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אין לעשות כל שימוש מסחרי במאמרים.
Fire in Mediterranean Ecosystems

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THE RESILIENCE TO FIRE OF PASSERINE BIRDS IN AN EAST-MEDITERRANEAN PINE FOREST ON MOUNT CARMEL, ISRAEL: THE EFFECTS OF POST-FIRE MANAGEMENT

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SUMMARY

Passerine birds were censused after the massive fire on Mount Carmel in September 1989 at three different plots: (1) a burned forest in which the burned pines were cut and removed from the plot; (2) a burned forest - without treatment; and (3) unburned control. The bird species were adversely affected by the fire and the different treatments. Several all-year resident species (such as Turdus merula, Parus major, and Troglydotes troglodytes) and wintering species (such as Erithacus rubecula) preferred the unburned forest in the first year of the study but began to reestablish in the burned plots in the second year. However, other all-year residents (such as Sylvia melanocephala) and wintering species (such as Prunella modularis and Saxicola torquata) showed a clear preference either for the burned plot or for the burned-and-cut plots. In addition, the burned-and-cut treatment enhanced the colonization of birds (such as Prinia gracilis) which usually inhabit the shrubby habitats around the pine forests. In general, the unburned control forest supported more bird species and individuals than the burned and the burned-and-cut plots. There was no difference in species richness between the burned plots and the burned-and-cut plots.

Multivariate direct gradient analysis (canonical ordination) by CANOCO (Canonical community ordination for community ecology) was used in each season to explain the response of bird composition to the differently treated plots. This analysis revealed that there were significant differences in bird relative abundance between the three different treatments in most seasons. In the first stage of the succession, these differences essentially reflect differences in habitat structure rather than in vegetation composition. In addition, the mosaic of different treatments in the study area probably increased habitat heterogeneity, and consecutively increased species richness in the whole area.
1. INTRODUCTION

The effects of fire on vertebrate populations in woodlands and forests of the Mediterranean basin are not well documented (18,19). The ecological evolution of the flora and fauna of the Mediterranean basin have been affected by fire for the last 400,000 years. Therefore, fire is considered as the most important disturbance in Mediterranean ecosystems (13), especially in the eastern Mediterranean ecosystems where severe fire hazards prevail for six or more of the relatively dry months between April and November (16). Yet the impact of fire on the vertebrates at this region in general, and in the eastern Mediterranean ecosystems in particular, had been the subject of little research.

Indigenous east Mediterranean Aleppo pine (Pinus halepensis Mill.) natural relic stands are small but important vegetation formation with unique genetic (23) and silvicultural characters (24). In the past, these forests were subjected to continuous consequences of fire, grazing, and wood cutting. Since the 1950's these stands have been protected and declared "natural reserves" without any kind of active vegetation and animal management.

In September 1989 a massive fire burned some 12% of the largest pine population on the Carmel Mountain, Israel. The damage caused by this conflagration raised much public interest, which stimulated integrative ecological research work on the impact of the fire on plants and animals. The aim of this study is to define optimal management regimes of the burned area in accordance with the future use of the land by people (such as nature reserve, recreational areas, grazing areas etc.). However, an appropriate management regime can be achieved only after a basic understanding of the succession of both plants and animals has been acquired.

One of the most important changes caused by the fire concerns the structure of the vegetation. The changes in vegetation structure may be responsible for the short- and long term changes in bird community (2, 12) through the shortage of nest sites, the intensive competition for food and shelter (6), the increase in predation in open areas (7), and the decrease in infestation by external and internal parasites (3, 8). Several studies on the impact of fire on passerine birds in different ecosystems around the world have demonstrated that the short-term effects were more clear cut than those in the long term (27). Short-term effects include many granivorous and omnivorous bird species attracted to the exposed ground of the areas that had been recently burned (4, 5, 19, 27). Komarek (14) noted also that the number of insectivores increased during and soon after a fire.

