Landscape effects of non-direct regeneration after a large fire on a mediterranean bird community

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Abstract

Fire is one of the major ecological processes that have shaped Mediterranean ecosystems. Recent studies (Rodrigo and others 2004) indicate that Mediterranean forest communities have different abilities to recover after fire. In this study, we analyze the effect of variability in post fire regeneration patterns on a Mediterranean bird community and evaluate the impact of landscape change on the conservation value of the bird species using the new variegated landscape arising after fire.

We used data from a large fire occurred in the central Catalonia (NE Spain) in 1998. The fire affected about 26.000 ha of a land mosaic mainly covered by *Pinus nigra* forests and cereal crops. We used line transects to estimate bird abundance and describe vegetation structure and habitat variables. Principal components analysis (PCA) was used to simplify vegetation structure variables. Redundancy analysis (RDA) was employed to relate the species abundance data to the environmental variables.

The mosaic landscape generated after the fire induced the appearance of three groups of bird species virtually absent or rarer from pre-fire, forested conditions. Our results suggest that large fires affecting non-direct regenerating forest types lead to a new and radically different mosaic landscape offering new opportunities to species with unfavourable conservation status at the European level

Introduction

Wildfires represent one of the most important natural disturbances in Mediterranean ecosystems (Trabaud 1994, Whelan 1995). They play a decisive role in the dynamics and structure of plant and animal communities. It has been traditionally accepted that Mediterranean plant communities have a high resilience, that is, the composition and structure of burned communities is restored very quickly and the burned ecosystems cannot be distinguished from the predisturbance state after a few decades (Trabaud and Lepart 1980). However recent studies (Rodrigo and others, 2004) indicate that Mediterranean forest communities have different abilities to recover after fire. Resprouting and seeder species with efficient germination recover rapidly, whereas seeder species that produce few seedlings or for which seedling survival is low after fire do not recover and are replaced by other vegetation types. In these cases, of non-direct vegetation regeneration, forests communities may undergo important compositional and structural changes potentially leading to changes in forest types. The main goal of this study was to analyze the effect of variability in post fire regeneration patterns in an area dominated by non-direct regeneration processes on a Mediterranean bird community. In particular, we examined to which degree spatial differences in bird community structure appearing after fire tracks patterns of vegetation recovery. Finally, since burnt zones have been reported as interesting areas in terms of overall biodiversity conservation (Blondel and Aronson, 1999), we also attempted to evaluate the conservation value of the bird species that appears in the new landscape originated after fire.

Methods

Study area

The study area is located in a large fire occurred in 1998 in the Solsonès county (Lleida, North-Eastern Iberian Peninsula, between 41º59' and 41º44' North and 1º21' and 1º39' East) (Fig. 1). This large fire impacted over an extension of ca. 26000 ha. The 67% of the total burned area affected forested lands, with the rest composed of agrarian crop-fields (IEFC 2000). The primary forest species affected included *Pinus nigra* (74%), *Pinus halepensis* (11%), *Quercus faginea* (7%) and *Quercus ilex* (3%) (Gonzalez and Castellnou, 1998).

Figure 1- Geographical location of the Solsonès fire that took place on summer of 1998 in the North-easter Iberian Peninsula. Fire perimeter and transects done during the field work are shown in the figure.

Bird censuses

We used line transects to estimate bird presence and abundance (Bibby and others 1992). Censuses were conducted in 2005 between the third week of April and the last week of June. We covered each transect twice in order to cover the phenology of the majority of species present in the study area. All transects were conducted within 3 hours from sunrise. Raptors, aerial feeders (swallows, swifts and bee-eaters) and crepuscular species were excluded from the analysis because this method is not appropriate to assess their abundance (Bibby and others 1992). Censuses were performed by the same observer to avoid interpersonal errors, and always conducted during good weather conditions, without rainfall or wind.

We sampled bird censuses within the burnt area using a random stratified sampling. In the first place, we randomly located 25 points within the fire perimeter. Around each of these points (2 km radius), we located 4 bird sampling transects. Each bird sampling transect took 20 minutes to be completed and covered about 700 m in length (range 602-820 m). Birds were counted when heard or seen within 25 and 100 m belts on both sides of transects.

