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Comparing the effect of salvage logging on birds in the Mediterranean Basin and the Rocky Mountains: Common patterns, different conservation implications

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ABSTRACT

Postfire salvage logging is currently a controversial issue because of the impact that the removal of snags has on ecosystem structure and function. Although it is a common practice worldwide, the absence of comparisons across regions hinders the development of broad generalizations. Here we compare bird response to postfire salvage logging in two regions with significant differences in landscape and bird communities, the Mediterranean Basin and the Rocky Mountains. The Mediterranean Basin features a landscape dominated by a mosaic of small-sized forests, farmland and shrublands, while the Rocky Mountains have large extensions of continuous forests. Bird conservation priorities are also different. In the Mediterranean Basin, priorities are oriented toward farmland birds, while they are oriented toward fire-specialists in the Rocky Mountains. We used databases describing bird species occurrence in burned forests from both regions and defined three groups of species based on their level of association with snags. We then compared the richness of each group among logged and unlogged sites, and also between regions. We found a higher proportion of species that showed some degree of association with snags in burned forests of the Rocky Mountains than in the Mediterranean Basin. Highly snag-associated birds from both regions showed a common negative response to salvage logging. Not snag-associated species increased in salvaged areas, but only in the Mediterranean Basin. The general negative effect of salvage logging on forest-dwelling species that are associated with trees or snags is a noteworthy pattern given the big differences between regions. Nevertheless, in the Mediterranean, some threatened farmland species benefit from logging, so the overall effect of the removal of snags appears to be relatively more detrimental to birds in the Rocky Mountains.

1. Introduction

Wildfires are a crucial part of the natural dynamics of many forest ecosystems worldwide. Species living in environments that have been repeatedly affected by fire show adaptations to a particular disturbance regime; in some instances, species even appear to have evolved to depend on the presence of relatively intense fire events (Hutto, 2008; Pausas and Keeley, 2009). Wildfire is a natural component of the forest dynamics in most systems, but in areas where forests are managed for wood harvesting, wildfire is usually considered to be a problem because it destroys economically valuable timber. Consequently, the prevailing public perception in many countries is still that wildfires are environmental disasters that have to be avoided, and that burned forests must be "restored" or rehabilitated to re-create "healthy" forests as rapidly as possible (Swanson et al., 2011). This public perception has also led to a level of fire suppression that has affected forest structure and dynamics (Hessburg and Agee, 2003; Pausas et al., 2008), and to current postfire management practices that emphasize salvage logging over a hands-off management strategy. In private forests aimed at timber production, postfire logging allows the landowner to recoup some of the economic losses caused by fire, which seems reasonable given the primary objective of the landowner. In public forests, however, ecological sustainability should be the overarching management goal and, therefore, salvage logging for the sake of mining the economic value tied up in the standing dead timber is not as easily justified. After all, there are values associated with a standing dead forest to consider. Specifically, snags and other coarse woody debris play important roles in the ecosystem after fire, being sources of nutrients and providing habitat to species that need burned forest conditions (McIver and Starr, 2000; Lindenmayer and Noss, 2006). Nevertheless, public land managers tend to couple economic values with a perceived need for "forest restoration" to gain public support for salvage logging operations.

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Salvage logging profoundly affects the process of natural forest succession after fire and can be viewed as a second form of disturbance rather than a restoration activity. The impact of salvage logging on the biota living in burned forests has been studied mostly with birds, which show responses that differ among species (Llimona et al., 1993; Kotliar et al., 2002; Morisette et al., 2002). In general, forest birds are negatively affected by the removal of snags, while early-successional species may benefit from this practice. Interestingly, most studies that have focused on the issue of salvage logging have been developed primarily in conifer forests from two regions: northwestern United States and Canada (e.g. see Saab and Dudley, 1998; Morisette et al., 2002; Hutto, 2008) and, to a lesser extent, the Mediterranean Basin (e.g. Izhaki and Adar, 1997; Rost et al., 2010; Castro et al., 2010). For millennia, wildfires have played (and still play) an important role in the vegetation and landscape dynamics of both regions (Arno et al., 2000; Hessburg and Agee, 2003; Pausas et al., 2008), which also share salvage logging as the most commonly performed management treatment after a conifer forest burns (Lindenmayer and Noss, 2006).

