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ORIGINAL PAPER

Postfire forest management and Mediterranean birds: the importance of the logging remnants

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Abstract Fire is a crucial element needed to understand the biodiversity patterns of forest landscapes in most Mediterranean countries. However, little is known about the quantitative responses of bird communities to postfire forest management in this region, in which the logging of burnt trees is a common practice. Several studies have already described the negative effects of felling burnt trees on birds but none has focussed on the remaining wood remnants. We investigated this question in a large burnt area located in north-east Iberian Peninsula. The amount of logging remnants left on the ground had positive linear and negative quadratic relationships with the indices of bird abundance and bird richness. The results obtained at a species level were similar, since 36% of the most abundant species revealed the same type of relations with logging remnants, whereas none showed an opposite pattern. Thus, birds in general seem to be positively influenced by the amount of wood remnants left on the ground to a certain point, from which the relation reverses. The results of this study indicate that a moderate amount of wood remnants left on the ground may be positive for the overall bird community. We suggest that management plays a role in the recovery of the bird community after fire and, therefore, biodiversity criteria should be incorporated in the guidelines driving postfire actions.

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Introduction

The idea that natural disturbances affect the structure of biological systems is a major paradigm in ecology (Gaston and Blackburn 2000). In the Mediterranean Basin, fire is one of the most important agents of change and plays a fundamental role for understanding the composition of bird communities. In the last decades, the study of bird succession in burnt areas has caught researchers' attention (Prodon et al. 1987; Pons and Prodon 1996; Imbeau et al. 1999; Herrando et al. 2002). More recently, the study of the consequences of fire regimes at a landscape scale (Moreira et al. 2001; Brotons et al. 2004) and of the colonisation processes that follow wildfires (Brotons et al. 2005) has improved our knowledge of the bird responses to this disturbance.

In contrast, few studies have focused on the effects of postfire forest management in burnt Mediterranean areas, which is quite surprising considering that the complete logging of burnt trees (salvage logging) is the most common practice in Mediterranean areas (e.g. Haim and Izhaki 2000; Tsitsoni et al. 2004). Llimona et al. (1993) and Izhaki and Adar (1997), however, emphasised the negative effects of logging dead trees on bird richness and abundance after a fire, which could even cause higher decreases than those caused by the fire itself. Izhaki (1996), Haim et al. (1997) and Izhaki and Adar (1997) pointed out that the number of bird species in an ecosystem may increase as a result of applying certain postfire treatments. These may create a mosaic of different micro-habitats, thus contributing to maintain high bird diversity. Negative effects of felling burnt trees have been more deeply analysed by several studies conducted in North America, where the bird community that feed and nest in burnt snags is especially rich and includes highly specialised birds (Apfelbaum and Haney 1981; Hutto 1995; Murphy and Lehnhausen 1998; Kreisel and Stein 1999; Dixon and Saab 2000; Leonard 2001; Nappi et al. 2003). Therefore, it is well known that logging burnt trees has general negative effects on many bird species. However, logging is a complex postfire management practice and it goes beyond felling trees by itself, since wood remnants can be handled in several ways, from complete removal to in situ spread. Removing trunks and branches of felled trees from the burnt area is a practice usually intended to reduce fuel load and pests (McIver and Starr 2000 and references therein), whereas leaving them on the ground is commonly used as a way of diminishing soil erosion (Raftoyannis and Spanos 2005; Marqués and Mora 1998). Little is known about the effects of the practices associated with logging on birds.

The aim of this study was to investigate the consequences of different practices associated with salvage logging on a Mediterranean bird community. Specifically, we attempted to address the question of what kind of management is more appropriate for birds: removing trunks and branches of felled trees from the burnt area, or leaving them on the ground. Finally, we also investigated the potential effects of piling these remnants up or simply spreading them on the ground.

