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Possibilities for fire as a management tool on Kras (SW Slovenia): a bird's perspective

Gozdni požar kot orodje upravljanja zemljišč na Krasu (JZ Slovenija): ptičja perspektiva

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The response of birds to wildfires in sub-Mediterranean areas and the possible use of fire as a nature management tool in Kras (SW Slovenia) is reviewed. In recent years the limestone region called Kras was forested with Austrian Pine *Pinus nigra* and became more and more overgrown by bushes and trees due to depopulation and land abandonment, which has made it more vulnerable to fire. The latter patterns in particular are occurring throughout the whole sub-Mediterranean area and are affecting bird diversity drastically. Bird mortality during fires is low. For the first few years after a fire the richness and abundance of bird species decrease, and the species composition turnover rate is very high, from open habitat species to scrubland species. However, birds will colonise the burned area only when there is a neighbouring source population. In addition, larger burned areas are colonised more quickly than smaller ones. It is assumed that many birds will emigrate, while a number of species will adapt their territory size, nesting and foraging behaviour to the changed habitat. The severity of the habitat alteration and the change in food availability affect bird population dynamics. Bird species composition changes in parallel with vegetation succession. The effects of different aspects of fire, such as the size of the burned area, fire intensity, fire frequency and burning season, are reviewed. There are still many gaps in our knowledge of bird responses to fire, such as bird emigration after fires. However the impact of fire on birds is apparently not always detrimental and can even have a positive effect on populations. We therefore emphasize the importance of the continuation of research into the possibilities of fire as a management tool.

Key words: birds, Aves, Karst, Slovenia, wildfire, prescribed fire, population dynamics
Ključne besede: ptice, Aves, Kras, Slovenija, požar, nadzorovani požar, populacijska dinamika

1. Introduction

Fire has influenced landscapes throughout the ages and all over the world. However, the severity of fires is dependent, among other factors, on the ecosystem and meteorological conditions. With the appearance of humans, fire frequency increased dramatically. The combination of human initiated fire and natural fires, such as those caused by lightning, can alter habitats dramatically.

In Europe the most fire-adapted biogeographical region is the Mediterranean basin. Kras, as a sub-Mediterranean region in Slovenia, is very sensitive to fires (Global Fire Initiative 2004). By the 15th century, Kras had been deforested by humans and sheep and was only covered by stones. Kras became overgrown again due to forestation of Austrian Pine *Pinus nigra* and natural vegetation (mainly oaks *Quercus* sp.) The depopulation of the countryside and the abandonment of pastures and meadows in

more recent decades accelerated the succession. The accumulation of woody material, like dry bushes and needles from Austrian Pine (so-called fuel), increases the chance of fire in Kras.

One of the methods of preventing wildfire is prescribed fire. Prescribed fire has already been used for a few centuries in Central Europe (Goldammer & Page 2000). It varies from burning garbage to burning large patches for agriculture. However with the increasing fear of fire, these practices disappeared. Nowadays prescribed burning is also suggested for nature conservation (Global Fire Initiative 2004). First of all, flammable fuel can be removed with smaller prescribed fires. Secondly, the destructiveness of fire can create new local habitats which can increase regional biodiversity (Moreira *et al.* 2003). Moreover, the increase of open areas could attract endangered open area birds such as Tawny Pipit *Anthus campestris* and Ortolan Bunting *Emberiza hortulana* (Pons & Bas 2005).

As a reaction to the awareness of using fire for conservation purposes, much research has been done on this phenomenon. This review will focus mainly on the consequences of fire for birds, with a special focus on the possibility of fire as a management tool on Kras. Only one report on birds in Slovenia takes a sub-Mediterranean ecosystem into account (Geister 1999), so we have included research from comparable ecosystems.

2. Study area

Kras is an area located in the southwest of Slovenia. It is divided between Italy and Slovenia and has a sub-Mediterranean climate. It is a limestone area and karstic phenomena exist in most parts, so that there is almost no surface water.

Kras supports a wide variety of vegetation types due to human management and exploitation. In former times most of it was covered by pastures and meadows but nowadays it is slowly becoming overgrown with scrub of a variety of species, depending on the local (and very variable) climate. Moreover, Kras is largely covered by Austrian Pine, which was planted in the 18th century by Austrians (Kranjc 1997).

Over the last six years, 15.5 ha on average of Primorska, the southwesteren province of Slovenia, was burned annually (Šipec *et al.* 2000, Šipec & Babic 2001, Šipec & Babic 2002, Šipec & Babic 2003, Šipec & Babic 2004, Šipec & Krupenko 2005). Although the burned area is a small percentage of the province, large parts, such as Snežnik and urban areas, are less fire-prone, while most wildfires occur in the dryer Kras region.

3. Fire as a management tool

Fire is a phenomenon full of possibilities for nature management, as can already be seen with wildfires. Factors like size, intensity, frequency and season can interact and have different individual effects and, further, can easily be adapted. A higher frequency of fires for instance can take the ecosystem back into succession (reviewed in Boerwinkel *et al.* 2004).

With the necessary experience and the right conditions, the intensity of a fire can be adapted with burning against (back fire) and with (head fire) the wind. The effects however are completely different. Back fires are known to be much hotter and go deeper into the ground, with detrimental effects for the litter layer, the seed banks and sheltering ground arthropods. The head fire, on the other hand, is used for burning the woody species, as they develop high temperatures in the upper flame ranges (up to 1000°C) and run fast through the vegetation, leaving the soil layer incompletely burned (reviewed in Boerwinkel *et al.* 2004). The burned area can vary, resulting from fires that create heterogeneity at the micro habitat scale to large fires at the landscape level (reviewed in Boerwinkel *et al.* 2004).

Another important factor which should be taken into account is the season in which burning occurs. On Karst for instance one can identify a dry and a wet season. The dry season will often result in hot fires, which burn everything, whilst the wet season results in less hot fires with less complete burns (reviewed in Boerwinkel *et al.* 2004).

All these factors can interact, producing different effects on the ecosystems. Another important factor is the amount of the fuel (e.g. dry wood, bushes, leaves etc.). The spatial heterogeneity in fuel will also give heterogeneity in fire intensity and burned area size (reviewed in Boerwinkel *et al.* 2004). However, one has to be very careful with fire and therefore guidelines are issued by many authorities (Nature Conservancy 2007).