Despite the shared importance of fire and postfire management in these regions, they differ in many important ways, regarding forest management, fire regime, human settlement and land-use histories, and the landscape configuration and composition of their bird communities. Northwestern North American forests have undergone lower human pressure and management intensity than those in the Mediterranean Basin (Hessburg and Agee, 2003), and they harbor a higher number of forest specialist birds, including several fire specialists (Hutto, 2006). In contrast, Mediterranean forests have been deeply modified by humans for centuries (Pausas et al., 2008), and their bird communities are basically composed of species that are widely distributed across most European forests (Blondel and Aronson, 1999). On the other hand, the bird species that have captured most conservationists' concerns and efforts in Europe in recent decades are those from steppes and farmlands because those species have sharply declined due to habitat loss and degradation (BirdLife International, 2004). Some of these species colonize recently burned areas, apparently benefitting from fire (Pons and Bas, 2005; Brotons et al., 2008) and logging (Castro et al., 2010; Rost et al., 2010). Therefore, differences in the avifauna and conservation priorities in different regions need to be considered when assessing the impact of salvage logging on bird communities.

The plant species of both regions show several common adaptations to fire, which reflect the fact that they may have evolved with a long history of fire (Pausas and Keeley, 2009). There are pines with serotinous cones that open and release the seeds in the presence of fire (Aleppo pine (*Pinus halepensis*) in the Mediterranean Basin, Lodgepole pine (*Pinus contorta*) in the Rocky Mountains), there are species with thick bark, high canopy and few low branches that avoid torching, that can survive surface fires (European black pine (*Pinus nigra*) in the Mediterranean Basin, Ponderosa pine (*Pinus ponderosa*) in the Rocky Mountains), and even some species that resprout after being burned (Holm and Cork oaks (*Quercus ilex* and *Quercus suber*) in the Mediterranean Basin, Western larch (*Larix occidentalis*) in the Rocky Mountains).

However, there are fundamental differences in the fire regimes between the two regions. Although most fires occur in the same season (late summer) in both regions, in the western Mediterranean Basin most fires are human-caused, while in northern Rocky Mountains most fires ignite by natural causes (lightning). This is not surprising, given that the population density in Catalonia (about 230 people/km^2) is roughly 50 times that of western Montana. The average fire size is much smaller in the western Mediterranean Basin than in the Rocky Mountains (Table 1), which is partly a consequence of the differences in landscape configuration between the two regions. Most fires in the western Mediterranean Basin are high-severity, stand-replacement fires, which have increased in number in recent decades (Pausas, 2004; González and Pukkala, 2007) due to rural depopulation, farmland abandonment (Pausas et al., 2008), and fire exclusion policies that contributed to increases in fuel loads and forest connectivity. In the northern Rocky Mountains, most fires are mixed-severity fires, and the fire regimes associated with all but the lowest elevation dry forest type are well within what is expected of the natural fire regimes in the region (Arno et al., 2000; Baker, 2009).

The way salvage logging is carried out in both regions also has some particularities that are worth highlighting here. In our study area in Catalonia, 80% of the forests are privately owned, so salvage logging is mainly intended to recoup the economic losses caused by fire. This means that the most usual postfire treatment consists in logging everything except the smallest snags and the trees that were not killed by fire, which results in large clearcuts. Selective logging is rare, and carried out almost entirely on publicly owned forests under the guise of creating a certain level of habitat heterogeneity, sometimes in an experimental way. In contrast, most forests in the northern Rocky Mountains are public and managed by the US Forest Service. There, postfire salvage logging occurs in relatively small patches or management units (which average about 40 ha in extent). Managed burned forests in the northern Rocky Mountains usually consist of a mix of unlogged patches, lightly logged patches, and clearcuts.