The aim of this study was to compare post-fire succession of passerine birds in different treatments and thus, to correlate bird abundance, bird richness, and bird composition with different treatments in a long-term study. The results presented here are concern the second and third year after the fire.
2. METHODS

Study site

The study site is located on Mount Carmel (320 m above sea level) 7 km from the Mediterranean shore (32°44' N 35°01' E). The forest in the area is dominated by Pinus halepensis with other species such as Quercus calliprinos, Pistacia lentiscus, and Cistus salviifolius (see area map in ref. 17).

Plot treatments

Twenty-nine 70 x 70 m plots were established in the burned area (previously unburned for 50 years until the wildfire in September 1989). A nearby area that had not been burned during the past 50 years served as unburned control. The burned plots were randomly divided into two different treatments and a burned area receiving no treatment. The first treatment included the cutting of the burned trees and their removal from the study plot. The second treatment included the cutting of the burned trees, removal of the trunks only, and leaving the twigs on the ground (for full description of these treatments see ref. 17). However, for bird observations, these two treatments in the burned area have been considered as one treatment. Therefore, bird observations were carried out in three different areas which will be termed hereafter as “burned plot”, “burned-and-cut plot”, and “control plot”.

Bird censuses

Bird observations were began in winter 1990-1991, one year post-fire, and the results reported here are until summer 1992. Birds were censused in each treatment 1-2 times per month in permanent routes with fixed observation points. Each census was not limited to the limits of the 70 x 70 m plot but passed through a several consecutive plots of the same treatment. All birds seen or heard were recorded for 10 minutes in several point-counts along this fixed route. Observations were made during the mornings and the sequence of plot visitation was rotated randomly to reduce temporal biases.

Data analysis

Since the avifauna in Israel is characterized by the large number of transients and winter residents, the analysis was carried out for each season separately. The data was categorized into 4 seasons, Winter (December-February), Spring (March-May), Summer (June-August), and Fall (September-November).

To determine differences in the number of observed birds of each species among treatments within a sampling season, data were analyzed using a general linear model for analysis of variance (GLM procedure, SAS, 22). When significant differences between treatments were detected, the Duncan multiple range test (P<0.05) was used to determine which treatments were different.

The similarity index of the presence of bird species between two different treatments was calculated for each season using Mountford’s binary coefficient (28):
where \( A \) is the number of bird species in treatment 1, \( B \) is the number of bird species in treatment 2, and \( C \) is the number of shared species of treatments 1 and 2. This index may range from 0 (no similarity) to unlimited.

Bird composition

The Multivariate direct gradient analysis (canonical ordination) - CANOCO was used to explain the response of bird species by ordination axes that are constrained to be linear combinations of the supplied environmental variables (different treatments). The "species-descriptors x sample matrix" submitted to CANOCO included the number of individuals of each species observed during each of the 10 min point-counts and the type of the treatment on a disjunctive form (001, 010, 100). The diagram obtained optimally displays the differences in species composition among different types of treatments (25, 26). The Monte Carlo permutation test was used to test statistically whether the observed differences in bird relative abundance could be accounted for by pure chance (25, 26).

3. RESULTS

Bird richness and total abundance

A total of 29 passerine species were recorded in the study plots. The unburned control pine forest supported more bird species in the two studied years than the burned plot and the burned-and-cut treatment (Fig. 1a). The most notable differences were observed in the two post-fire springs when a large influx of transients occur in Mount Carmel. However, there was no marked difference in species richness between the burned plot and the burned-and-cut treatment throughout the study period (Fig. 1a).

The control area was inhabited by several bird species which were not observed in the burned and the burned-and-cut plots (Fig. 1b). This phenomena was particularly marked in the first spring when 7 winter residents (e.g. Phylloscopus collybita, Erithacus rubecula, Pardus philomelos, and Loxia curvirostra), 2 transients (P.