Methodology

Study area

This study was carried out in the area of influence of the Sant Llorenç del Munt Natural Park, which is located in Catalonia, north-east Iberian peninsula (Fig. 1). The area affected

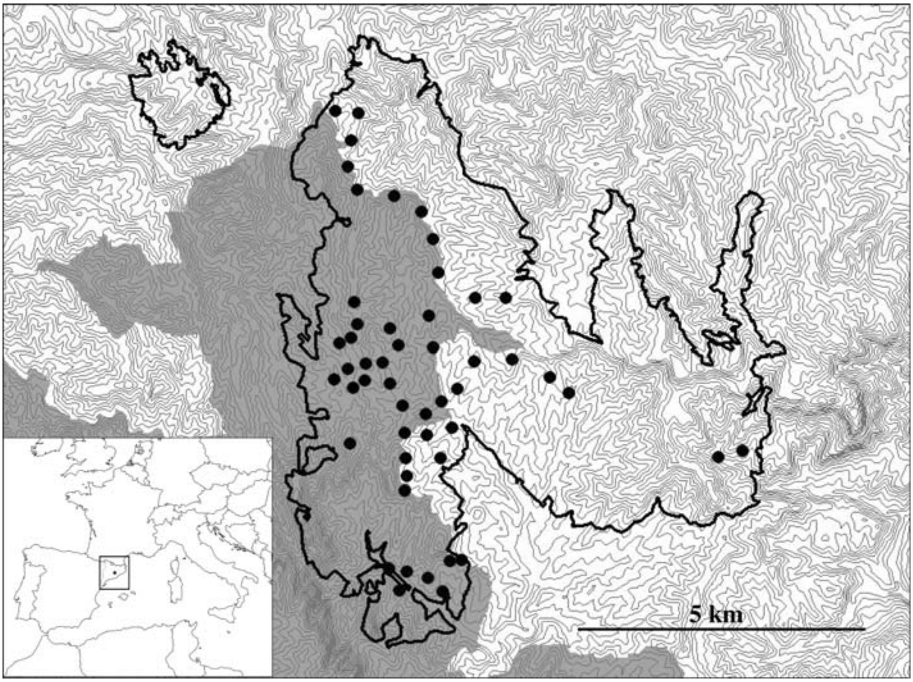

Fig. 1 Location of the study area. Fire boundaries are outlined in *black*. *Dots* inside them correspond to the 51 census stations. The territory occupied by the St. Llorenç del Munt Natural Park is shown in *grey*. *Inset* regional location of the study area

by the fire was about 5,000 ha. Aleppo Pine *Pinus halepensis* and Holm Oak *Quercus ilex* forests covered 90% of the area before the fire. Impelled by wind, the fire passage was quite fast and all the area burnt in just one day (10th August 2003). Timber extraction begun soon after fire, and 2 years later most of the area was completely logged, leaving no or very few standing snags.

We selected 51 stations within the burnt area (mainly within the boundaries of the Natural Park, Fig. 1). Forestry works were in a late phase when we conducted our field work: the majority of the burnt area was completely logged, and the wood remnants removed. As a consequence, we applied a stratified sampling to increase the number of stations with trunks and branches on the ground. In spite of this, we consider that the degree of variation in habitat structure within the final set of selected stations (Fig. 2) is large enough to perform suitable statistical analyses. Mean distance between nearest stations was 388 m (SD = 134, range = 205–946).

Bird counts

We conducted bird censuses in the breeding season (May–June) of 2005, that is, almost 2 years after fire. The point count method was the method employed to estimate the species richness and abundance of birds at each station. This is generally accepted as a suitable method to relate birds with habitat features (Bibby et al. 2000). Unfortunately, logging activity (that also took place within the census period) was completely out of our control, which not only impeded finer experimental designs but also prevented us from conducting