4. Effect of fire on birds

4.1. Direct effect

The direct consequences of fire depend on the severity, uniformity and season of the burn (Kruse & Piehl

1986, Lehman & Allendorf 1989, Robbins & Myers 1992, Smith 2000). During the fire, mortality, fleeing, disorientation and even attraction can occur.

The mortality among adults is relatively low, as they can easily escape (Rotenberry *et al.* 1995, Finch *et al.* 1997, Smith 2000). However a fire during the breeding season has detrimental effects on nestlings and fledglings (Patton & Gordon 1995, Finch *et al.* 1997, Smith 2000). In other cases breeding success may be reduced due to reductions in food supply (Patton & Gordon 1995, Finch *et al.* 1997).

Another consequence is attraction. Swallows are known to hunt near the smoke as there are lots of insects, whilst raptors and scavengers may search for carcasses behind the fire (reviewed in Pons 2002).

4.2. Post-fire dynamics

Pons (2002) has already pointed out that the population dynamics after fires are mainly influenced by colonisation, emigration, site tenacity, philopatry, and local breeding success (Table 1). However, we must first examine how the bird community reacts to fire and try to explain this with the above mentioned population dynamics.

In the first or second year after stand replacing fires, several studies have found that there is a decline of bird abundance and species richness in Mediterranean shrubland and in several types of pine forest (Prodon *et al.* 1987, Pons & Prodon 1996, García 1997, Izhaki & Adar 1997, Smith 2000, Moreira *et al.* 2003). In the first years the turnover rate was also faster than in later years (Izhaki & Adar 1997). Izhaki & Adar (1997) found that, in a burned forest of Aleppo Pine *Pinus halepensis*, species richness increased when compared with the surrounding unburned areas. After the usual initial decline, there were different patterns for the species richness, varying from increase (Pons & Prodon 1996) to no change (Wilson *et al.* 1995, Artman *et al.* 2001) or even decrease (Pons 1999). One study even reports species richness and abundance higher than that of the surrounding unburned control habitats (Herrando *et al.* 2002a). Contrasting results have been found regarding seasonal variability, varying from low difference of species richness in burned areas (Izhaki & Adar 1997) to low species richness in winter but high in the breeding season (Herrando *et al.* 2002b). Depending on the vegetation type it is estimated that bird species composition and richness can recover after 1 year in dry grassland, some 15 years in a Cork Oak *Quercus suber* forest and probably around one century in a mature Evergreen Oak *Quercus ilex* forest (Prodon 1988).

Although it is assumed that, in parallel with the alteration of the habitat, the species composition also may change dramatically, Herrando *et al.* (2002a) found no temporal shift between the first and the sixth year after a fire. Moreira *et al.* (2003) suggest that the fire-created scrublands provide habitats for specialists that would otherwise be unavailable. Increasing numbers of insectivores (Izhaki & Adar 1997), granivorous and omnivorous bird species (Bendell 1974, Woinarski 1990) were found on the burned sites. The burned area can also be used as a hunting site for scavengers and birds of prey, because prey is more abundant or more exposed. However, forest species are also often still observed in the burned areas. With forest fires, ground-dwelling bird populations are likely to be affected by fires of any severity, whereas canopy dwelling populations may be unaffected by understory fires (Smith 2000). However these responses of bird communities to fire depend on the subsequent management, as the snags provide nest and foraging sites (Finch *et al.* 1997).

4.3. Colonisation

The colonisation of burned areas by birds is dependent upon both regional and local factors. On the local level, the nature of the pre-fire bird community (Wooller & Calver 1988, Pons & Prodon 1996), the post-fire habitat structure (Hobson & Schieck 1999) and the site tenacity of survivors (Pons *et al.* 2003a) are of importance as colonisation factors, while on the large scale the magnitude and proximity of population sources are important (Brotons *et al.* 2005). However, Brotons *et al.* (2005) suggest that local scale ecological processes may be more important than regional scale processes. Although, long distance colonisations are occasionally reported (Brotons *et al.* 2005), most colonisers are likely to come from neighbouring populations. Whenever abundance decreases, post-fire colonisation becomes less likely. Pons & Bas (2005) also reported biogeographical constraints on colonisation of new habitats created by fire.

Isolation and accessibility are important for re-colonisation of an area. For example, when a fire affects previous heavily forested areas, birds of open habitats would have difficulty in colonising the sites unless areas with similar habitats were nearby (Brotons *et al.* 2005). Habitat heterogeneity is an important factor (Dunning *et al.* 1992) as it enhances colonisation by open habitat

Table 1: Comparison of effects of fire on birds in Mediterranean habitats. It should be noted that the fire variables of area extent, intensity, frequency and season frequently interact and should not be considered individually, but be taken together when determining the overall effects on bird populations.

Tabela 1: Primerjava tabela učinkov ognja na ptice v sredozemskih habitatih. Parametrov požara (obseg, jakost, pogostost in obdobje leta) ne smemo obravnavati ločeno od ostalih ampak le njihov skupni (kombinirani) vpliv na populacije ptic.

	Short term trend/ Kratkoročni trend	Long term trend/ Dolgoročni trend	Site tenacity/ Vztrajanje na gnezdišču	Reproduction/ Razmnoževanje	Colonization/ Kolonizacija
Forest and shrubland birds/ Gozdne in grmovne ptice	populations decrease, but do not always become extinct/ populacije upadajo, vendar vedno ne izumrejo	populations increase, species richness does not decrease/ narašča, vrstna diverziteta ne upada	a low percentage survives in remnants of bushes and because of high food availability/ nizek procent preživi v ostankih grmovja zaradi dobre dostopnosti hrane	low reproduction due to less suitable habitat and behavioural change/ nizka produktivnost zaradi manj primernega habitata, kar je povezano s spremembami v obnašanju	no information available
Open habitat birds/ Ptice odprtih habitatov	increase/ narašča	decrease, species richness decreases/ upada, vrstna diverziteta prav tako upada	no information available/ ni podatkov	no information available/ ni podatkov	mostly local colonization, few examples of regional colonization/ večinoma lokalna, nekaj primerov regionalne kolonizacije
References	Izhaki & Adar 1997, Pons 1998, Pons & Bas 2005	Wilson *et al.* 1995, Artman *et al.* 2001, Pons 1999, Herrando *et al.* 2002a	Pons & Prodon 1996, Pons *et al.* 2003a	Herrando & Brotons 2002	Brotons *et al.* 2005, Pons & Bas 2005

continuation of Table 1 (right side) / nadaljevanje tabele 1 (desna stran)