We used species richness and the highest abundance's value between the two visits of each transect as variables in further analyses.

Conservation value

Species were also classified according to their conservation status using indices derived from the EU Birds Directive (70/409/CEE). The Directive-based index was computed by assigning a value of 1 to the species included in the Birds Directive, and 0 to the remaining species. For each index the conservation values of all species within each transect were summed, yielding indexes of the distribution of the conservation importance for the bird fauna in the study area.

Habitat and post-fire management descriptors

We described vegetation structure using a modification of the cover estimation method proposed by (Prodon and Lebreton, 1981). We estimated the cover of distinct layers (bare ground, rock cover, herbaceous vegetation (0-0.5 m), shrubby vegetation 0.25-1 m) and an overall assessment of the cover of different tree species (Aleppo pine, *Pinus halepensis,* Holm oak *Quercus ilex* and Lusitanian oak *Quercus humilis)* as habitat variables along the transect. Within each variable, the relative cover value was defined as the projection of the foliage volume of the layer (or rock and bare ground layer) onto a horizontal plane. We estimated this projection by comparison with the reference chart according to (Prodon and Lebreton, 1981) procedure.

Finally, we estimated the cover of surrounding agricultural fields and non-burnt forest patches in 250 m belt (seven categories of increasing cover). Aspect and slope were also estimated using a Digital Elevation Model (DEM) generated by the ICC from topography 1:50.000 maps. The DEM has a spatial resolution of 30 m and it was used to calculate the mean aspect and proportion of pixels with North orientation and with South orientation within each transect.

In order to assess the effect of different post fire management treatments on bird community in our study area, we estimated within each transect the amount of standing and laying dead burnt trunks (seven categories of increasing density).

Data analyses

Principal Components Analysis (PCA, Statistica V.6) with a varimax normalized rotation, which maximizes the correspondence between the factors and the original variables, was used to simplify vegetation variables. Mean values of habitat variables of both visits for each transect were used in this analysis. Redundacy Analysis (RDA, Canoco for Windows 4.5) was employed to relate the species abundance data to the environmental variables (ter Braak 1986). Species abundance and the factors obtained by PCA were used in this analysis. The number of factors was then reduced using the automatic forward selection option in the Canoco programme. This allows for the step-wise building of a model for the species data, starting with the variable that explains most of the variance. Subsequent factors were included only if they significantly improved the explained variance (based on Monte-Carlo permutation tests) (ter Braak 1995).

To further investigate to which degree post fire heterogeneity in vegetation recovery affects the conservation value of the bird community, we used generalized linear model (with R programme). We used number of species with a conservation status, SPEC 2 or SPEC 3, within each transect as a dependent variable and used logistical regressions (Poisson distribution).

Results

Habitat differences between transects

The PCA summarized environmental descriptors in seven principal factors, explaining 81% of data variability (Table 1). The first factor (F1OakReg) represented a gradient of decreasing regeneration of *Quercus humilis* dominating northern slopes to areas with virtually no regeneration of this deciduous oak species in southern dominated slopes. This factor explained a quarter of the data variability. The second factor (Farmland) represents a gradient of decreasing agricultural fields and not burnt areas to areas with high aspect. The third factor (post-fire management) is related mainly with the amount of standing and laying dead burnt trunks. The fourth factor (Pinus) is related with resprouters of *Pinus halepensis*. The fifth factor (Vegetation) represents a gradient of decreasing shrub vegetation to areas with low vegetation cover. The sixth factor (Stream) is related with stream and the seventh is related with resprouters of *Quercus ilex.*

Table 1- *Variables describing the habitat structure and factors loading of each variable in relation to the seventh factors obtained in the Principal Components Analysis (factor rotation: varimax normalised).*

