ʰʱʱ Cape Town

המאמרים במועברת הדפים דוкупונים ול-פל

חוק 2 ביניות ויזריות

dפסת מאמרים الهيئة '}ל首相י ליימור והוראת בלבד

アイל לעשوت כל שימוש מסחרי במאמרים.
RODENT SPECIES DIVERSITY IN PINE FORESTS RECOVERING FROM FIRE

ABRAHAM HAIM, IDO IZHAKI, AND AMNON GOLAN
Department of Biology, University of Haifa at Oranim, Kiryat Tiv'on 36006, Israel

ABSTRACT
Fire is a frequent disturbance in Mediterranean pine forests. The recovery of post-fire habitats occurs through a succession of plants and animals. The fire on Mount Carmel in 1989 provided us with an opportunity to study the recovery of the habitat in its early stages, and under three different management treatments, which included untreated plots, as well as plots from which the trees and the twigs were removed, and plots from which trees were removed, whereas twigs were gathered and left in the field. Rodent species diversity values in these plots were compared with those from a similar forest that burned 22 years ago, as well as those from a control forest which, to our knowledge, has not had a fire in the last 100 years. Our results indicate that four and a half years after the fire, untreated post-fire plots had high species diversity levels. These plots included both species that invaded the habitat and recolonizers. Twenty years after a fire, species diversity is close to its original state.

INTRODUCTION
Fire is a common form of disturbance in the pine forests of the Mediterranean ecosystem. It can destroy such habitats in just few hours and cause dramatic changes. Fire is an important ecological force shaping landscapes and communities in the countries of the Mediterranean basin (Trabaud and Prodon, 1993). Fires can either occur naturally or be caused by human activity. The latter kind has played a role ever since the adoption of fire by humans (Naveh, 1990a). Recovery from such a disturbance can take between twenty and thirty years. However, the vegetation in these habitats seems to be well adapted to cope with fire. Tree species such as Quercus are able to resprout rapidly, and Pinus trees disperse most of their seeds during fires, and their seedlings reestablish the pine forest (Lahav, 1988).

The impact of fire on the community of small mammals inhabiting the Mediterranean ecosystem has been studied extensively around the Mediterranean basin (Prodon et al., 1987; Sgardelis and Margaris, 1992; Arrizabalaga et al., 1993; Fons et al., 1993; Haim, 1993; Izhaki et al., 1993; Haim and Izhaki, 1994). The immediate impact of fire on small mammals is their elimination from the post-fire habitat due to the high temperatures and

Accepted March 1996.
the smoke produced by the fire. Moreover, the arboreal destruction has a lasting effect on the rodent community. The serial responses of these communities, which ultimately result in reestablishment, are through succession (Friend, 1993), a process dependent on the recovery of vegetation in the habitat.

The east-Mediterranean pine forests on Mount Carmel have been exposed to human disturbances for at least 60,000–70,000 years, and fires occur quite frequently in this habitat (Naveh, 1984, 1990b). When undisturbed, the forest is inhabited by three arboreal omnivorous murids: the yellow-necked wood-mouse Apodemus flavicollis, the broad-toothed wood-mouse A. mystacinus, and the black rat Rattus rattus. The latter is common on pine trees, and pine seeds are an important item in its diet (Aisner and Terek, 1992).

A fire in September 1989 destroyed thousands of acres of natural Aleppo pine (Pinus halepensis) forest, including oaks (Quercus calliprinos), which form the understorey of the pine forest. Rodent populations were monitored for almost four years, starting one year after the fire. To determine the best management scheme for the recovery of the forest, rodents were used as bioindicators to test the efficiency of three different treatments. Since a fire took place in a very similar habitat on Mount Carmel 22 years ago, it was possible to compare the rodent-species diversities between the two habitats.

We also studied the rodent community in a Mount Carmel pine forest which, to our knowledge, has not burned in the last 100 years. Comparisons were made in spring, when rodent populations usually peak on Mount Carmel.

Thus, the aims of this study were: (1) to compare changes in rodent diversity in post-fire habitats subjected to different treatments; (2) to compare species diversity in the first years after the 1989 fire with that of a post-fire habitat 22 years after the last fire; and (3) to estimate the time until full recovery.

MATERIALS AND METHODS

STUDY AREA

The pine forest recovering from the fire in September 1989 is on Mount Carmel (32°44′N; 35°01′E), in northern Israel. The site is located 7 km from the Mediterranean coastline at an altitude of 320 m. The pine forest that burned in 1974 and the control forest are both located approximately 10 km south and 2 km west of the first site. The climatic conditions in all localities are identical. The mean annual temperature is 18.8 °C with daily fluctuations of 6–8 °C and a mean temperature difference between summer and winter of 12–13 °C. The mean annual precipitation is about 700 mm and the average daily relative humidity is 65–70% (Atlas of Israel, 1970; Jaffe, 1988). The vegetal composition of the post-fire habitat was described by Ne’eman et al. (1993).

SAMPLING

In the 1989-fire locality, five randomly selected plots were sampled under three post-fire treatments: (1) "burned and twigs" (BT)—the burned trees were cut down, the trunks removed, and the twigs were collected in small piles and left on the plots; (2) "burned
and cleared" (BC)—the burned trees were cut down, and the trunks and the twigs were removed; (3) "control" (C)—the burned trees were left untouched after the fire. In the second locality (site of the 1974 fire) three plots were selected. Three plots were also selected in a nearby pine forest which, as far as we know, has not been burned in the last 100 years. All plots were about 5,000 m².