Fire area extent/ Obseg požara	Fire intensity/ Jakost požara	Fire frequency/ Pogostost požara	Fire season/ Obdobje v letu
large burned areas affect forest and shrub bird diversity negatively / velika območja požara vplivajo negativno na diverziteto gozdnih in grmovnih ptic shrub birds are less negatively affected when small bushes remain in the larger burned area or when smaller areas of their habitat are burned/ ptice grmišč so manj prizadete, če na večjem pogorišču ostane manjše grmovje ali pa če so pogorišča manjša, sredi njihovega habitata the smaller the forest fragments remaining after a fire, the larger is the negative effect on forest birds/ gozdne ptice so bolj prizadete, če so fragmenti gozda po požaru manjši	more intensive wildfires are more detrimental than prescribed burning/ intenzivni gozdni požari so bolj škodljivi od načrtovanih požarov	fire frequency of once every 5 years can maintain the habitat of shrub birds/ pogostost požarov enkrat na pet let lahko ohranja habitat grmovnih ptic fire frequency of once every 15–29 years is maximal for maintaining the habitat of Grey Partridge *Perdix perdix*/ pogostost požarov enkrat v obdobju 15–29 let vzdržuje habitat jerebice *Perdix perdix*	fire during breeding season can be destructive/ ogenj med gnezdilno sezono je lahko destruktiven "Wet" seasons affect habitat (bushes) less and are better for shrubland birds like Grey Partridge/ požari med "mokrimi" sezonami so boljši za vrste grmiščnih habitatov (jerebica)
large, evenly burned areas favour open habitat birds/ velika enakomerno požgana pogorišča pozitivno vplivajo na ptice odprtih habitatov	no information available/ ni podatkov	fire frequency of not more than once every 20 years, necessary for maintaining the habitat of open habitat birds/ pogostost požarov enkrat na 20 let za vzdrževanje habitata ptic odprtih habitatov fire frequency of prescribed burning once every 1 to 7 years, coupled with additional grazing, maintains the habitat of open habitat birds/ pogostost požarov enkrat na 1–7 let nadzorovanih požarov z dodatno pašo za vzdrževanje habitatov ptic odprtih habitatov	fire during breeding season can be destructive/ ogenj med gnezdilno sezono je lahko destruktiven
Novoa *et al.* 1998, Moreiri *et al.* 2003, Herrando *et al.* 2003, Pons & Bas 2005	Pons *et al.* 2003a	Moreiri *et al.* 2003, Herrando *et al.* 2002a, Pons *et al.* 2003b	Smith 2000, Novoa *et al.* 1998

species, as well as scrubland species which still find refuge in the scrubby and forested habitats from which they can colonise the area (Herrando *et al.* 2003). These findings suggest that the landscape context is an important factor in colonisation of a site.

Post-fire habitat quality and spatial extent are important in determining the suitability of the burned areas for colonisation (Pons & Bas 2005). However, re-colonisation in an Allepo Pine forest was found to be strongly tied to plant succession (Izhaki & Adar 1997). Burned areas are regarded as second-choice habitats for scrubland species and more asymmetrical juveniles were found in burned areas than in unburned ones, although the origin of these juveniles was not known. The size of the burned areas is also important (Herrando & Brotons 2001). Larger burned areas have a higher probability of being discovered and of containing a suitable habitat. Large areas tend to have higher habitat diversity and, as a result, more bird species are able to find available niches (Pons & Bas 2005).

Birds re-colonised a burned Allepo Pine forest just 3 to 5 years after the fire (Izhaki & Adar 1997). The best colonisers of recently burned areas were generalists in terms of habitat structure (Pons & Bas 2005).

4.4. Emigration

The dispersal of birds after large fires has not been well investigated. Pons (2002) reported an increase of Sardinian Warbler *Sylvia melanocephala* at a ringing station two weeks after a huge fire 20 km away.

4.5. Site tenacity

Site tenacity here refers to local survival of the population. The plasticity of habitat use and nest selection by birds after an alteration of their habitat are mechanisms that allow site tenacity to occur (Winter & Best 1985, Brooker & Rowley 1991, Pons & Prodon 1996, Pons 2001, Pons *et al.* 2003a). Birds have been shown to exhibit these behaviours in several studies (reviewed in Smith 2000, Pons and Prodon 1996, Herrando *et al.* 2003). Site tenacity has been demonstrated especially for warblers with colour ringed birds (Pons *et al.* 2003a).

Furthermore it was observed that birds can demonstrate a larger variation of nest site selection (Winter & Best 1985, Brooker & Rowley 1991). Winter and Best (1985) found that, as a result of reduced cover after a fire, Sage Sparrows *Amphispiza belli* bred not only in bushes but also began breeding on the ground. However this has not yet been reported from a European ecosystem.

Among some feeding guilds, such as foliage dwelling birds, site tenacity is impossible where foliage is almost completely burned (Pons 2001). However for birds from other feeding guilds site tenacity is probably the reason why, immediately after a fire, there is no dramatic decrease in abundance of these birds, and post-fire effects are therefore probably delayed (Pons *et al.* 2003a).

4.6. Local reproduction

After a fire, it is found that some breeding populations decline dramatically. It is suggested that the cause is a decrease in the recruitment rate and an increase in the proportion of non-breeders.

The Dartford Warbler *Sylvia undata* is usually unable to breed in the first year after a severe fire (Prodon & Lebreton 1983, Prodon *et al.* 1987, López & Guitian 1988, Sgardelis & Margalis 1992, Herrando *et al.* 2002a). Pons *et al* (2003a) saw that two adults of this species which previously had territories, but were no longer territorially active. A similar case is described for the Red Grouse *Lagopus l. scoticus* (Watson 1985). On the other hand, Smith (2000) reported that nesting success in a post-fire habitat depends on the pre-fire quality. In another habitat type, the Rocky Mountains, most nesting birds used broken-topped snags which were already present before the fire (Hutto 1995, Smith 2000).

5. Habitat and fire

One of the most obvious effects of fires is habitat modification, which affects birds through changes in food supply, or changes in abundance of competitors and predators (Rotenberry *et al.* 1995). These effects may be especially important because many birds respond strongly to habitat features (MacArthur & MacArthur 1961, Koplin 1969, Lovejoy 1974, Tomoff 1974, Willson 1974, Power 1975, James & Warner 1982, Rotenberry 1985). Fires reduce or destroy the organic soil layer (Urbančič 2002) that contains the bulk of the soil fauna (Mršič 1997) and seeds.