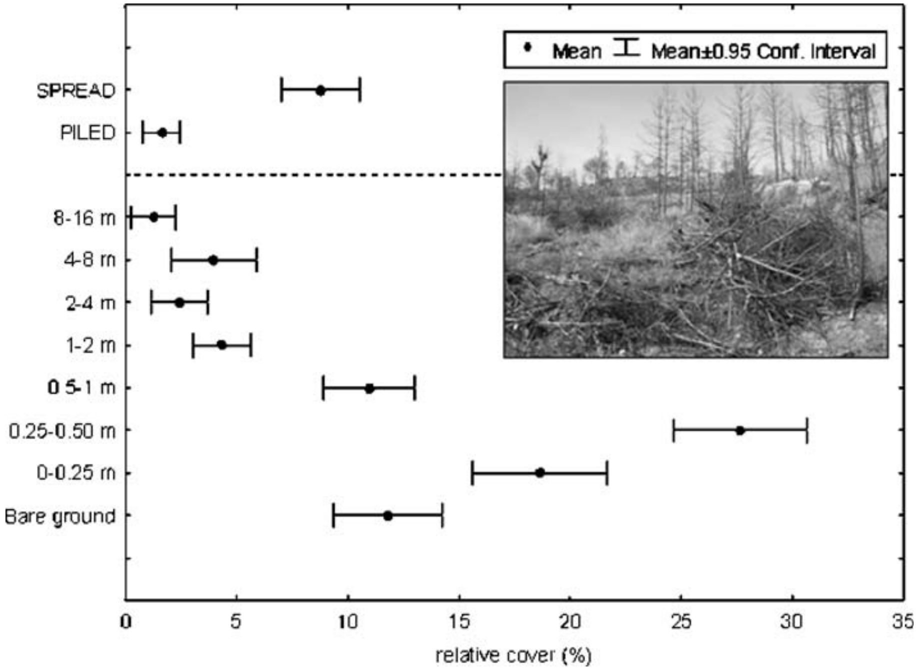

Fig. 2 Relative cover of each vertical layer, from bare ground to 16 m height (below the *dashed line*). Relative cover of dead branches and trunks spread on the ground (SPREAD) and relative cover of the piled up material (PILED); $n = 51$ stations. The photograph shows a station with piled wood remnants

more than one visit per station. In each of these visits we carried out 2 consecutive point-count censuses (5 min + 5 min) exactly in the same place and with no elapsed time between them. Only birds located within a 100-m radius from the observer were included in the analyses. All point counts were carried out early in the morning, the period of higher bird detectability. Censuses were performed by the same observer to avoid interpersonal biases, and under good weather conditions, without rainfall or wind (Bibby et al. 2000).

Richness and abundance were selected as the variables that integrate the largest piece of information from the overall breeding bird community. The number of species detected per station was used as a relative index of bird species richness. Moreover, in order to study the effects of logging treatments at a species specific level, we also conducted analyses for the most frequent species which are defined as those present in at least 25% of the stations. For each species, the maximum number of individuals detected in the two censuses was used as an index of abundance. Potentially, such abundance indexes could be biased because of the variation in detectability due to different vegetation covers (Bibby et al. 2000). However, open areas, such as those recently affected by fire, may present little or no differences in bird detectability, as Herrando et al. (2001) found in burnt areas located 40 km away from this one. Thus, this predictable constancy in species detectability allowed us to consider the number of individuals per point as a relative index of species abundance.

Habitat structure sampling

Habitat characteristics have repeatedly been reported to contribute to the structuring of bird communities (Wiens 1989). Specifically, Prodon and Lebreton (1981) showed that habitat structure was the main determinant of bird community structure in Mediterranean shrublands. We, therefore, decided to use only structural variables as descriptors of habitat, and surveyed the vegetation structure at each bird count station. We estimated the cover of seven virtual vegetation layers (0–0.25, 0.25–0.5, 0.50–1, 1–2, 2–4, 4–8, 8–16 m) and bare ground in an area of about 100-m radius around the observer. Within each layer, the relative cover was defined as the projection of the vegetal volume of the layer (including the bare ground) onto a horizontal plane, and was estimated by comparison with a reference chart (Prodon and Lebreton 1981). According to these authors, the method produces data that are reliable to ±90%.

Two main practices followed salvage logging in the study area. Wood remnants were either spread on the ground close to the stumps or piled up in mounts of about 1–1.5 m tall, up to 4 m long and 2 m wide. Thus, in addition to data from these basic habitat features, we also obtained specific data from the wood remnants by quantifying: (1) the cover of dead branches and trunks spread on the ground (SPREAD), and (2) the cover of piles of dead branches and trunks (PILED). This quantification was made following the same procedure used for vegetation layers. All the structural variables were obtained by the same observer to avoid any interpersonal bias.