On each plot, 50 live Sherman traps were set in permanently marked sites. They were set along 5 lines, 10 traps per line, 10 m apart; the distance between lines was 10 m. Traps were set in the late afternoon and collected in the early morning. Trapping in the first locality started in August 1990, while trapping in the second and third localities started only in May 1994.

Shannon’s diversity index (Zar, 1984) was used to assess rodent species diversity.

RESULTS

The post-fire habitat in the 1989 locality was invaded by three rodent species, which are not known to be forest dwellers, but usually occur in the margins of the forest: the Macedonian mouse Mus macedonicus, Wagner’s gerbil Gerbillus dasyurus, and Tristram’s jird Meriones tristrami. These species are still found in the habitat almost five years after the fire. Among the forest dwellers, the first species to reestablish itself was A. flavicollis (Filippacchi et. al. 1989). A. mystacinus reappeared in very low numbers in the winter of 1991. Five years after the fire, no black rats were trapped and no signs of their activity, such as stripped pine strumholes, were found. From the summer of 1993, a secondary invader, the common spiny mouse Acomys cahirinus, appeared in the study area, and its numbers increased mainly in the BT and C plots.

The Shannon diversity index (Fig. 1) indicates that generally in the plots recovering from the 1989 fire, the highest species diversity is in C. In the spring and winter of 1992 the diversity was higher in BT, while in the winter of 1992 it was also high for BC. However, it seems that four and a half years after the fire, species diversity in BC and BT is similar (Fig. 1).

Diversity in plots burned 22 years ago is higher than that in non-burned controls (n = 46 and n = 22, respectively. See Fig. 2). However, the values obtained after 22 years of recovery are lower than those obtained in C after four and half years of recovery. The results also show that during the fourth year, species diversity is higher than during the third and second years after the fire (Fig. 2). R. rattus, which was still missing from the 1989 study, appears in plots that were set on fire 22 years ago.

DISCUSSION

Because the forests on Mount Carmel are on a fringe of the Mediterranean ecosystem, they suffer from marked seasonal asymmetry, i.e., the wet and cold season last for only three months, whereas the dry season may last up to eight months. The recovery of Palearctic species in such habitats after a severe fire may be a long process, as water is a limiting factor. The destruction of the habitat by fire resulted in the invasion of granivo-
Fig. 1. Temporal changes in species diversity (as measured by the Shannon diversity index) of a rodent community inhabiting a post-fire habitat on Mount Carmel, Israel, under three different management regimes.

Fig. 2. Species diversity (as measured by the Shannon diversity index) of three rodent communities on Mount Carmel, Israel. The data for the 1989 location represents the “burned control” plots. The data for the control location was taken on Mount Carmel plots that to the best of our knowledge have not burned in the last 100 years.
rous rodent species, and one of these, *G. dasyurus*, a rock dweller, usually inhabits some of the hottest and driest parts of the Palearctic deserts (Haim and Tchernov, 1974; Harrison and Bates, 1991). The results of this study support the idea that the recovery of the rodent community is through succession (Haim, 1993; Izhaki et al., 1993; Haim and Izhaki, 1994).

The Shannon diversity index accounts not only for the number of species existing in the habitat but also for the relative evenness among the species (Piérou, 1977). The higher values obtained in the plots recovering from fire may result from the greater number of species occurring in the post-fire habitat. While in unburned forests only three rodent species exist, in the post-fire habitat, the invasion by species occurring at the margins of the forest together with recolonization by the common forest dwellers may increase this number twofold (Haim and Izhaki, 1994). Therefore, the BT and C treatment regimes are the best for recovery, at least in the short term. The high species diversity in such plots may be the result of superior abiotic conditions, most probably because the removal of twigs exposes the surface of rocks and soil to high radiation. In seasonally asymmetrical ecosystems, this exposure may impede recolonization by omnivorous species, which depend on dietary water (Haim and Rubal, 1992; Haim and Izhaki, 1994).

The decrease in species diversity during the spring of 1993 (February to April) in the BT and BC plots (Fig.1) is an outcome of a marked growth in the *G. dasyurus* population. This growth was accompanied by the disappearance of the two wood-mice species and of the common-spiny mouse. Therefore, the decrease reflects a low species evenness (Piérou, 1977). An increase in diversity in all three regimes was noted during the summer of 1993 (June), the season in which all species are active.

The rodent community of the plots that were burned in 1974 seems to be almost fully recovered. All three resident species are found, but the *M. macedonicus* population is found in quite large numbers. In plots that have not burned in the last century, *M. macedonicus* is rare, accounting for approximately one in twenty rodent individuals, and although *R. rattus* was not trapped in these areas, its activity was evident.

The highest species diversity was seen during the fourth year after the fire (Fig. 2). In this period, granivorous invaders still coexist in the habitat with the omnivorous species, such as the wood mouse and the common spiny mouse. Therefore, the results of our study suggest that in the first stages of recovery of the post-fire habitat there is an increase in species diversity, while later stages will be characterized by a decrease.

**ACKNOWLEDGMENTS**

We thank Dr. Joy Hoffman for her comments. This research was supported by a grant from the Carmel Foundation at the Israel Ministry of the Environment and by a grant from the GSF-Forschungszentrum für Umwelt und Gesundheit, Neuherberg, through the Israel Ministry of Science and the Arts.
REFERENCES


REFERENCES


Prodon, R., Fons, R., and Athias-Binche, F. 1987. The impact of fire on animal communities in
Mediterranean areas. In: Trabaud, L. ed. The role of fire in ecological systems. SPA
Sgardelis, S.D. and Margaritis, N.S. 1992. Effects of fire on birds and rodents of phryganic (East
ean ecosystems. E. Guyot, Brussels, pp. 7–9.