Although large, intense burns greatly alter bird habitat in the short-term, they may be necessary for long-term maintenance of natural forest succession patterns of some forest types (Hejl *et al.* 1995, Hutto

1995). Plant species diversity on Kras is higher after fires (Batič 2001). Some insect- and plant-eating bird populations depend on such alterations in food and cover (Smith 2000). Prodon *et al.* (1987) showed that the recovery of bird populations in Mediterranean successions depended on how vegetation regenerated. Many species of deciduous trees and some shrub species in the sub-Mediterranean region show great ability to re-sprout from roots in the same season after a large fire (Batič 2001). Many oak species re-sprout after a fire and may recover quickly, even if top-kill occurs (Caprio & Zwolinski 1992, Barton 1995). Some oak species may need more sunlight than they would get in the shade of closed-canopy forests. Therefore, although fire may reduce the number of large oaks in the short-term, in the long-term, fire-created openings can be beneficial in maintaining oak as a landscape component (but see Barton 1995).

The herbaceous and shrub layer are one of the important components in the vegetation for birds in Maritime Pine *Pinus pinaster* stands (Moreira *et al.* 2003). After prescribed fire a modal growth occurred with maximum development of the herbaceous vegetation after ca. 3 years, and shrub development increased linearly with time after the fire. Five years after the fire, understory vegetation structure was similar to that in control plots (Moreira *et al.* 2003).

Besides food and cover changes, life history characteristics also influence the response of particular bird species to fire. Cavity-nesting birds, timber-drilling birds, granivores, and some flycatchers generally respond positively to burns in the short term because of increased nesting substrates, such as snags for cavities and foraging and nesting resources (Blackford 1955, Stoddard 1963, Koplin 1969, Bock & Lynch 1970, Kilgore 1971, Granholm 1982, Raphael *et al.* 1987, Hejl *et al.* 1995, Hutto 1995, Finch *et al.* 1997, Blondel & Aronson 1999, Jurč 2001). Habitat suitability for woodpeckers declines over time as snags fall and food resources decrease (Koplin 1969, Bock *et al.* 1978, Raphael *et al.* 1987, Finch *et al.* 1997).

Fire is a key mechanism of creating and maintaining habitat heterogeneity in Mediterranean landscapes, by turning continuous woody landscapes into mosaics of forest and shrubland (Herrando & Brotons 2002). Mediterranean landscapes periodically and frequently exposed to fires are characterized by a turnover of habitat types from grasslands to forests (Blondel & Aronson 1999) which replace each other in space and time like a "moving mosaic" (Moreira *et al.* 2001). Although fires reduce the cover of available habitat for Mediterranean forest bird species, they simultaneously create new landscapes where the remaining forest patches are suitable habitats for these species. However, the size of the forest patches is positively correlated with the species richness of the canopy birds, with the result that the patch size is important for promoting forest bird communities in Mediterranean landscapes (Herrando & Brotons 2002).

6. Food and fire

Although it is known that bird populations respond to changes in food availability (e.g. arthropods and seeds) caused by fire (Smith 2000, Moreira *et al.* 2003), not many studies deal with the direct relationship between the trend of bird populations and food availability in a post fire habitat (Herrando *et al.* 2005).

Fire causes a disastrous change in the composition of insect species and species richness (Moreira *et al.* 2003). Foliage insects, the main food source of insectivores in forested and bushy areas, decrease dramatically after wildfires (Swengel 2001, Herrando *et al.* 2005), although, in the unburned patches of bushes in the burned sites, foliage insect numbers were higher than in the adjacent unburned sites (Herrando *et al.* 2005). The loss of foliage insects was replaced by an increase in flying insects (Pons 1998, Herrando *et al.* 2005). Also for hunters of ground-dwelling insect species, like shrikes, there will probably be a decline, since important food sources, like carabid beetles and other ground dwelling insects, are drastically reduced (Swengel 2001, Cook & Holt 2005), although the population will never be reduced to zero (Swengel 2001). Colonisation of insects like carabid beetles occurred rapidly from underground and from long distances (Cook & Holt 2005). However the resilience of arthropods is likely to differ between different habitats.

Although arthropod availability appears to be important for bird populations, Herrando *et al.* (2005) found that it was still high enough to sustain the pre-fire number of birds and that the reason for the decrease in bird populations in the first few years after a fire was therefore due to something other than decrease in food availability.

In several habitat types, seed accessibility increased after the fire (Dean 1987, Woinarski 1990) and, in consequence, there is often an influx of seed eaters. Some tree species adapt to this situation; directly after a fire Aleppo Pine releases dark grey-brown seeds,

whereas late-disperse seeds are a yellowish colour (Saracino *et al.* 1997). The greyish seeds were found to be less predated by birds on ash grey background, produced by fire, than on pre-fire yellowish background (Saracino *et al.* 2004). Therefore it can be argued that if the birds are favoured by the increase in seed availability if some seeds are less visible due to an equal coloured background.

7. Effects of different fire variables

7.1. Area size

The size of a fire is highly important in influencing bird populations (Finch *et al.* 1997, Pons *et al.* 2003a). In the literature we found examples of small-scale fires (up to 18 ha) (Moreira *et al.* 2003, Pons & Bas 2005) and large-scale fires (more than 300 ha) (Herrando *et al.* 2003).

With small-scale fires the species abundance and species richness did not change dramatically (Moreira *et al.* 2003). In a mosaic landscape in the Pyrenees, the small size of the burned areas (patches of 0.9–16.5 ha) allowed habitat heterogeneity and high beta diversity, including both open habitat and forest species (Pons *et al.* 2003b).

For a ground dwelling bird, such as the Grey Partridge *Perdix perdix*, there should be cover in the surroundings and the area size should therefore not be large. Novoa *et al.* (1998) recommend a burned area of less than 5 ha, separated by patches of 10–15 ha.

On the other hand, large replacement fires exhibit a dramatic change in species composition from forest or scrubland species to those of open habitat (Pons & Bas 2005). As noted above, the larger burned areas may be more easily discovered and therefore more easily colonised (Brotons *et al.* 2005). However, bird diversity depends strongly on habitat heterogeneity within burned areas (Herrando 2001, Herrando *et al.* 2003, Pons *et al.* 2003b), which is a consequence of the spatial pattern of fire intensity.

7.2. Intensity

Only one study takes the effect of intensity of fire into account by comparing wet and dry fires, i.e. fires with high and low intensity (Novoa *et al.* 1998). Most wildfires have a greater intensity than prescribed burning, so we compare the differences between wildfires and prescribed burning as rather than intensity differences.