In this study, we compare the response of birds from these two distant regions to postfire salvage logging to understand the effects of postfire forest management when placed in different geographical and political contexts. We would expect that birds with similar levels of association with snags would share common responses to the removal of snags in a burned forest. On the other hand, given that there are more forest specialist species in the Rocky Mountains, and that open-habitat appear more threatened than forest species in the Mediterranean Basin, we would also expect that the impact of postfire salvage logging would be more severe in the Rocky Mountains than in the Mediterranean Basin. With these questions in mind, we took advantage of the availability of information on the occurrence of birds in burned areas gathered in Catalonia (Mediterranean Basin) and western Montana (Rocky Mountains), and studied the response of bird guilds from both regions to salvage logging after fire.

Table 1
Summary of the number of burned sites, their average size (in hectares) and the number of samples included in the study for each region (see Appendix A for further information).

Region	Fires	Mean fire size	Sample sizes[a]		
			Total	UL	LG
West Mediterranean Basin	22	648	309 transects	170	139
Northern Rocky Mountains	17	6944	666 point counts	542	124

[a] Postfire treatment: UL, unlogged; LG, logged.

2. Methods

2.1. Study area

Catalonia, located in the western part of the Mediterranean Basin is a 32,000 km^2 region located in the northeastern corner of the Iberian Peninsula (latitudinal range from 40°N to 42°N; Fig. 1). Excluding the temperate and colder Pyrenees Mountains in the north and northwest, which are forested but where wildfires are very rare, the rest of Catalonia has a typical Mediterranean climate and a rugged landscape dominated by a mosaic of farmland, forest and shrubland. These low-elevation forests are dominated by Aleppo pines (*P. halepensis*), European black pines (*P. nigra*) and Holm oaks (*Q. ilex*). Most of them are second-growth forests that have colonized former agricultural areas.

The northern Rocky Mountains study area is a 80,000 km^2 region located in the northwestern part of the United States, in western Montana (latitude between 46°N and 48°N). The region's climate is continental, and the landscape is dominated by mountains covered by conifer forests, whose main species are Ponderosa pine, Lodgepole pine and Douglas-fir (*Pseudotsuga menziesii*). Sagebrush, prairies and farmland are found mostly in valleys. In contrast with the Catalan system, the Rocky Mountains system is largely intact, and many forests grow as they have for millennia.

2.2. Data on birds and postfire management

We gathered data on the occurrence and abundance of birds in recently burned forests in association with independent monitoring projects. In Catalonia, birds were surveyed by line transects (Zozaya et al., 2010), counting birds along 15-min transects walked at a relatively constant pace. Each transect was separated from other transects by at least 150 m. In these transects, birds were counted in three distance bands (0–25 m, 25–50 m and 50–100 m). In western Montana, surveys were carried out using 10-min point counts. Points were separated from one another by at least 250 m. At each point, observers registered the distance from the observer to the bird. In both surveys, birds were detected both visually and aurally, and birds flying over were not registered. Surveys were carried out in the breeding season (spring) in both cases. Taking into account the differences in methods, we used only the occurrence of each bird species detected within 50 m of the observer. This relatively short fixed distance allowed us to be confident that we detected most birds in the area immediately surrounding the transect or point count (Gottschalk and Huettmann, 2011). Most fires surveyed occurred in late summer (August–September).

In both locations, we gathered information on the postfire management treatment performed at the sample level (transect or point count). Management possibilities were: unlogged (UL), when the sample area was not logged, and logged (LG), when the area was clearcut or very few snags were left standing (less than 10 snags/ha). Since information about snag density was not available in the databases, partially logged areas (where a certain amount of snags were left unlogged while others were removed) were not considered.