Fig. 1. Time-course changes in the (a) total number of bird species, (b) number of exclusive species in the three different treatments.
trochilus and P. bonelli), and 2 all-year residents (Todus merula and Nectarins osea) populated only the unburned control plots. However, these control plots attracted only 4 "exclusive" species in the second spring (Fig. 1b). The control plots were also populated in summers by 3-4 "exclusive" species such as Pycnonotus xanthopygos, Parus major, and Carduelis chloris. The burned-and-cut treatment usually attracted a lower number of "exclusive" species than the control. Two transients (Sylvia communis and Oenanthe hispanica) were observed in the first spring only in the burned-and-cut treatment. The burned plot was populated by "exclusive" species only in the first spring (e.g., by Muscicapa striata) and in the second winter (Fig. 1b). The control plots also supported more individuals than the other two treatments. The major differences were observed at the beginning of the study until summer 1991; but subsequently less pronounced.

Relatively high values for the similarity index of avifauna composition (based on the presence of bird species but not on bird density) between all treatments were detected in the winter and summer of the first year and in summer 1992 (Table 1). The similarity indices in spring 1991 were very low and were much higher in spring 1992. The most similar treatments in terms of species composition were the control and the burned plot in the 1990-1991 winter. The mean similarity between treatments during all study periods was calculated by averaging the indices from all seasons. The burned plot and the burned-and-cut treatment were the most similar in species composition while the control and the burned-and-cut treatment were the most dissimilar (Table 1).

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Table 1: Mountford similarity index in the presence of passerine bird species between different treatments (see methods for details).

Is bird status correlated with habitat (treatment) preference? The total number of species in each status category was calculated from total observed birds during all seasons in each year (Fig. 2). The number of all-year residents and winter residents were similar and usually larger than the number of transients for all treatments in both years of the study. However, no significant correlations were detected in the number of bird species between their status category and the three treatments either in the first year of the study ($X^2=1.11$, d.f.=4, $P>0.05$) or in the second year ($X^2=0.31$, d.f.=4, $P>0.05$).
Fig. 3. Post-fire succession of several bird species in three different treatments. When significant differences between treatments were detected by ANOVA, the Duncan multiple range test (P<0.05) was used to determine which treatments were different (Indicated by different latter above bars). Error bars - Standard errors.
when most of the transient species as well as all-year residents were more abundant in the unburned control (Fig. 4b). However, in spring 1992 some transient species were more abundant in the burned plot while most of the all-year resident species still preferred the unburned control (Fig. 4c).

Fig. 4. Ordination diagrams based on canonical correspondence analysis of passerine birds in three seasons in post-fire pine forest with respect to the three treatments. The diagram optimally displays the differences in species composition among the three types of management (which are located on the diagram at the centroids of the sample). Species abbreviations are: ANTRI - Anthus trivialis, CARCHL - Carduelis chloris, CARSPI - Carduelis spinus, ERIRUB - Eriithacus rubecula, FRICOE - Fringilla coelebs, GARGLA - Garrulus glandarius, LUSMEG - Luscinia megarhynchos, NECOSE - Nectarinia osea, PARMAJ - Parus major, PHYCOL - Phylloscopus collybita, PHYTRO - P. trochilus, PRIGRA - Prunella modularis, SXTOR - Saxicola torquata, SYLTH - Sylvia atricapilla, SYLCUR - S. curruca, SYLMEL - S. melanoleuca, TROTR - Troglydtes troglodytes, TURNER - Turdus merula, TURPHI - Turdus philomelos.
4. DISCUSSION

Although the post-fire recovery of both vegetation and avifauna will probably require several decades (19), the present research examined only the short-term responses of birds to fire. In addition, this study did not investigate the immediate response of birds to fire since it was started one year after the fire. However, the results of the present study point out several phenomena which should be continuously examined for as long as possible.