Statistical analyses

A principal component analysis (PCA, varimax normalised) was performed with vegetation layers to reduce their multicollinearity in subsequent multivariate analyses. In order to study the relationships between bird parameters (overall indices of richness and abundance, and the abundance of common species) and habitat structure variables we employed generalised linear models (GLZ, McCullagh and Nelder 1989). The predictors selected in the analyses were the habitat structure variables, that is, the factors obtained from the PCA, plus SPREAD and PILED. In order to deepen into the effects of logging treatments, the quadratic terms $SPREAD^2$ and $PILED^2$ were also included in the set of predictors. Likelihood Type III tests were computed for controlling the effects of the other predictor variables. All statistical analyses were performed with Statistica (StatSoft Inc 2004).

Results

We detected a total of 68 bird species in our point counts, most of them in low to very low abundance (Table 1). Most abundant species were: Woodlark *Lullula arborea* (0.94 individuals/station), Subalpine Warbler *Sylvia cantillans* (0.80 individuals/station), Wren *Troglodytes troglodytes* (0.80 individuals/station), Sardinian Warbler *Sylvia melanocephala* (0.65 individuals/station) and Dartford Warbler *Sylvia undata* (0.51 individuals/station).

The vegetal cover showed the typical pattern of recently burnt areas, reaching a maximum in the 0.25–0.50 m layer, which corresponded to short, mostly resprouting bushes and grasses (Fig. 2). The slight increase in the 4–8 m layer coincided with the remaining scarce trees, most of them completely burnt. The cover of SPREAD and the cover of PILED were low, especially the latter (Fig. 2).

PCA showed three components with eigenvalues > 1 (Table 2). PCA1 was negatively correlated to the amount of tall shrubs (2–4 m) and trees (4–16 m). PCA2 was negatively correlated to the amount of bare ground, grass and very short shrubs (0–0.25 m) and positively with shrubs (0.5–2 m). Finally, PCA3 was negatively correlated with short shrubs (0.25–0.5 m). As a whole, these three components explained 71% of the total variance of the data matrix.

Table 1 Percentage of occurrence and mean abundance of the species detected in this study

Scientific name	English name	Occurrence (%)	Abundance (individuals/station)
Falco peregrinus	Peregrine Falcon	2	0.04
Alectoris rufa	Red-legged Partridge	2	0.04
Columba palumbus	Woodpigeon	2	0.06
Strix aluco	Tawny Owl	2	0.02
Caprimulgus europaeus	Nightjar	2	0.02
Merops apiaster	Bee-eater	4	0.08
Upupa epops	Hoopoe	2	0.02
Picus viridis	Green Woodpecker	2	0.02
Dendrocopos major	Great Spotted Woodpecker	18	0.20
Galerida cristata	Crested Lark	2	0.02
Lullula arborea	Woodlark	55	0.94
Anthus campestris	Tawny Pipit	18	0.20
Troglodytes troglodytes	Winter Wren	43	0.80
Erithacus rubecula	Robin	16	0.22
Luscinia megarhynchos	Nightingale	18	0.27
Saxicola torquatus	Stonechat	33	0.43
Oenanthe hispanica	Black-eared Wheatear	4	0.04
Turdus merula	Blackbird	35	0.47
Turdus philomelos	Song Thrush	4	0.04
Turdus viscivorus	Mistle Thrush	4	0.04
Hippolais polyglotta	Melodious Warbler	14	0.22
Sylvia undata	Dartford Warbler	27	0.51
Sylvia cantillans	Subalpine Warbler	57	0.80
Sylvia melanocephala	Sardinian Warbler	45	0.65
Sylvia atricapilla	Blackcap	18	0.24
Phylloscopus bonelli	Bonelli's Warbler	18	0.24
Regulus ignicapilla	Firecrest	2	0.02
Parus cristatus	Crested Tit	22	0.24
Parus ater	Coal Tit	6	0.08
Parus caeruleus	Blue Tit	14	0.22
Parus major	Great Tit	29	0.41
Certhia brachydactyla	Short-toed Treecreeper	14	0.16
Garrulus glandarius	Jay	12	0.12
Corvus corone corone	Carrion Crow	2	0.06
Sturnus vulgaris	Starling	4	0.33
Passer domesticus	House Sparrow	2	0.02
Petronia petronia	Rock Sparrow	2	0.02
Fringilla coelebs	Chaffinch	33	0.47
Serinus serinus	Serin	31	0.37
Carduelis chloris	Greenfinch	14	0.16
Carduelis carduelis	Goldfinch	2	0.02
Carduelis cannabina	Linnet	2	0.02