In order to focus on the most similar habitats and disturbance effects, we chose only conifer forests that were burned by high-severity fires. Although surveys were conducted since the first year after fire in both locations, we used only those samples that were obtained in the third and fourth year after fire because of the lack of enough salvaged samples in the two first years after fire. That allowed us to better control any variability related to time since fire in the studied bird communities. Impacts and differences in postfire bird communities are especially remarkable during the first and second years after fire, and rapidly diminish later on (Herrando et al., 2002; Smucker et al., 2005; Saab et al., 2007). Therefore, we did not differentiate between the third and fourth years after fire, as other authors have previously done (Pons and Clavero, 2010). Transects or points were surveyed only once per year. In total, 25% of points in Montana and 64% of transects in Catalonia were surveyed both in the third and the fourth year after fire. This resulted in a sample of 309 transects in 22 burned sites in Catalonia and 666 points in 17 sites in western Montana (Table 1).

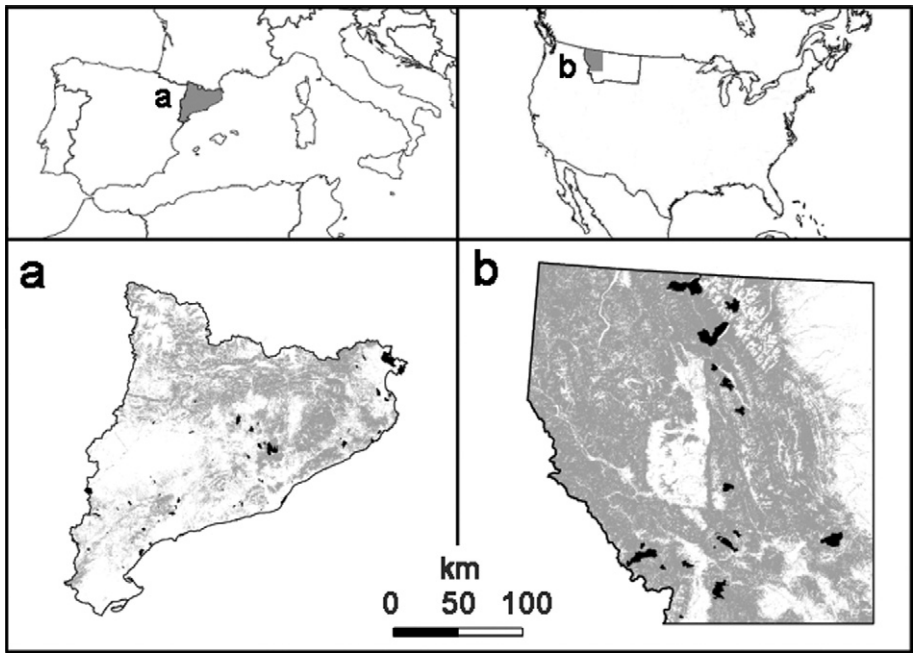

Fig. 1. Location of the two regions compared: (a) West Mediterranean Basin (Catalonia) and (b) Northern Rocky Mountains (north-western Montana). In the enlarged pictures, which are in the same scale, studied burned areas that were used in the comparison are highlighted in black. Areas darkened in gray represent forest cover, which are shown in order to highlight landscape configuration differences between the two regions.

2.3. Species classification

In order to compare the occurrence rates of different bird species between regions, we classified all species detected according to their known association with snags. We used known life-history traits of each species, using information from literature (Ehrlich et al., 1988; Cramp, 1998; Estrada et al., 2004) and our own knowledge (in case information from literature was incomplete or based on data from regions other than those studied here, which occurred in very few cases) to classify the species in three categories:

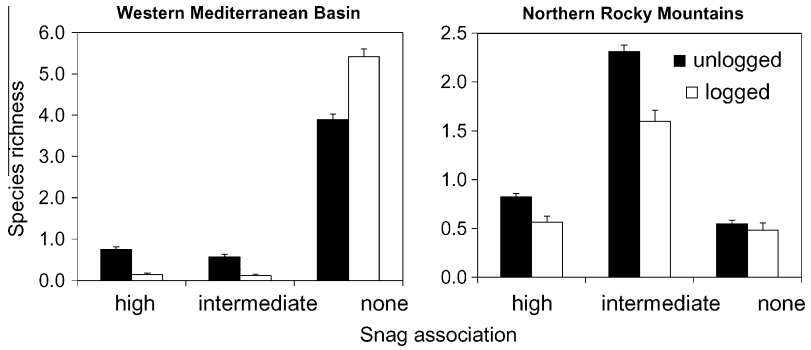

Fig. 2. Species richness of highly snag-associated species (HSA), intermediate snag-associated species (ISA) and not snag-associated species (NSA) in samples of burned forests that had not been logged (black bars) or had been logged (white bars), in the Western Mediterranean Basin and in the Northern Rocky Mountains.

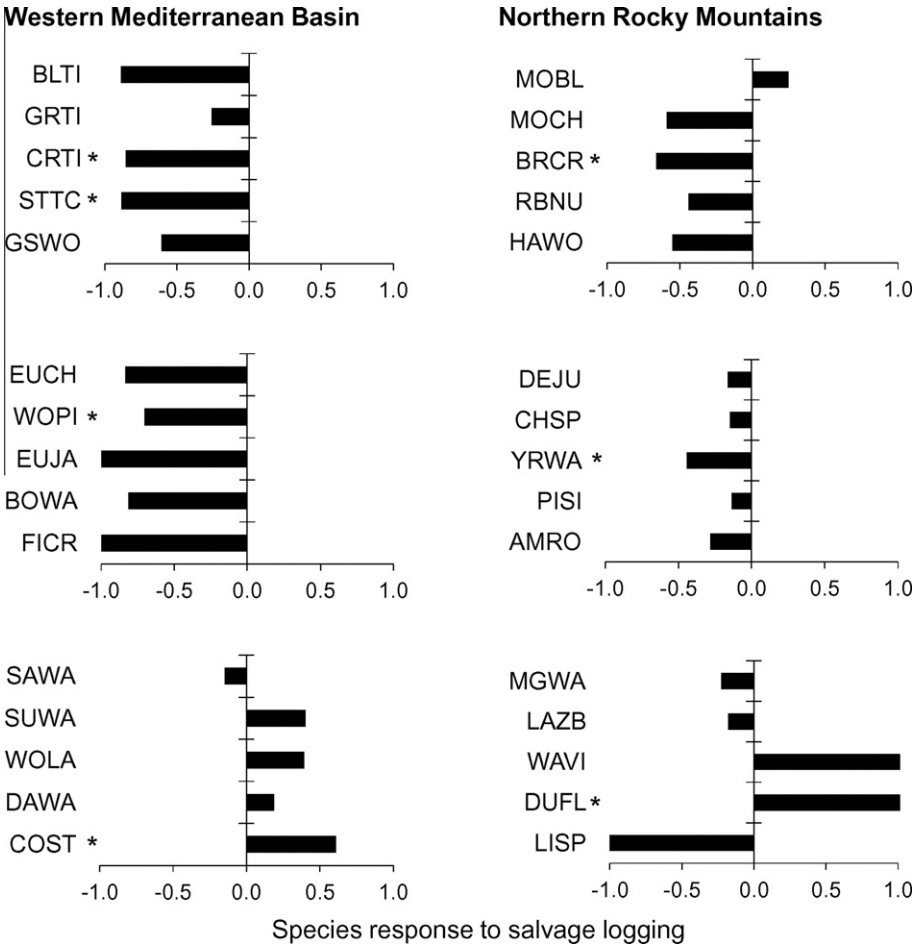

Fig. 3. Response of five most common species (BLTI: Blue Tit, GRTI: Great Tit, CRTI: Crested Tit, STTC: Short-toed Treecreeper, GSWO: Great Spotted Woodpecker, EUCH: Eurasian Chaffinch, WOPI: Wood Pigeon, EUJA: European Jay, BOWA: Bonelli's Warbler, FICR: Firecrest, SAWA: Sardinian Warbler, SUWA: Subalpine Warbler, WOLA: Wood Lark, DAWA: Dartford Warbler, COST: Common Stonechat; MOBL: Mountain Bluebird, MOCH: Mountain Chickadee, BRCR: Brown Creeper, RBNU: Red-Breasted Nuthatch, HAWO: Hairy Woodpecker, DEJU: Dark-eyed Junco, CHSP: Chipping Sparrow, YRWA: Yellow-rumped Warbler, PISI: Pine Siskin, AMRO: American Robin, MGWA: McGillivray's Warber, LAZB: Lazuli Bunting, WAVI: Warbling Vireo, DUFL: Dusky Flycatcher, LISP: Lincoln's Sparrow) of each snag association category (HSA: highly snag-associated species, ISA: intermediate snag-associated species, NSA: not snag-associated species) to salvage logging. Bars represent the proportion of samples with presence of the species in unlogged samples minus the proportion of samples with presence of the species in logged ones (black bars), divided by the sum of both proportions. Asterisks indicate which species' occurrence showed significant differences ($P < 0.05$) between postfire categories. No analysis could be performed with European Jay (EUJA), Firecrest (FICR) and Lincoln's Sparrow (LISP) occurrence because it was not detected in any logged sample.

(1) highly snag-associated species (HSA), those that almost only use snags to nesting and/or foraging, i.e., all tree-cavity nesters and bark foragers; (2) intermediate snag-associated species (ISA), those that do not actually need snags to nesting and/or foraging, but that may use them for such purposes, i.e., canopy gleaners and canopy nesters, and (3) not snag-associated species (NSA), those that do not use snags either for nesting or foraging.

2.4. Data analysis