The general richness pattern of passerine birds in the unburned pine forest is also characterized in different types of natural woodlands in Israel such as the Quercus calliprinos maquis (1, 9, 21). The highest species richness in these woodlands occurs during migration periods in fall and spring, a moderate richness occurs in winter, and the lowest richness occurs in summer. However, this seasonal pattern was less evident in the burned plot and in the burned-and-cut treatment. Hence, the general season-dependent changes in bird richness was masked to some extent by the fire and the treatment.

Total bird densities and richness were lower in the burned area and in the burned-and-cut treatment than in the unburned control area, particularly in the first year of the study (second year after the fire). In the third year, some recovery in total density and bird richness were noted in the burned plot and in the burned-and-cut treatment (see also 20). Moreover, the difference in bird richness between treatments was most pronounced during migration periods when a large influx of transients inhabited the study area.

Avian species that preferred unburned areas, such as Turdus merula and Erithacus rubecula are abundant in broad-leaved woodlands in Israel. On the other hand, several species that preferred unburned areas such as Parus major and Troglodytes troglodytes are abundant within pine forest in northern Israel. These species did not ignore the burned areas and the burned-and-cut treatments but appeared there in the second year post-fire although in small numbers. Most of these species recovered dramatically in the third year post-fire, especially T. troglodytes in summer 1992. It should be emphasized that the observed recovery was in bird presence but not in their ability to establish a territory and to breed. It seems that these species were able to re-establish in the burned areas despite the substantial change in vegetation structure (17). They are probably able to forage and to explode food items in the burned area and to include these areas as part of their territory. However, a full recovery which includes breeding can only be expected after a matter of decades.

The burned plots were relatively similar as concerns the presence of bird species to the burned-and-cut treatment plots. The average similarity index between these two areas was the highest (Table 1). Thus, despite the drastic modification of the forest structure by cutting and removing the burned trees, the differences in avian composition between these two areas were relatively small. The best indicator of the burned-and-cut treatment, Prinia gracilis, which typically populates the forest edge or bushy areas, totally ignored the unburned control and burned plots in the second and third post-fire years and was observed only in the burned-and-cut treatment plots.

The most noted differences in species presence were between the unburned control plots and the burned-and-cut plots (Table 1). Several species that preferred the unburned areas, such as Parus major and
Troglodytes troglodytes almost totally ignored the burned-and-cut plots. Others, such as Sylvia melanocephala and Prunella modularis appeared in higher numbers in the burned-and-cut plots than in the unburned controls. Sardinian warbler, a frugivore species (10, 11) which usually prefers shrubby habitats, was probably attracted to the burned-and-cut treatment due to the relatively high fruit abundance from climbers such as Asparagus aphyllus which in these plots yielded fruit immediately after the fire. However, the Dunock, a pure insectivore, was probably attracted to the burned twig piles in the burned-and-cut treatment which it used as observation points for prey.

The three treatments were significantly different in bird composition in most seasons as indicated by taking into consideration the relative abundance of each bird species. Thus, bird relative abundance among treatments was not random but showed that different species had clear preference for different treatment (Fig. 4). However, the relative 'contribution' of each treatment to these differences is not equal. The most "unique" plots in terms of species richness and density were the unburnt controls while the burned plots had a marginal affect on these differences (Figs. 1, 4, Table 1). It is rather surprising that bird composition was different for the different treatments whereas there were no significant differences in the relative abundance of perennial plants for the same treatments and during the same study period (17). Hence, the significant differences which were observed in bird composition among treatments in the first stages of the succession were probably the result of the different habitat structure of different plots (such as with/without burned logs, piles of burned twigs, exposed rocks and ground etc.) rather than the plant composition itself. It is hypothesized that the significance of the regenerating vegetation on bird composition will be more dominant in the coming years. The long-term plant-birds relationships will be associated with the succession of plant communities, so that discrete assemblages of bird species may typically be associated with particular seral stages (15).

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REFERENCES