Novoa *et al.* (1998) found that Grey Partridges were more affected by the burning of brood habitat by dry fires than by wet fires. The habitat for nesting hens and nestlings contains a large cover of two vegetation layers providing protection against predators (0.05–0.25 m and 0.25–0.50 m), these suitable habitat recovers after more then eight years while the 3 week old broods, need less cover of shrubs and their habitat can therefore already recover after five or six years.

The local survival of some bird species tended to be more affected by wildfire than by prescribed burning (Pons *et al.* 2003a). Other studies had found that prescribed burning has a relatively low impact on bird communities (Bock & Bock 1983, Petersen & Best 1987, Pons 1998) – but see Robertson & Jarvis (2000). The replacement of shrubland by grassland does not always mean an increase in erosion (Garcia-Ruiz *et al.* 1996). Prescribed burning can be used to eliminate the aerial shrub layer without burning the grass, thus preventing erosion in mountain areas (Pons *et al.* 2003b).

On the other hand, stand replacement fires, which are often more intense, result in the pre-fire species being replaced by new species (Hutto 1995). In contrast, cool understory burns in forests have little effect on the canopy species composition (Horton & Mannan 1988).

7.3. Frequency

Only five studies considered the frequency of fires when studying at their effect on birds (Novoa *et al.* 1998, Herrando & Brotons 2002, Herrando *et al.* 2003, Moreira *et al.* 2003, Pons *et al.* 2003b).

At the landscape level, Herrando *et al.* (2003) suggest that the wildfire frequency should be approximately once 20 years. This is favourable for open habitat birds when there is a nearby population from where the burned area can be colonised.

The consequences of a fire in a Mediterranean landscape that affected mainly understory vegetation height and cover – an important feature for birds – were studied at the local level (Moreira *et al.* 2003). After five years the vegetation cover and bird abundance had recovered. For particular species the recovery time may be longer, for instance for the Grey Partridge the frequency of fires should not exceed one every 15–29 years (Novoa *et al.* 1998).

In Railleu, France, the preferred management for open habitats is a moderate burning of the shrubland

followed by cattle grazing, repeated at intervals of 1 to 7 years. This proved to be sustainable for the plant community (Rigolot *et al.* 2002) and beneficial for bird conservation (Pons *et al.* 2003b).

7.4. Time of the year

A spring fire during the breeding period is the most destructive for birds (Ward 1968, Erwin & Stasiak 1979, Smith 2000). Ground-nesting birds are especially vulnerable to spring fires (Smith 2000). Bird nest site selection, territory establishment and nesting, among others, can be affected by the season of fire (Smith 2000).

Birds can also be affected indirectly by the season of the fire. In areas with contrasting wet and dry seasons, as in Australia, the season of the fire can dramatically alter the bird community (Valentine *et al.* 2007). The season influences the intensity of the fire and therefore the post-fire habitat. On Kras, precipitation increases slightly in the second part of the year, but still reaches less than 200 mm a month (ARSO 2007). In this situation of very low precipitation throughout the year it would nevertheless be interesting if the seasons affected the post burned habitats differently.

8. Concluding remarks and discussion

Local populations can be affected severely by fire and may suffer from increased mortality and decreased reproduction and recruitment. Bird community succession is the result of an assembly of responses of species to a variety of environmental factors that go further than simple changes in the local habitat (Herrando & Brotons 2002, Herrando *et al.* 2003, Herrando *et al.* 2005). Bird populations often decline after scrubland fires, but decline may be offset by populations that rebound if the fire spread is patchy, leaving some areas unburned, and if species usually associated with grassland communities invade the burn (Smith 2000). The consequences of wildfires are not necessarily detrimental and can even enhance the bird diversity. Increases in the number of open area species and of species abundance have been reported. In southern Europe, burned areas appear to be very important for decreasing and vulnerable bird species (Prodon 1987, Pons & Bas 2005). Geister (1999) also found an increase in a few species that are declining in Europe in recently burned areas of Kras. Furthermore, fires usually help to maintain the open Mediterranean landscape.

Wildfires often exhibit completely different behaviour from that of prescribed fires. The latter are often less intense and have therefore less deleterious impact than wildfires. This has to be taken into consideration when comparing the value of the two. Furthermore most of the research reviewed here was carried out on a Mediterranean landscape, which has a long fire history. Kras has a sub-Mediterranean landscape that is sensitive to fire, although this disturbance does not occur regularly. Bird responses to fire are known to have biogeographical constraints.

Most of the impacts have been assessed by examining the situation found after a fire. Simple aspects of fire type, area or intensity are still poorly understood (but see Novoa 1999), although we have tried to assess them in this review. Within a wildfire these elements always interact and it therefore becomes difficult to draw firm conclusions. In addition, checks on the various aspects, pre-fire assessments and control measurements are often lacking. There is a need for a proper experimental design to address this problem.

In this review the underlying assumption has been made that the regenerated post-fire habitat is similar to the pre-fire habitat. Nowadays some plant species invade ecosystems and alter them by out competing native species. Burned areas can be perfect areas for invasion, due to a lack of natural enemies or biotic resistance. For example a North American tree, the False Acacia *Robinia pseudoacacia* is colonising certain areas in Slovenia and starting to dominate burned areas. It is therefore important to predict the responses of bird populations to such a habitat alteration.

Another gap in research relates to population dynamics and, in particular, the difficult study of emigration after a fire. Where do the birds go? Do they come back or is the population lost forever?

The need for proper management to recreate open areas and, by this, to increase the biodiversity of Kras, makes it important to take every possible management tool into account. Although fighting fire with fire is literally a hot topic, this review suggests that the consequences for birds are mainly not detrimental. However it should to be emphasized that only birds have been taken into account. This suggests that more research should be carried out on invertebrate taxa, as these are often under-represented in the literature, and by this to come to a better insight into the consequences of fire for the ecosystem.