In order to compare the response of HSA, ISA and NSA species to salvage logging, we calculated the richness of those species in each sample (transect or point). We then analyzed the effect of forest management (logged *vs.* unlogged) on the species richness of the three species groups using Generalized Linear Mixed Models (GLMMs). Since the bird survey method was different in each region, we performed separate analyses for each region. Forest management, a categorical factor with two levels, was included as a fixed effect. Samples were not entirely independent because they were grouped in different fires, and 25% of points and 64% of transects were surveyed twice (i.e. in two consecutive years), so we included two random factors to overcome such pseudoreplication—site and sample nested within site. Since the response variable was species richness, we used a model with Poisson error distribution and log link. In order to detect possible overdispersion problems, we checked the relationship between the generalized chi-square parameter and the degrees of freedom of each model. This value was close to 1 in all cases, and therefore we can conclude that models were not overdispersed. Furthermore, we also analyzed whether the presence of the five most frequent species of each snag association group from each region were affected by salvage logging. To do so we used the same fixed and random factors as in the previous analyses, performing models with binomial distribution and logit link function. We evaluated the significance of fixed effects with F tests with $P < 0.05$ judged to be statistically significant. We performed all these analyses with SAS 9.1.

3. Results

We obtained information on the occurrence of 70 species in Catalonia and of 80 in western Montana. Salvage logging affected species with different levels of snag association differently (Fig. 2). The effect of logging was significantly negative on the number of HSA species present in the transects or point counts (Catalonia: $F_{1;115} = 9.45$, $P = 0.003$; Montana: $F_{1;101} = 4.89$, $P = 0.029$.). The effect was also negative, and consistent between regions, for ISA species (Catalonia: $F_{1;115} = 5.69$, $P = 0.019$; Montana: $F_{1;101} = 16.34$, $P < 0.001$). In contrast, the richness of NSA species was not affected by salvage logging in western Montana ($F_{1;101} = 0.40$, $P = 0.530$), whereas it was in the Mediterranean Basin, where the number of NSA species was significantly higher in logged areas than in unlogged ones ($F_{1;115} = 5.41$, $P = 0.029$).