	F1 (Oak Reg)	F2 (Farmland)	F3 (Management)	F4 (Pinus)	F5 (Vegetation)	F6 (Stream)	F7 (Holm Oak)
Bare soil	-0.67	-0.29	-0.01	0.01	0.44	-0.20	0.09
Low vegetation	0.02	-0.06	-0.16	-0.04	-0.86	0.18	-0.01
Shrub vegetation	-0.40	-0.09	0.05	0.02	0.72	0.16	0.15
Resprouters of Quercus ilex	-0.21	0.13	0.01	0.05	0.08	-0.03	0.90
Resprouters of Pinus halepensis	-0.01	-0.07	-0.05	0.94	0.03	-0.13	0.05
Resprouters of Quercus humilis	0.83	0.19	0.11	-0.21	-0.13	-0.13	-0.17
Dead branches in the soil	-0.35	-0.11	0.68	0.44	0.13	0.00	-0.17
Dead trees	0.12	0.07	0.90	-0.18	0.12	-0.02	0.11
Rock	-0.66	-0.14	0.12	-0.06	0.32	0.10	0.46
Aspect	-0.43	-0.58	0.00	0.15	0.35	0.24	-0.10
Stream	0.13	-0.08	-0.01	-0.13	-0.07	0.93	-0.01
North orientation	0.87	-0.15	-0.06	-0.04	0.00	0.09	-0.04
South orientation	-0.85	-0.07	0.03	-0.07	0.08	-0.17	0.04
Agricultural fields	0.02	0.79	0.03	-0.12	-0.12	-0.12	0.33
Not burnt areas	0.04	0.87	-0.01	0.04	0.15	0.06	-0.13
Prp.Totl	**0.24**	**0.13**	**0.09**	**0.08**	**0.12**	**0.07**	**0.08**

Bird-habitat relationships

We selected those species which were detected in more than 5% of the transects in order to delete rare species. A total of 45 species were selected (Table 2). 51 percent are listed among the species of European conservation concern (SPEC) with a vulnerable or declining status in Europe (SPEC2 or SPEC3 respectively, Bird Life International, 2004)

Factors from the PCA would be able to explain up to 28.8% of the total variability in bird community composition. The explanatory effect of all factors except factor 3 (Management) ($p>0.05$) was significantly different and was taken into account in the analysis. The first axis was correlated mainly with *Quercus humilis* resprouters and with the vegetation cover. The second ordination axis is positive more correlated with farmland and negative more correlated with *Quercus humilis* resprouters (Fig. 2).

Table 2-*List of the bird species found in more than 5 percent of the transects inside fire perimeter. The highest abundance (number of individuals seen or heard) between both visits and percentage of transects occupied by each species (occurrence) are shown.*

Scientific name	**Common name**	**Abbreviated name**	**Abundance (number of individuals)**	**Occurrence (pct)**
Alectoris rufa	Red-legged Partridge	Ale_ruf	85	50
Columba palumbus	Word Pigeon	Col_pal	48	34
Streptopelia turtur	Turtle Dove	Str_tur	54	35
Cuculus canorus	Common Cuco	Cuc_can	13	13
Upupa epops	Hoopoe	Upu_epo	13	10
Jynx torquilla	Wryneck	Jyn_tor	24	22
Picus viridis	Eurasian Green Woodpecker	Pic_vir	14	12
Dendrocopos major	Great Spotted Woodpecker	Den_maj	32	27
Galerida theklae	Thekla Lark	Gal_the	19	14
Galerida cristata	Crested Lark	Gal_cri	6	6
Lullula arborea	Woodlark	Lul_arb	246	91
Alauda arvensis	Skylark	Ala_arv	10	10
Anthus campestris	Tawny Pipit	Ant_cam	17	17
Troglodytes troglodytes	Wren	Tro_tro	30	26
Luscinia megarhynchos	Nightingale	Lus_meg	166	75
Saxicola torquata	Stonechat	Sax_tor	172	80
Oenanthe hispanica	Black-eared Wheatear	Oen_his	76	39
Monticola saxatilis	Rock Thrush	Mon_sax	43	30
Turdus merula	Blackbird	Tur_mer	56	48
Hippolais polyglotta	Melodious Warbler	Hip_pol	134	58
Sylvia undata	Dartford Warbler	Syl_und	355	80
Sylvia cantillans	Subalpine Warbler	Syl_can	363	90
Sylvia melanocephala	Sardinian Warbler	Syl_mel	44	32
Sylvia hortensis	Orphean Warbler	Syl_hor	18	17
Sylvia atricapilla	Blackcap	Syl_atr	30	23
Phylloscopus bonelli	Bonelli's Warbler	Phy_bon	53	38