Table 1 continued

Scientific name	English name	Occurrence (%)	Abundance (individuals/station)
Emberiza cirlus	Cirl Bunting	22	0.37
Emberiza cia	Rock Bunting	28	0.37

Abundance was calculated as the average of the maximum number of individuals detected in the 2–5 min censuses carried out at each station ($n = 51$ stations)

Table 2 Factor loadings between the relative cover of each structural layer and the three factors of the principal component analysis with eigenvalues >1 (PCA1, PCA2 and PCA3)

Variables	PCA1	PCA2	PCA3
% Bare ground	0.30	−0.70	0.18
% 0–0.25 m	0.35	−0.67	0.28
% 0.25–0.50 m	0.19	0.00	−0.94
% 0.50–1 m	0.24	0.82	0.08
% 1–2 m	−0.07	0.71	0.22
% 2–4 m	−0.74	0.18	0.31
% 4–8 m	−0.91	0.08	0.00
% 8–16 m	−0.84	0.02	0.05
Cumulative explained variance (%)	35.2	57.7	70.9

Table 3 Results of the generalised linear model (GLZ) type 3: relation of bird abundance and richness to habitat structure (PCA1, PCA2, PCA3, SPREAD and PILED)

	Degrees of freedom	Chi-square	*P*	Coefficient
Abundance				
PCA1	1	50.05	<0.0001	−0.301
PCA2	1	32.92	<0.0001	0.280
SPREAD	1	10.30	0.0013	0.076
$SPREAD^2$	1	9.48	0.0021	−0.003
PILED	1	7.65	0.0057	0.145
$PILED^2$	1	6.41	0.0113	−0.015
Richness				
PCA1	1	35.66	<0.0001	−0.302
PCA2	1	3.92	0.0477	0.118
SPREAD	1	6.23	0.0125	0.071
$SPREAD^2$	1	5.05	0.0246	−0.003
PILED	1	2.71	0.0995	0.107
$PILED^2$	1	2.48	0.1152	−0.011

For variables related to wood remnants (SPREAD and PILED), quadratic terms were included in the set of predictors

Type 3 GLZ indicates the relation between a dependent variable and a predictor variable by simultaneously controlling the effects of other predictor variables

The results of the GLZ performed for both indices of richness and abundance were very similar (Table 3). SPREAD was positively and significantly related to richness and abundance and, as it is shown by the negative sign of the quadratic effect, there was a maximum beyond which higher values of SPREAD were associated with lower values of richness and abundance. PILED follows the same interpretation than SPREAD, although richness was only marginally significant ($P = 0.1$) in this case. The threshold cover value of SPREAD from which its relation to abundance and richness changes from positive to