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9. Povzetek

Pregledni članek obravnava odziv ptic na požare v naravi v submediteranskih območjih in njihovo morebitno uporabo kot orodje za upravljanje naravnih območij na Krasu (JZ Slovenija). Kras je bil pogozden s črnim borom *Pinus nigra*, na ostalih delih pa se intenzivno zarašča, zaradi česar je ranljiv za požare. Ta položaj je značilen tudi za ostale submediteranske regije, kar drastično vpliva na diverziteto ptic. Smrtnost ptic med požari je nizka. Prvih nekaj let se diverziteta vrst in številčnost zmanjšujeta, sestava vrst pa se hitro spreminja, od ptic odprte krajine h grmovnim vrstam. Ptice kolonizirajo pogorišča le, če je v bližini primerna izvorna populacija. Večja pogorišča so kolonizirana hitreje kot manjša. Veliko vrst se odseli, nekaj vrst pa novim razmeram prilagodi velikost teritorija ter gnezditveno in prehranjevalno obnašanje. Populacijska dinamika se spremeni v odvisnosti od velikosti spremembe habitata in dostopnosti hrane. Sestava vrst ptic se spreminja sočasno s sukcesijo vegetacije. Članek obravnava učinke različnih parametrov požara: velikosti pogorišča, intenzitete, pogostosti in sezone. V splošnem ugotavlja slabo raziskanost odseljevanja ptic z območja požara. Vplivi požarov niso vedno negativni in je pomembno raziskovati njihovo uporabo kot orodje upravljanja.

10. References

ARSO (2007): Climatic changes over the last 30 years – [www.arso.gov.si/vreme/napovedi%20in%20podatki/podneb_30_tabele.html]

Artman, V.L., Sutherland, E.K. & Downhower, J.F. (2001): Prescribed burning to restore mixed-oak communities in southern Ohio: effects on breeding-bird populations. – Conserv Biol 15: 1423–1434.

Barton, A.M. (1995): Fire adaptations in pines and oaks: Tree population responses to fire suppression in Arizona's Madrean forests. – Symposium on fire in wilderness and park management, Res. Stn. Ogden, UT., USDA Forest Service.

Batič, F. (2001): Vpliv požarov na vrstno sestavo vegetacije na primerih s Krasa in Istre v jugozahodni Sloveniji. – Zbornik gozdarstva in lesarstva 66: 25–38.

Bendell, J.F. (1974): Effects of fire on birds and mammals. T.T. Kozlowski and C.E. Ahlgren Fire and ecosystems. Academic Press, New York.

Blackford, J.L. (1955): Woodpecker concentration in burned forest. – Condor 57: 28–30.

Blondel, J. & Aronson, J. (1999). Biology and Wildlife of the Mediterranean region. – Oxford University press. Oxford, UK.

Bock, C.E. & Bock, J.H. (1983): Responses of birds and deer mice to prescribed burning in Ponderosa pine. – J Wildl Manage 47: 836–840.

Bock, C.E. & Lynch, J.F. (1970): Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. – Condor 72: 182–189.

Bock, C.E., Raphael, M.G. & Bock, J.H. (1978): Changing avian community structure during early post-fire succession in the Sierra Nevada. – Wilson Bulletin 90: 119–123.

Boerwinkel, F.S., De Groot, M., Mies, G.W., Poutsma, J. & Tuyl, M.H. M.V. (2004): From smoking swamps to hot heather: fire as nature management tool. – AMC report, Wageningen University: 57.

Brooker, M.G. & Rowley, I. (1991): Impact of wildfire on the nesting-behavior of birds in heathland. – Wildlife Research 18: 249–263.

Brotons, L., Pons, P. & Herrando, S. (2005): Colonization of dynamic Mediterranean landscapes: where do birds come from after fire? – J Biogeography 32: 789–798.

Caprio, A.C. & Zwolinski, M.J. (1992): Fire effects on two oak species, *Quercus emoyi* and *Q. oblongifalia*, in southeastern Arizona. – Ecology and management of oak and associated woodlands: perspectives in the southwestern United States and northern Mexico. P. F. Ffolliott, G.J. Gotttried, D.A. Bennett *et al*. Fort Collins, CO, Rocky Mountain Forest and Range Experiment Station.

Cook, W.M. & Holt, R.D. (2005): Fire frequency and mosaic burning effects on a tallgrass prairie ground beetle assemblage. – Biodivers Conserv 15 (7): 2301–2323.

Dean, W.R.J. (1987): Birds associating with fire at Nylsvley Nature Reserve, Transvaal. – Ostrich 58: 103–106.

Dunning, J.B., Brent, J.D. & H.R., P. (1992): Ecological processes that affect populations in complex landscapes. – Oikos 65: 169–175.

Erwin, W.J. & Stasiak, R.H. (1979): Vertebrate mortality during the burning of reestablished prairie in Nebraska. – Am Midl Nat 101(1): 247–249.

Finch, D.M., Ganey, J.L., Yong, W., Kimball, R.T. & Sallabanks, R. (1997): Effects and Interactions of Fire, Logging, and Grazing. pp. 152. – W. M. Block and D. M. Finch Songbird ecology in southwestern ponderosa pine forests: a literature review., Department of Agriculture, Forest service, Rocky Mountain Forest and Range Experiment Station, Colorado.

García, J.A. (1997): Caracterización y uso del hábitat por la avifauna en los bosques quemados de la provincia de León, Universidad de León.

Garcia-Ruiz, J.M., Lasanta, T., Ruiz-Flano, P., Ortigosa, L. & White, S. (1996): Land-use changes and sustainable development in mountain areas: a case study in the Spanish Pyrenees. – Landsc Ecol 11: 267–277.

Geister, I. (1999): Gnezdilke popogoriščnega habitata na Petrinjskem Krasu. – Annales, series Historia et Sociologia 17 (2): 299–302.

Global Fire Initiative (2004): Fire, Ecosystems and People, a preliminary assessment of fire as a global conservation issue. – The Nature Concervancy. Talahasee, FL.

Goldammer, J.G. & Page, H. (2000): Fire History of Central Europe: Implications for Prescribed Burning in Landscape Management and Nature Conservation. – Baltic Exercise for Fire Information and Resources Exchange.

Granholm, S.L. (1982): Effects of surface fires on birds and their habitat associations in coniferous forests of the Sierra Nevada, California. Davis, University of California.

Hejl, S.J., Hutto, R.L., Preston, C.R. & Finch, D.M. (1995): Effects of silvicultural treatments in the Rocky Mountains. pp. 489. T.E. Martin and D.M. Finch Ecology and management of Neotropical migratory birds. Oxford University Press, Oxford, UK.

Herrando, S. & Brotons, L. (2001): Fluctuating asymmetry in Sardinian Warblers *Sylvia melanocephala* inhabiting two shrublands affected by fire. – Bird study 48: 180–187.

Herrando, S. & Brotons, L. (2002): Forest bird diversity in Mediterranean areas affected by wildfires: a multi-scale approach. – Ecography 25: 161–172.