Scientific name	Common name	Abbreviated name	Abundance (number of individuals)	Occurrence (pct)
Aegithalos caudatus	Long-tailed Tit	Aeg_cau	18	9
Parus cristatus	Crested Tit	Par_cri	12	9
Parus caeruleus	Blue Tit	Par_cae	13	10
Parus major	Great Tit	Par_maj	89	56
Oriolus oriolus	Golden Oriole	Ori_ori	35	25
Lanius meridionalis	Great Grey Shrike	Lan_mer	62	49
Lanius senator	Woodchat Shrike	Lan_sen	35	26
Garrulus glandarius	Jay	Gar_gla	44	33
Corvus corone	Carrion Crow	Cor_cor	15	12
Sturnus vulgaris	Starling	Stu_vul	18	11
Petronia petronia	Rock Sparrow	Pet_pet	27	9
Fringilla coelebs	Chaffinch	Fri_coe	8	7
Serinus serinus	Serin	Ser_ser	69	47
Carduelis carduelis	Goldfinch	Car_car	23	14
Carduelis cannabina	Linnet	Car_can	297	83
Emberiza cirlus	Cirl Bunting	Emb_cir	85	51
Emberiza cia	Rock Bunting	Emb_cia	227	87
Emberiza hortulana	Ortolan Bunting	Emb_hor	155	61
Emberiza calandra	Corn Bunting	Emb_cal	239	76

The multivariate analyses (RDA) described three main groups of species according to how they were associated to post-fire vegetation gradients. A first group, defined by open habitat specialists (*Emberiza hortulana*, *Anthus campestris*, *Oenanthe hispanica*…) using sparse vegetation with no or poor tree regeneration. The second group defined by shrubland generalist species using areas where resprouters of *Quercus* species dominate (*Hippolais polyglotta, Sylvia cantillans, Sylvia atricapilla*,…), especially in north-facing slopes. Finally, the third group was characterised by habitat mosaic species using burnt areas near agricultural land and small patches of non-burnt pine forests (*Streptopelia turtur*, *Lanius senator*, *Oriolus oriolus*,…) (Fig. 2).

The conservation value of the bird species community was significantly related to post-fire regeneration patterns. In particular, the bird community conservation value increases in areas with sparse vegetation (Factor 5).

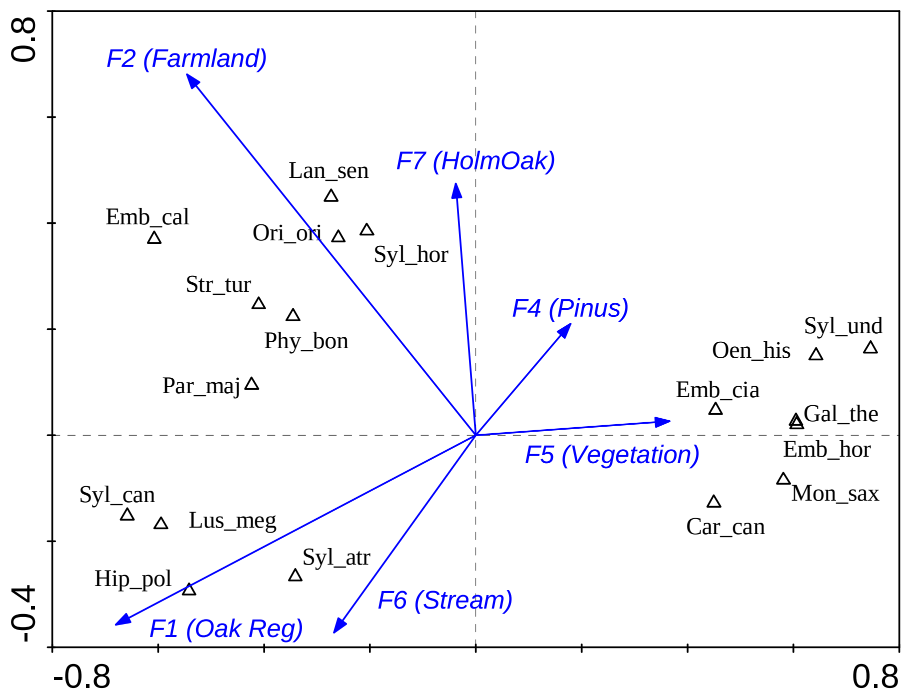

Fig 2-Associations estimated between the bird species and the environmental variables selected by the Redundancy analysis (RDA). The variables have been selected from a progressive evaluation of the meaning of the different variables, by mean of the Monte Carlo test. Only the variables with a p-level of at least 0.05 are included. There are too many species arrows and labels in the resulting diagram, so we display only the bird species, which are well characterized by the first two axes. In order to interpret the environmental variable and the species acronym's, see Table 2.