The individual responses of the most frequently detected bird species can help us to better understand these regional differences and, specifically, how bird community composition changes after postfire logging (Fig. 3; see Appendix B for further details). In general, most frequent HSA and ISA species from both regions showed negative responses to salvage logging (Fig. 3), which were significant in the case of the Crested Tit (*Parus cristatus*), the Short-toed Treecreeper (*Certhia brachydactyla*), the Wood Pigeon (*Columba palumbus*), the Brown Creeper (*Certhia americana*) and the Yellow-rumped Warbler (*Dendroica coronata*). Regarding NSA species, the response was positive in four out of the five most frequent Mediterranean species (but significant only in the case of the Common Stonechat *Saxicola torquata*), while in Montana only two out of the five most frequent NSA species were more frequent in logged areas, and the Dusky Flycatcher (*Empidonax oberholseri*) was the only one that showed a significant result. The responses of European Jay (*Garrulus glandarius*), Firecrest (*Regulus ignicapilla*) and Lincoln's Sparrow (*Melospiza lincolnii*) could not be tested statistically since they were never detected in logged samples, suggesting a strong negative effect of salvage logging on their occurrence.

4. Discussion

In burned forests from regions as different as the Mediterranean Basin and the American Rocky Mountains, the change in habitat structure following salvage logging produces a common pattern: a decline in bird species that are heavily associated with snags. The number of most forest-restricted species from both regions (chickadees, tits, creepers, woodpeckers, nuthatches, arboreal warblers and finches) decreased markedly as a result of salvage logging. This is consistent with the results of previous studies, which have shown that the occurrence or breeding success of fire-specialists, i.e. those birds especially linked to severely burned pine forests depends on the presence of relatively densely stocked burned forests (Kotliar et al., 2002; Hutto and Gallo, 2006; Saab et al., 2007; Hutto, 2006, 2008). This response is also shown by bird species that could be considered less dependent on the availability of snags (intermediate snag-associated birds, i.e., canopy nesters and foragers), and therefore could be hypothetically less sensitive when facing salvage logging. Nevertheless, few of these intermediate snag-associated birds showed significant responses, and there are highly snag-associated species whose presence seemed not to be affected by salvage logging, such as the Mountain Bluebird (*Sialia currucoides*). However, some other aspects of the biology of these species may still have been negatively affected. For instance, Hutto and Gallo (2006) demonstrated that Mountain Bluebirds nest density was much lower in salvaged patches than that in unlogged ones due to the reduction in the number of cavities in logged areas. Therefore, information about the occurrence of bird species, although being a useful metric for understanding the distribution and habitat preferences of species, should be supplemented by other information related to the species' biology that may also be affected by salvage logging (e.g., issues related to breeding success).

Not snag-associated bird species showed different responses to salvage logging between regions. In the northern Rocky Mountains they did not show a significant response as a whole group, while in the western Mediterranean Basin its species richness increased in logged areas. On one hand, both regions had a handful of shrub-dwelling birds (e.g., warblers and shrikes) that, in general, did not show significant differences between unlogged and logged areas. These species are probably more linked to shrubland regeneration itself rather than to the presence of snags. Therefore salvage logging is less likely to affect shrub-dwelling species even when some of them, provided there is enough shrub cover, may prefer more open, logged areas (e.g., Subalpine Warbler (*Sylvia cantillans*), Warbling Vireo (*Vireo gilvus*) and Dusky Flycatcher (*E. oberholseri*), which showed significant or almost significant responses (Appendix B)). On the other hand, in the western Mediterranean Basin there are many bird species that typically inhabit farmland and steppe-like habitats that colonize burned forests (Brotons et al., 2005; Pons and Bas, 2005), and that generally benefit from salvage logging (Rost et al., 2010). Species such as larks, buntings or pipits (generally known as "farmland" species) are far more common in Mediterranean burned areas than in those in the Rocky Mountains, which is probably a consequence of the different landscape configurations between regions. These colonizers tend to occur in recently burned areas only if there are source populations

