open-habitat species density increased. In addition, four new species arrived in plot A in the period from the first to the third year after the fire. Prescribed burning was less severe in plot B and cover reduction was fairly moderate in its burned areas. Accordingly, the bird species composition in this plot was modified less, although changes were apparent along the first axis of the CA (Figure 4) probably due to the post-fire disappearance of the Dartford Warbler. Furthermore, overall bird density changed in parallel with vegetation volume (Figure 3). This pattern, consistent between plots and before and after fire, suggests that resources required by birds are strongly associated to variations in habitat structure (James & Wamer 1982). Functional changes in the bird communities

have not been evaluated in this study, but are interesting aspects that could be explored further after shrubland burning.

Before the fire, the bird conservation value was slightly higher in plot B, despite the lower bird density, since this plot had more SPEC 2 and 3 species (those with unfavourable conservation status in Europe). The conservation value decreased after fire but tended to recover afterwards in both plots, with greater species richness and abundance, a finding that coincides with larger scale studies (Pons & Clavero 2010). The present study, in particular, contributes to the knowledge of bird assemblages in managed high mountains. In these areas, the preservation of traditional activities (Lasanta-Martínez *et al.* 2005), including burning and livestock grazing, helps to maintain the open habitats necessary for several declining bird species, and helps counteract the current general trend of afforestation (Roura *et al.* 2005).

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## Resum

### La comunitat d'ocells d'una pastura subalpina abans i després del foc: cremes prescrites als Pirineus Orientals

Les pastures d'alta muntanya acullen poblacions importants d'espècies amenaçades d'ocells, alhora que es veuen afectades per importants canvis en els usos del sòl. Aquest treball estudia la comunitat d'ocells nidificants de dues parcel·les de matollar a 1.850-2.100 metres sobre el nivell del mar als Pirineus. Es van cartografiar els territoris de reproducció durant quatre anys, abans i després d'una crema prescrita encaminada a augmentar el valor de pastura de la zona. Les espècies més abundants (amb  $\geq 3$  parelles /10 hectàrees en almenys una parcel·la i un any) van ser el Pardal de Bardissa *Prunella modularis*, la Tallareta Cuallarga *Sylvia undata*, el Bitxac Comú *Saxicola torquatus*, el Sit Negre *Emberiza cia* i l'Hortolà *Emberiza*

*hortulana*. La parcel·la de matollar obert contenia un nombre similar d'espècies d'ocells nidificants (10 vs. 9), però una menor densitat (23 vs. 28 parelles/10 ha) que la parcel·la de matollar dens. La majoria de les espècies reproductores també hi van ser presents a l'hivern. Després del foc, el nombre d'espècies d'ocells, la densitat total i el valor de conservació (un índex que inclou la densitat de totes les espècies i les seves categories d'interès de conservació a Europa) es va reduir, però va tendir a recuperar-se posteriorment. Aquests resultats poden ajudar a entendre la composició i dinàmica de les comunitats d'ocells en àrees de muntanya gestionades.

## Resumen

### La comunidad de aves de un pasto subalpino antes y después del fuego: quemas prescritas en los Pirineos Orientales

Los pastos de alta montaña acogen poblaciones importantes de especies amenazadas de aves, al tiempo que se ven afectados por importantes cambios en los usos del suelo. Este trabajo estudia la comunidad de aves nidificantes en dos parcelas de matorral a 1.850-2.100 metros sobre el nivel del mar en Pirineos. Se cartografiaron los territorios de reproducción durante cuatro años, antes y después de una quema prescrita encaminada a aumentar el valor pastoral de la zona. Las especies más abundantes (llegando a  $\geq 3$  parejas / 10 hectáreas en al menos una parcela y un año) fueron el Acentor Común *Prunella modularis*, la Curruca Rabilarga *Sylvia undata*, la Tarabilla Común *Saxicola torquatus*, el Escribano Montesino *Emberiza cia* y el Escribano Hortelano *Emberiza hortulana*. La parcela de matorral abierto contenía un número similar de especies de aves nidificantes (10 vs. 9), pero una menor densidad (23 vs. 28 parejas/10 ha) que la parcela de matorral denso. La mayoría de las especies reproductoras también estuvieron presentes en invierno. Después del fuego, el número de especies de aves, la densidad total y el valor de conservación (un índice que incluye la densidad de todas las especies y sus categorías de interés de conservación en Europa) se redujeron, pero tendieron a recuperarse posteriormente. Estos resultados pueden ayudar a entender la composición y dinámica de las comunidades de aves en áreas de montaña gestionadas.

## References

- Anton, M., Herrando, S. & Quesada, J. 2009. Do nest-boxes encourage the recovery of bird populations after fire? A field experiment with tits in a Mediterranean forest. *Rev. Catalana Ornitol.* 25: 1-10.