Discussion

Postfire regeneration

The non-direct regeneration of the pre-fire dominating tree species in the area, *Pinus nigra*, appeared to have critical consequences in the vegetation gradients arising 7 years after fire. In particular, the dominating regeneration patterns, *Quercus* dominated stands and those characterised by a lack of tree regeneration were found to have a profound effect on the composition and conservation value of the prevailing bird community. Other authors have found that dominating tree species or grassland depend on topography and/or management features that favour or hinder the establishment of *Quercus* individuals (Espelta and others, 1995; Broncano and others, 1998), and our study has shown how these arising gradients structure bird community patterns in a non direct regeneration context.

We have shown that non-direct regeneration of *Pinus nigra* in our area leads to the formation of three main different habitat gradients depending on their structural and landscape characteristics. The first defined habitat was a new kind of forest type arising in the area and formed by resprouters of *Quercus humilis* prevailing mainly in the northern slopes. A second characteristic habitat was the mosaic of non-burnt forests, burnt areas and agriculture lands prevailing in flat areas. The third habitat appeared to be located in southern slopes in which pre-fire abundance of resprouters was low most likely due to recent land use history, leading to a poor vegetation recovery dominated by grasses and low shrubs.

Pine forests have increased in the most of Catalonia following land abandonment of previous agricultural land. The colonising process is headed by pines and continued by *Quercus* species installed in the understory thanks to long distance dispersal facilitated mainly by birds and rodents (Mosandl and Kleinert, 1998, Gomez, 2003). However, in many areas this second process has not been yet possible and therefore, pine forest understory is scarce. Reduced vegetation recovery in burnt areas may be further worsened by the impact of grazing activity as is corroborated by the reduced vegetation cover measured in grazed areas and further shown in experimental works in the area (Bonfil and others, 2004)

Bird community

The variegated, mosaic landscape, generated after the fire induced the appearance of three groups of bird species virtually absent or rarer from pre-fire, forested conditions:

One group defined by bird species using areas where resprouters of *Quercus* species dominate, specially in north-facing slopes as *Hippolais polyglota, Luscinia megarynchos* and *Sylvia atricapilla*. A second group defined by open habitat species using sparse vegetation with no or poor tree regeneration. Prodon, 1987; Real, 2000 already found a positive effect of fires on these species during the first successional stages although they tend to disappear later in succession. However, our study has taken in different context because direct regeneration was not observed. Non-direct regeneration had a positive effect on this group of bird species by postponing extinction processes related to vegetation recovery. A third group defined by species using burnt areas near agricultural land and small patches of non-burnt pine forests. This agroforested mosaic landscape counted with the highest number of bird species. Some open habitat species were present in this group, as the woodlark, *Lullula arborea* and the corn bunting *Emberiza calandra*. These species need of some trees remaining to establish their territories but dense standing trees constitute a serious barrier for them. On the other hand, more forest bird species as the Great tit, *Parus major*, and the golden oriole, *Oriolus oriolus*, were also present in this group due to their use of the forest patches habitat remaining within the prevailing mosaic.

Common forest bird species as *Certhia brachydactyla*, *Regulus ignicapillus* and *Phylloscopus collybita* were present in very low numbers after the fire. These species concentrate their activity in the canopy stratum. In the present study area, this habitat is only present in small patches and is surrounding for non-adequate habitat and this might not be enough for the presence of these species on the area.

The main contribution of this study consists in demonstrating that large fires affecting forests with a non-direct regeneration of the vegetation may have a significant impact on the landscape composition and structure leading to characterize bird community patterns. Large fires affecting non-direct regenerating forest types lead to a new and radically different mosaic landscape offering new opportunities to species with unfavourable conservation status at the European level.

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