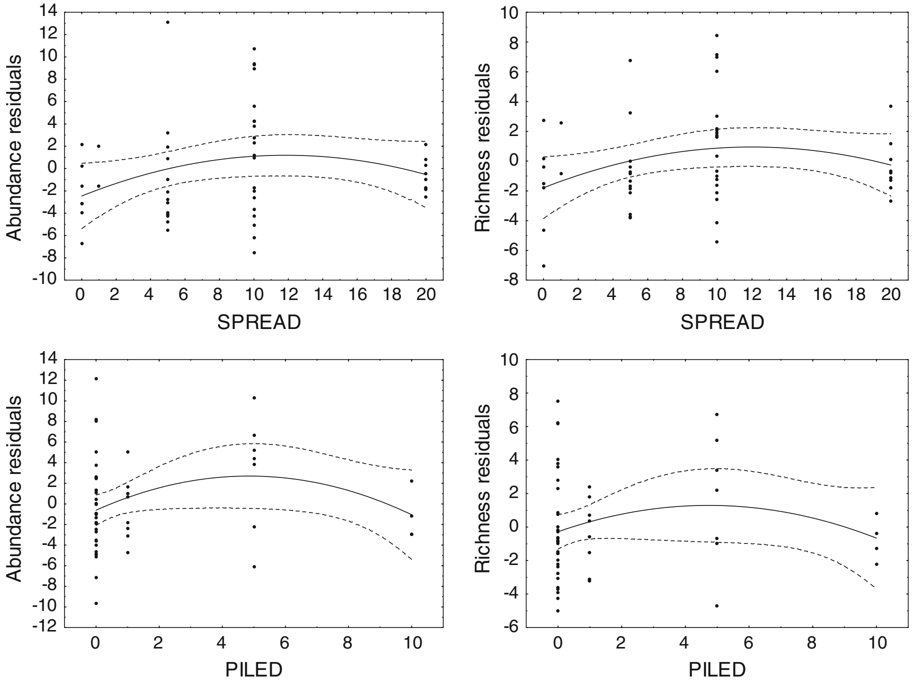

Fig. 3 Quadratic fitting between the residuals of abundance and richness and the variables PILED and SPREAD. In these regression lines, the residuals are standardised by the other predictor variables considered in the GLZ models (see Table 3). 95% regression bands are shown

negative (maximum of the quadratic effect) is located at about 15%, whereas that for PILED this maximum lies at around 3–5% (Fig. 3). The GLZ performed at a species specific level showed that 36% of the commonest species (4 out of 11) were positively affected by SPREAD or PILED, and negatively by SPREAD^2 or PILED^2 (Table 4). These relationships were consistent with those found in the analyses conducted for the indices of richness and abundance (Table 3).

Discussion

Removal of dead trees after natural disturbances is a usual forestry practice worldwide (Jones et al. 2000; Robichaud et al. 2000; Beschta et al. 2004; Raftoyannis and Spanos 2005; Lindenmayer and Ough 2006). In many Mediterranean countries, salvage logging is currently only possible because of the financial support of government agencies, since timber exploitation itself does not yield economical benefits (e.g. Raftoyannis and Spanos 2005). Apart from economic and socio-political aspects, felling burnt snags have been supposed, primarily by land managers, to have ecological benefits by contributing to restoration of the ecosystem (Morelan et al. 1994; Sessions et al. 2004), but increasingly more studies question the hypothetical positive effects of such practices (McIver and Starr 2000; Lindenmayer et al. 2004). For example, Donato et al. (2006) showed that postfire logging in Oregon increased fire risk and hindered vegetation recovery. On the other hand,

Table 4 Results of the generalised linear model (GLZ) type 3: relation of the abundance of the 11 most frequently detected bird species (those present in at least 25% of the stations) to habitat structure (PCA1, PCA2, PCA3, SPREAD and PILED)

Scientific name	English name	Significant predictors
Sylvia cantillans	Subalpine Warbler	
Lullula arborea	Woodlark	(+) PCA1
Sylvia melanocephala	Sardinian Warbler	
Troglodytes troglodytes	Winter Wren	(−) PCA1; (+) PCA2; (−) $SPREAD^2$
Turdus merula	Blackbird	
Saxicola torquatus	Stonechat	
Fringilla coelebs	Chaffinch	(+) PCA2
Serinus serinus	Serin	(+) PILED; (−) $PILED^2$
Parus major	Great Tit	
Emberiza cia	Rock Bunting	(+) SPREAD; (−) $SPREAD^2$
Sylvia undata	Dartford Warbler	(+) PCA1; (−) PCA3; (+) PILED; (−) $PILED^2$

For variables related to wood remnants (SPREAD and PILED), quadratic terms were included in the set of predictors

Type 3 GLZ indicates the relation between a dependent variable and a predictor variable by simultaneously controlling the effects of other predictor variables

Only significant predictors ($P < 0.01$) and the sign of the coefficient (between parenthesis) are shown

As we conducted 77 analyses (7sp × 11 variables), a *P*-level of 0.01 was chosen to be sure that the probability of obtaining a false positive was lower than 1 out of 100

several studies have shown the negative effects of this practice on birds (Llimona et al. 1993; Hutto 1995; Hitchcox 1996; Nappi et al. 2003).