Herrando, S., Brotons, L., Del Amo, R. & Llacuna, S. (2002a): Bird community succession after fire in a dry Mediterranean shrubland. – Ardea 90: 303–310.

Herrando, S., Brotons, L. & Llacuna, S. (2002b): Does fire increase the seasonal variability of bird communities? A case in Mediterranean shrublands. – Revue d'écologie 57 (2): 151–163.

Herrando, S., Brotons, L. & Llacuna, S. (2003): Does fire increase the spatial heterogeneity of bird communities in Mediterranean landscapes? – Ibis 145: 307–317.

Herrando, S., Brotons, L. & Llacuna, S. (2005): Post-fire in Mediterranean shrubland: are bird communities structured by arthropod availability? – Revista Catalan d'Ornitologia 21: 17–28.

Hobson, K.A. & Schieck, J. (1999): Changes in bird communities in boreal mixedwood forest: harvest and wildfire effects over 30 years. – Ecol Appl 9: 849–863.

Horton, S.P. & Mannan, R.W. (1988): Effects of prescribed fire on snags and cavity-nesting birds in southeastern Arizona pine forests. – Wildl Soc Bull 16 (1): 37–44.

Hutto, R.L. (1995): Composition of bird communities following stand-replacement fires in northern Rocky Mountain conifer forests. – Conserv Biol 9 (5): 1041–1058.

Izhaki, I. & Adar, M. (1997): The effects of post-fire management on bird communities succession. – Int J Wildland Fire 7 (4): 335–342.

James, F.C. & Warner, N.D. (1982): Relationships between temperate forest bird communities and vegetation structure. – Ecology 63: 159–171.

Jurč, M. (2001): Vpliv požarov na entomofavno – predvsem subkortikalno, v monokulturahcrnega bora (*Pinus nigra* Arn.) na slovenskem krasu. – Zbornik gozdarstva in lesarstva 66: 39–64.

Kilgore, B.M. (1971): Response of breeding bird populations to habitat changes in a giant sequoia forest. – Am Midl Nat 85: 135–152.

Koplin, J.R. (1969): The numerical response of woodpeckers to insect prey in a subalpine forest in Colorado. – Condor 71: 436–438.

Kranjc, A. (1997): Slovene classical karst. – Znanstvenoraziskovalni center SAZU, Zalosba ZRC & Institut za raziskovanje krasa ZRC SAZU, Ljubljana.

Kruse, A.D. & Piehl, J.L. (1986): The impact of prescribed burning on ground-nesting birds. – The prairie: past, present and future: Proceedings, 9th North American prairie conference, Moorhead, MN. Fargo, ND: Tri-College University Center for Environmental Studies.

Lehman, R.N. & Allendorf, J.W. (1989): The effects of fire, fire exclusion and fire management on raptor habitats in the western United States. In: Proceedings of the western raptor management symposium and workshop; 1987 October 26–28; Boise, ID. Scientific and Technical Series No. 12. Washington, DC: National Wildlife Federation: 236–244.

López, B. & Guitian, J. (1988): Evolución de las comunidades de aves después del incendio en pinares de la Galicia Occidental. – Ardeola 35: 97–107.

Lovejoy, T.E. (1974): Bird diversity and abundance in Amazon forest communities. – Living Bird 13: 127–191.

MacArthur, R.H. & MacArthur, J.W. (1961): On bird species diversity. – Ecology 42: 594–598.

Moreira, F., Delgado, A., Ferreira, S., Borralho, R., Oliveira, N., Inácio, M., Silva, J.S. & Rego, F. (2003): Effects of prescribed fire on vegetation structure and breeding birds in young *Pinus pinaster* stands of northern Portugal. – Forest Ecology and Management 184: 225–237.

Moreira, F., Ferreira, P.G., Rego, F.C. & Bunting, S. (2001): Landscape changes and breeding assemblages in northwestern Portugal: the role of fire. – Landsc Ecol 16: 175–187.

Mršič, N. (1997): Živali naših tal Uvod v pedozoologijo – sistematika in ekologija s splošnim pregledom talnih živali. – Avtor in TZS. Ljubljana.

Nature conservancy (2007): Global Fire Initiative – Integrated Fire Management – http://www.nature.org/initiatives/fire/strategies/art18357.html.

Novoa, C., Dumas, S. & Prodon, R. (1998): Changes in reproductive habitat of gray partridge after burning. – J Range Manage 51: 607–613.

Patton, D.R. & Gordon, J. (1995): Fire, habitats, and wildlife, USDA Forest Service, Coconino Natl. For. Flagstaff, AZ.: 85.

Petersen, K.L. & Best, L.B. (1987): Effects of prescribed burning on nongame birds in a sagebrush community. – Wildl Soc Bull 15: 317–329.

Pons, P. (1998): Bird site tenacity after prescribed burning in a Mediterranean shrubland. L. Trabaud Fire Management and Landscape Ecology. International Association of Wildland Fire, Fairfield, Washington.

Pons, P. (1999): Brûlage dirigé et incendie sauvage: ont-t-ils l'un et l'autre le meˆme impact sur l'avifaune? – Forêt Méditerranéene 20: 103–113.

Pons, P. (2001): The wintering of migrant Dunnocks *Prunella modularis* in two habitats after fire. – Bird study 48: 68–75.

Pons, P. (2002): The population responses of birds to fire in Mediterranean ecosystems. Fire, landscape and biodiversity: an appraisal of the effects and effectiveness (ed. by G. Pardini & J. Pinto´), pp. 57–68. Servei de Publicacions de la Universitat de Girona, Girona.

Pons, P. & Bas, J.M. (2005): Open-habitat birds in recently burned areas: the role of the fire extent and species' habitat breadth. – Ardeola 52 (1): 119–131.

Pons, P., Henry, P.Y., Gargallo, G., Prodon, R. & Lebreton, J.D. (2003a): Local survival after fire in Mediterranean shrublands: combining capture-recapture data over several bird species. – Popul Ecol 45: 187–196.

Pons, P., Lambert, B., Rigolot, E. & Prodon, R. (2003b): The effects of grassland management using fire on habitat occupancy and conservation of birds in a mosaic landscape. – Biodivers Conserv 12: 1843–1860.

Pons, P. & Prodon, R. (1996): Short term temporal patterns in a Mediterranean shrubland bird community after wildfire. – Acta Oecol 17 (1): 29–41.

Power, H.W. (1975): Similarity among avifaunas of the Galapagos Islands. – Ecology 56: 616–626.