- Bibby, C.J., Burgess, N.D. & Hill, D.A.** 1997. *Bird census techniques*. London: Academic Press.
- BirdLife International.** 2004. *Birds in Europe: population estimates, trends and conservation status*. Cambridge: BirdLife International.
- Castro, J., Moreno-Rueda, G. & Hódar, J.A.** 2010. Experimental test of postfire management in pine forests: impact of salvage logging versus partial cutting and nonintervention on bird-species assemblages. *Conserv. Biol.* 24: 810–819.
- Davies, N.B.** 1992. *Dunnock behaviour and social evolution*. Oxford: Oxford University Press
- Drachmann, J., Broberg, M.M. & Søggaard, P.** 2002. Nest predation and semicolonial breeding in Linnets *Carduelis cannabina*. *Bird Study* 49: 35–41.
- Fink, A.D., Thompson, F.R. & Tudor, A.A.** 2006. Songbird use of regenerating forest, glade, and edge habitat types. *J. Wildlife Manage.* 70: 180–188.
- Fuller, R.J. & Moreton, B.D.** 1987. Breeding bird populations of Kentish sweet chestnut (*Castanea sativa*) coppice in relation to age and structure of the coppice. *J. Appl. Ecol.* 24: 13–27.
- Genghini, M., Gellini, S. & Gustin, M.** 2006. Organic and integrated agriculture: the effects on bird communities in orchard farms in northern Italy. *Biodiv. Conserv.* 15: 3077–3094.
- Gottschalk, T.K., Ekschmitt, K. & Bairlein, F.** 2007. Relationships between vegetation and bird community composition in grasslands of the Serengeti. *African J. Ecol.* 45: 557–565.
- Herrando, S., Brotons, L., Estrada, J., Guallar, S. & Anton, M.** (eds.). 2011. *Atlas dels ocells de Catalunya a l'hivern 2006–2009*. Barcelona: Lynx Edicions and Institut Català d'Ornitologia.
- Herrando, S., Brotons, L., Guallar, S., Sales, S. & Pons, P.** 2009. Postfire forest management and Mediterranean birds: the importance of the logging remnants. *Biodiv. Conserv.* 18: 2153–2164.
- James, F.C. & Wamer, N.O.** 1982. Relationships between temperate forest bird communities and vegetation structure. *Ecology* 63: 159–171.
- Jokimaki, J. & Suhonen, J.** 1993. Effects of urbanization on the breeding bird species richness in Finland: a biogeographical comparison. *Ornis Fennica* 70: 71–77.
- Laiolo, P., Dondero, F., Ciliento, E. & Rolando, A.** 2004. Consequences of pastoral abandonment for the structure and diversity of the alpine avifauna. *J. Appl. Ecol.* 41: 294–304.
- Lambert, B. & Parmain, V.** 1990. Les brûlages dirigés dans les Pyrénées-Orientales. De la régénération des pâturages d'altitude à la protection des forêts. *Rev. Forest. Française* 42: 141–155.
- Lasanta-Martínez, T., Vicente-Serrano, S.M. & Cuadrat-Prats, J.M.** 2005. Mountain Mediterranean landscape evolution caused by the abandonment of traditional primary activities: a study of the Spanish Central Pyrenees. *Appl. Geogr.* 25: 47–65.
- Moorman, C.E. & Guynn, D.C.** 2001. Effects of group-selection opening size on breeding bird habitat use in a bottomland forest. *Ecol. Appl.* 11: 1680–1691.
- Peñuelas, J. & Boada, M.** 2003. A global change-induced biome shift in the Montseny mountains (NE Spain). *Global Change Biol.* 9: 131–140.
- Pons, P. & Clavero, M.** 2010. Bird responses to fire severity and time since fire in managed mountain rangelands. *Anim. Conserv.* 13: 294–305.
- Pons, P., Lambert, B., Rigolot, E. & Prodon, R.** 2003. The effects of grassland management using fire on habitat occupancy and conservation of birds in a mosaic landscape. *Biodiv. Conserv.* 12: 1843–1860.
- Prodon, R. & Lebreton, J.-D.** 1981. Breeding avifauna of a Mediterranean succession: the holm oak and cork oak series in the eastern Pyrenees, 1. Analysis and modelling of the structure gradient. *Oikos* 37: 21–38.
- Rost, J., Clavero, M., Bas, J.M. & Pons, P.** 2010. Building wood debris piles benefits avian seed dispersers in burned and logged Mediterranean pine forests. *Forest Ecol. Manage.* 260: 79–86.
- Roura-Pascual, N., Pons, P., Etienne, M. & Lambert, B.** 2005. Transformation of a rural landscape in the Eastern Pyrenees between 1953 and 2000. *Mountain Res. Develop.* 25: 252–261.
- Sallabanks, R., Arnett, E.B. & Marzluff, J.M.** 2000. An evaluation of research on the effects of timber harvest on bird populations. *Wildlife Soc. Bull.* 28: 1144–1155.
- Senar, J.C. & Borrás, A.** 2004. Surviving to winter: Strategies of wintering birds in the Iberian Peninsula. *Ardeola* 51: 133–168.
- Sutherland, W.J., Newton, I. & Green, A.A.** (eds.). 2004. *Bird ecology and conservation: a handbook of techniques*. Oxford: Oxford University Press.
- ter Braak, C.J.F., & Smilauer, P.** 1998. *Canoco reference manual and user's guide to Canoco for Windows*. Ithaca, NY: Microcomputer Power.
- Tucker, G.M. & Evans, M.I.** 1997. *Habitats for birds in Europe: a conservation strategy for the wider environment*. Cambridge: BirdLife International.