המאמרים ב缅ראות הדפיסים וז מוגנים על-פי חוק זכויות יוצרים.

dפסת מאמרי תחתך לטרבי ליימוד והוראה בכל בחלק

אין לעשות כל שימוש מסחרי במאמרים.
Post-fire response of shrews (*Crocidura suaveolens*) on Mount Carmel, Israel

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Summary. — Resilience to fire of a shrew population (*Crocidura suaveolens*) was studied in a post-fire East Mediterranean pine forest on Mount Carmel, Israel. Since they are small body size secondary consumers, shrews can serve as bioindicators for assessing the various stages of post-fire recovery. Shrew abundance was correlated with abiotic and biotic variables. An attempt was also made to discover the response of population recovery under different post-fire forest treatments: "burned control" — untreated post fire plots; "burned and clear" — whereby burned pine trees and twigs are removed from the plots; "burned and twigs" — whereby burned pine trees are removed but the twigs are kept accumulated in situ. Within two and a half years since fire, shrew population had established itself in all treatments. Activity was high in ambient temperatures close to their thermoneutral zone and at relatively high humidity. Only in burned control plots shrew populations correlated positively with the height of *Pinus halepensis* and *Cistus salviifolius*. Abundance was negatively correlated with the abundance of *Mys macedonicus* and positively correlated with that of *Gerbillus dasyurus* and *Apodemus mystacinus*. Time since fire rather than treatments is the most important factor in the recovery after fire of the shrew population, but seasonality seems to play an important role in shrew abundance as well.

Résumé. — La résilience, par rapport à l’incendie, d’une population de musaraignes (*Crocidura suaveolens*), a été étudiée dans une piste après un feu, sur le mont Carmel, en Israël. Consommateurs secondaires de petite taille, les musaraignes peuvent servir de bio-indicateurs permettant d’évaluer les différentes étapes de la régénération post-incendie. L’abondance des musaraignes a été corrélée à des variables biotiques et abiotiques. On a également tenté de mettre en évidence l’évolution de la réponse des populations sous différents traitements forestiers post-incendie: «contrôles brûlées» — stations non traitées après le feu; «brûlées et nettoyées» — où les troncs et branches brûlés ont été enlevés; «brûlées et avec branches» — où les troncs brûlés ont été enlevés, mais les branches sont laissées en situ. Deux ans demi après le feu, les populations de musaraignes se sont rétablies dans tous les cas. Leur activité était importante aux températures proches de la zone de la neutralité thermique et aux taux d’humidité assez élevés. Les populations de musaraignes étaient corrélées avec la hauteur des *Pinus halepensis* et *Cistus salviifolius*, seulement dans les zones «contrôles brûlées». Leur abondance était négativement corrélée avec celle de *Mys macedonicus*, et positivement avec celles de *Gerbillus dasyurus* et *Apo- demus mystacinus*. Le temps écoulé depuis le feu apparaît être un facteur plus important que le type de traitement forestier dans le rétablissement des populations de musaraignes, mais la saisonnalité semble jouer un rôle important également.

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INTRODUCTION

Fire is a common disturbance in the Mediterranean ecosystem (Prodon et al. 1987; Naveh 1990). It causes a dramatic change in the habitat within a very short period, sometimes a few hours, while the recovery of the habitat can last as long as over 20 years and features a succession of plants and animals (Haim et al. 1994).

The fire that broke out on Mount Carmel, Israel, in September 1989 destroyed thousands of hectares of East Mediterranean pine forest comprising the Aleppo pine *Pinus halepensis* in the upper story, while one of the common tree species in the under story is the oak *Quercus calliprinos* (Ne‘eman et al. 1993). The changes of the rodent community in resilience to fire have been reported in several studies (Izhaki et al. 1993; Haim 1993; Haim and Izhaki 1994; Haim et al. 1994). So far no data have been published on the recovery of the shrew population in the East Mediterranean pine forest. The common shrew in this habitat is the lesser white-toothed shrew, *Crocidura suaveolens*. In the past, *C. suaveolens* (Catzeffis et al. 1985; Harrison and Bates 1991) in Arabia was considered as *C. rassula monacha* (Hellwing 1971). This small mammal seems to be well adapted to relatively xeric conditions of the habitat during the long dry and warm season. Furthermore, in Israel it even inhabits semi-arid environments (Harrison and Bates 1991). The distribution of this species in semi-arid areas is strongly supported by the evidence of its existence in Corsica where *C. rassula* the more mesic species is absent (Poltevin et al. 1987). As shrews are secondary consumers, the recovery of their populations in a post-fire habitat is of great interest as it points to the recovery of invertebrate communities they prey upon.

Therefore, the aim of this study was to test the hypothesis that since they are secondary consumers the return of shrews to post-fire habitat and their establishing populations there, will be delayed relatively to the return of such primary consumers as certain rodent species. Specifically this study describes the recovery of the shrew populations under three different treatments (including logging and removal of burned trees) also applied to the study of rodent communities.

MATERIALS AND METHODS

Study area

The study area is located in the Mount Carmel National Park 32°44’N 35°01’E, Israel, at an altitude of 320 m and about 7 km from the Mediterranean seashore. Winter is the rainy season, and the mean annual precipitation is about 700 mm. The mean annual temperature is 20° C with a mean temperature difference between winter and summer of 12° C. The daily average relative humidity is 65-70 % (Atlas of Israel 1970, Jaffe 1988). The study area is in a post-fire east Mediterranean Aleppo pine (*Pinus halepensis*) forest. The vegetation composition of the post-fire habitat at different stages up to four years after the fire, was described by Ne‘eman et al. (1993).