close enough, because the probability of colonization is limited by dispersal constraints (Brotons et al., 2005, 2008). Therefore, burned (and logged) areas located too far from source populations are less likely to be occupied than those areas located near those habitats supporting populations of potential colonizers. In the fine-grained Mediterranean landscape, forests are relatively close to farmland areas, which can explain the difference in response of farmland birds between regions. On average, the distance between the burned forests we studied in the Mediterranean Basin and the nearest farmland area was just 180 m. In contrast, in the northern Rocky Mountains, burned forests were two orders of magnitude farther away (on average, 17.8 km from prairies and pastures). Consequently, burned and logged forests in the northern Rocky Mountains could be suitable for species from open habitats, but were not as easily colonized as similar forests in the western Mediterranean Basin.

Our results, although showing interesting common responses between regions, also suggest that the impact of salvage logging cannot be considered equally severe in both regions as one might expect. Indeed, bird communities inhabiting burned forests are dominated by different kind of species in each region. In the Rocky Mountains, highly snag-associated birds constitute a higher proportion of the bird community (21 of 80 species, or 26%) than they do in the Mediterranean Basin (7 of 70 species, or 10%). Therefore, the impact of salvage logging can be greater in the Rockies because it is detrimental to a higher proportion of the bird community that occurs in burned forests than in the Mediterranean Basin. Furthermore, salvage logging (either clearcut or intermediate) is clearly detrimental in the Rocky Mountains to several fire specialists, like the Black-backed Woodpecker (*Picoides arcticus*) or the American Three-toed Woodpecker (*Picoides tridactylus*), which are relatively restricted to dense and severely burned forests (Saab and Dudley, 1998; Schwab et al., 2006; Hutto, 2008). In the western Mediterranean Basin, in contrast, none of the bird species can be considered to be fire specialists, and most species that are damaged by postfire salvage logging are common forest birds that have wide distributions across European forests, being neither rare nor threatened birds at a continental scale (Blondel and Aronson, 1999; BirdLife International, 2004). However, managers from certain areas of the Mediterranean Basin outside of our study area must be aware of the occurrence of narrowly distributed and endemic species, which may need to be preserved in the face of postfire salvage logging, like the Corsican Nuthatch (*Sitta whiteheadi*) (Moneglia et al., 2009). In contrast, most Mediterranean farmland species that occur in burned forest patches show negative population trends in Europe due to the loss and deterioration of their habitat (Fuller et al., 1995; BirdLife International, 2004). Therefore, the change in the cover type from forest to a more open habitat due to fire and salvage logging would be beneficial to them (Rost et al., 2010).

5. Conclusions

Postfire salvage logging appears to be strongly detrimental to species most closely tied to forest environments, a generalization that holds across two very different regions, the northern Rocky Mountains and the western Mediterranean Basin. We can expect that snag-associated birds would be the most negatively affected by postfire logging in other parts of the world as well. However, the gravity of those negative effects depends on the particularities of each region, and therefore it seems advisable not to generalize management decisions on burned forests, which should take into account each region's characteristics and conservation priorities. Specifically, it can be considered to be more detrimental to carry out salvage logging operations in a burned forest in the Rocky Mountains than in the Mediterranean Basin, where the negatively affected species are generally neither threatened nor restricted to postfire conditions. In the Rocky Mountains, the environment is still relatively pristine, and some species strongly depend on burned, unmanaged forest habitats. Thus, the ecological costs associated with postfire salvage logging appear to be much greater in Rockies than they are in Mediterranean Basin.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.biocon.2012.08.022.

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