This work intends to determine the effect of specific postfire management practices on bird numbers. Particularly, it provides quantitative evidence about how different treatments of the logging remnants may influence birds after clear cutting. Thus, we found a positive effect on breeding birds when a fraction of the branches and trunks cut are left on the ground, whereas the effect was negative when the cover of these remnants is too high or too low. This quadratic response can be directly interpreted as a positive effect of habitat heterogeneity. However, the outcome of our analyses should be taken with caution due to both their low sample size and their low effect-size (Tables 3, 4), which determine an overall low test power.

We found that four common species (Serin *Serinus serinus*, *Sylvia undata*, *Troglodytes troglodytes* and Rock Bunting *Emberiza cia*) were favoured by a moderate coverage of logging remnants, in some cases by those just spread on the ground, in others by those piled up. This suggests that the presence of burnt branches on the ground provides suitable ecological niches for these species. All these four species usually select positively Mediterranean shrublands in the study region (Estrada et al. 2004) and the presence of these wood remnants may emulate the structure of provided by bushes in subsequent succesional stages. The case of the Rock bunting and the Serin are particularly interesting since these species were not affected by any vegetation structure parameters other than wood remnants.

The low sample size prevented us from conducting analyses with uncommon species; however, the same relationship may occur in some of them. On the other hand, although our results for common birds do not shed light on this question, it is possible that a moderate cover of logging remnants on the ground may allow the coexistence of two groups of species, those that select areas with wood remnants (i.e. those species using the understory in more forested habitats) and those that avoid them and prefer more open vegetation type habitats. If certain, this would also allow high levels of richness and abundance compared with more homogeneous habitat structures. This could be considered as a predictable result since the positive role of habitat heterogeneity on diversity is a well known principle in animal ecology (Gaston and Blackburn 2000).

Postfire forestry practices may have clear effects on bird conservation. Logging itself should be considered negative because of the drastic reduction in vertical structure that causes. As already proposed by Beschta et al. (1995) and later on by Beschta et al. (2004) and Hutto (2006) for North American coniferous forests, instead of salvage logging, it is recommendable saving the best standing trees in order to enhance the conservation of bird species. The results of this study suggest that the decisions regarding the removal of burnt branches and trunks have consequences for bird conservation. In the Mediterranean Basin, the removal of non-commercial timber is a usual practice in burnt and logged forests. However, individual decisions among foresters seem decisive as for leaving or not a certain amount of burnt branches on the ground (either piled or just spread). These practices generate habitat heterogeneity which will be beneficial for biodiversity conservation.

Finally, it should be pointed out that the studied bird community is far from being stable since both regional population trends and local vegetation succession may affect its species composition and abundance. Therefore, this bird community would have surely been different in other scenarios (Brotons et al. 2005). For instance, two abundant species in the area were in very different situations in Catalonia in the study year (2005) compared to previous years: *Sylvia melanocephala* was decreasing, whereas *Lullula arborea* was increasing (www.sioc.cat, ICO 2007). However, regardless of the effect that this type of regional patterns may certainly had on the species abundance in the study area, it is difficult to imagine that a combination of species particular trends would have changed the relationships found between logging practices and avian richness or abundance. On the other hand, it is foreseeable that the subsequent stages of the postfire succession will drastically change the current role of the piled or spread logging remnants, since such structures will decay within a few years after the fire, and their contribution to the habitat structure will diminish in parallel with vegetation recovery. Nevertheless, given the amount of recently burnt and then logged areas in the Mediterranean Basin, this early successional stage may play an important role in biodiversity conservation. Unfortunately, this study faced important limitations at the moment of its execution due to the unpredictable salvage logging that was taking place. Consequently, it was impossible to define a detailed experimental design and to sample a larger spectrum of logging remnants cover. Further studies are needed to obtain more results on postfire logging effects that provide land managers with more guidelines in relation to animal conservation.

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