Prodon, R. (1987): Incendies et protection des oiseaux en France méditerranéenne. – L'Oiseau et la Revue Française d'Ornithologie 57: 1–12.

Prodon, R. (1988): Dynamique des systèmes avifaune-végétation après déprise rurale et incendies dans les Pyrénées méditerranéennes siliceuses, Université Paris: 333.

Prodon, R., Fons, R. & Athias-Binche, F. (1987): The impact of fire on animal communities in Mediterranean area. pp. 121–157. L. Trabaud The role of fire on ecological systems. SPB Academic Publishing, The Hague.

Prodon, R. & Lebreton, J.D. (1983): Prediction of bird census from vegetation structure. Application to the study of a post-fire succession. – Proc. 7th Int. Conf. Bird Census Work, University Leon, Leon.

Raphael, M.G., Morrison, M.L. & Yoder-Williams, M.P. (1987a): Breeding bird population twenty-five years of postfire succession in the Sierra Nevada. – Condor 89 (3): 614–626.

Rigolot, E., Lambert, B., Pons, P. & Prodon, R. (2002): Management of a mountain rangeland combining periodic burnings with grazing: impact on vegetation. pp. 325–337. T. L. and P. R. Fire and Biological Processes. Backhuys Publishers, Leiden, The Netherlands.

Robbins, L.E. & Myers, R.L. (1992): Seasonal effects of prescribed burning in Florida: a review. Misc. Pub. No. 8. Tallahassee, FL, Tall Timbers Research: 96.

Robertson, A. & Jarvis, A.M. (2000): Oxpeckers in north-eastern Namibia: recent population trends and possible negative impacts of drought and fire. – Biol Cons 92: 241–247.

Rotenberry, J.T. (1985): The role of habitat in avian community composition: physiognomy or floristics? – Oecologia 67: 213–217.

Rotenberry, J.T., Cooper, R.J., Wunderle, J.M. & Smith, K.G. (1995): When and how are populations limited? The roles of insect outbreaks, fires, and other natural perturbations. pp. 489. T.E. Martin and D.M. Finch Ecology and management of Neotropical migratory birds, Oxford University Press, Oxford, UK.

Saracino, A., D'Alessandro, C.M. & Borghetti, M. (2004): Seed colour and post-fire bird predation in a Mediterranean pine forest. – Acta Oecol 26: 191–196.

Saracino, A., Pacella, R., Leone, V. & Borghetti, M. (1997): Seed dispersal and changing seed characteristics in a Pinus halepensis Mill. forest after fire. – Plant Ecol 130: 13–19.

Sgardelis, S.P. & Margalis, N.S. (1992): Effects of fire on birds and rodents of a phryganic (east Mediterranean area) ecosystem. – Isr J Zool 38: 1–8.

Smith, J.K. (2000): Wildland fire in ecosystems: effects of fire on fauna. Gen. Tech. Rep. RMRS-GTR-42. Ogden, UT: U.S., Department of Agriculture, Forest Service, Rocky Mountain Research Station: 83.

Stoddard, H.L. (1963): Bird habitat and fire. In: Proceedings, 2nd annual Tall Timbers fire ecology conference; 1963 March 14–15; Tallahassee, FL. Tallahassee, FL: Tall Timbers Research Station: 163–175.

Swengel, A.B. (2001): A literature review of insect responses to fire, compared to other conservation managements of open habitat. – Biodivers Conserv 10: 1141–1169.

Šipec, S. & Babic, D. (2001): Naravne in druge nesreče v Republiki Sloveniji v letu 2000. Ljubljana, Uprava Republike Slovenije za zaščito in reševanje Ministrstva za obrambo.

Šipec, S. & Babic, D. (2002): Naravne in druge nesreče v Republiki Sloveniji v letu 2001. Ljubljana, Uprava Republike Slovenije za zaščito in reševanje Ministrstva za obrambo.

Šipec, S. & Babic, D. (2003): Naravne in druge nesreče v Republiki Sloveniji v letu 2002. Ljubljana, Uprava Republike Slovenije za zaščito in reševanje Ministrstva za obrambo.

Šipec, S. & Babic, D. (2004): Naravne in druge nesreče v Republiki Sloveniji v letu 2003. Ljubljana, Uprava Republike Slovenije za zaščito in reševanje Ministrstva za obrambo.

Šipec, S. & Krupenko, G. (2005): Naravne in druge nesreče v Republiki Sloveniji v letu 2004. Ljubljana, Uprava Republike Slovenije za zaščito in reševanje Ministrstva za obrambo.

Šipec, S., Šparovec, F., Babic, D., Damjan, J. & Šegatin, J. (2000): Naravne in druge nesreče v Republiki Sloveniji v letu 1999. Ljubljana, Uprava Republike Slovenije za zaščito in reševanje Ministrstva za obrambo.

Tomoff, C.S. (1974): Avian species diversity in desert scrub. – Ecology 55: 396–403.

Urbančič, M. (2002): Vpliv požarov na tla v crnoborovih in puhavcevih gozdovih Slovenskega primorja. – Zbornik gozdarstva in lesarstva 69: 9 – 40.

Valentine, L.E., Schwarzkopf, L., Johnson, C.N. & Grice, A.C. (2007): Burning season influences the response of bird assemblages to fire in tropical savannas. – Biol Cons 137: 90–101.

Ward, P. (1968): Fire in relation to waterfowl habitat of the delta marshes. – Proceedings, 8th annual Tall Timbers fire ecology conference, Tallahassee, FL., Tall Timbers Research Station.

Watson, A. (1985): Social class, socially-induced loss, recruitment and breeding of red grouse. – Oecologia 67: 493–498.

Willson, M.F. (1974): Avian community organization and habitat structure. – Ecology 55: 1017–1029.

Wilson, C.W., Masters, R.E. & Bukenhofer, G.A. (1995): Breeding bird response to pine-grassland community restoration for redcockaded woodpeckers. – J Wildl Manage 59: 56–67.

Winter, B.M. & Best, L.B. (1985): Effect of prescribed burning on placement of sage sparrow nests. – Condor 87: 294–295.

Woinarski, J.C.Z. (1990): Effects of fire on the bird communities of tropical woodlands and open forests in northern Australia. – Aust J Ecol 15: 1–22.

Wooller, R.D. & Calver, M.C. (1988): Changes in an assemblage of small birds in the understorey of dry sclerophyll forest in south-western Australia after fire. – Aust Wildl Res 15: 331–338.

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