Three different treatments were applied: (1) a mixed forest of burned pine and oak trees untouched after the fire – “burned control”; (2) burned trees were cut down, trunks removed, twigs piled and left in situ – “burned and twigs”; (3) burned trees were cut down and both trunks and twigs were removed – “burned and clear”. These plots were randomly chosen within an homogenous area of 1,200 m x 450 m. Traps
were also set during a year and a half in two plots of 5000 m² each, in an unburned forest close to the study area.

Sampling

Since the study was carried out in an area where fire was not prescriptive, we were unable to select different burned sites but had to use available sites. An effort was made to sample in plots that represent the maximal habitat variation under each treatment. Five plots of 5000 m² in each treatment were selected randomly. Trapping started on August 1990, almost one year after the fire, and lasted until January 1994. On each plot 50 live traps (Sherman, 23 × 7.5 × 9 cm) were set in permanent marked places. The traps were set in five lines, with 10 traps per line. The distance between the traps in each line as well as the distance between the lines was 10 m (Haim 1993; Izhaki et al. 1993; Haim and Izhaki 1994). The total trapping effort was 15 sessions, of no more than three months each, each session included a one-night visit to each of the five plots of each treatment. Thus, a total of 250 traps were set for each treatment in each session. The traps were set in the late afternoon and collected early the following morning in order to avoid shrew mortality due to overheating. Peanut butter spread on pieces of carrot or bread was used as bait. To provide protection against low ambient temperatures on cold nights during the winter, cotton-wool and tissues were added to the traps.

Maximal and minimal ambient temperatures were recorded using a maximum/minimum thermometer each time the traps were set. Humidity of early evening and early morning were recorded using a hygrometer.

The shrews were identified, weighed and then marked by toe clipping. Each shrew was released in the place where it was captured.

Analysis

To assess the abiotic and biotic variables that affect the abundance of the shrews in the post-fire habitat, correlations were made among the number of shrews trapped per trapping session, minimal and maximal ambient temperature, relative humidity, rodent abundance and vegetation, each year between 1991 and 1993. Seasons were defined as follows: Winter (December-February), Spring (March-May), Summer (June-August), and Fall (September-November). Data of Pinus and Cistus seedling height under the same treatments in the study area were collected (Table 1, Ne’eman unpublished data). The data for rodent abundances were taken from Haim and Izhaki (1994).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Plant species</th>
<th>Year 1991</th>
<th>Year 1992</th>
<th>Year 1993</th>
</tr>
</thead>
<tbody>
<tr>
<td>Burned control</td>
<td>Pinus</td>
<td>14.8±1.3</td>
<td>40.5±4.8</td>
<td>56.2±7.5</td>
</tr>
<tr>
<td></td>
<td>Cistus</td>
<td>31.8±5.8</td>
<td>65.8±7.9</td>
<td>78.3±8.5</td>
</tr>
<tr>
<td>Burned &amp; twigs</td>
<td>Pinus</td>
<td>11.1±5.6</td>
<td>28.8±3.3</td>
<td>39.3±5.0</td>
</tr>
<tr>
<td></td>
<td>Cistus</td>
<td>20.8±3.3</td>
<td>47.8±5.3</td>
<td>55.0±5.6</td>
</tr>
<tr>
<td>Burned &amp; clear</td>
<td>Pinus</td>
<td>13.2±2.0</td>
<td>29.0±4.1</td>
<td>42.0±10.2</td>
</tr>
<tr>
<td></td>
<td>Cistus</td>
<td>23.2±4.4</td>
<td>51.5±7.0</td>
<td>60.0±8.3</td>
</tr>
</tbody>
</table>

TABLE 1. – *Pinus halepensis* and *Cistus salvifolius* annual average (±SD) seedling height (cm) in each treatment (n=5 plots per treatment). Based on Ne’eman (unpublished data).
To weigh the number of trapped shrews in each treatment relative to trapping efforts, the total number of shrews trapped in a three-month period (session) was divided by the total number of trapping sessions per plot, and this was considered shrew abundance. In order to establish significant differences among treatments, seasons, and time since fire, a two-way ANOVA was used.

RESULTS

General biology

The mean body mass of all the trapped shrews throughout the study (n = 110) was 7.2 ± 2.2 g. This body mass value did not differ significantly from that of shrews trapped in the unburned forest (Wc = 7.1±1.8 g, n = 12). Therefore, the body mass of the shrews was analyzed in the different seasons of 1993 (Table 2). There is a significant difference in body mass among seasons, the mean body mass being the highest in winter and lowest in spring.

<table>
<thead>
<tr>
<th></th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Fall</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>9</td>
<td>9</td>
<td>12</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>9.6</td>
<td>6.8</td>
<td>8.5</td>
<td>8.1</td>
<td>2.86*</td>
</tr>
<tr>
<td>SD</td>
<td>2.0</td>
<td>2.2</td>
<td>2.3</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>

Shrew abundance was found to be correlated with ambient temperature, Te (Fig. 1). Maximal abundance was noted when the maximal Te recorded in the afternoon was 25-30°C and minimal Te during the night was 15-20°C. Their abundance was also correlated with relative humidity, and maximal abundance was recorded when relative humidity was 50-60% in the evening and 80-90% in the early morning (Fig. 2).

As the shrews had been marked individually, it was possible to follow their movements in the study area. The maximal duration recorded between capture and recapture of the same individual was 477 days. The maximal distance between two consecutive trappings of the same individual was 1000 m. The maximal recorded movement rate was 500 m in eight days. In these cases of long movement distances the first captures (n = 7) were in "burned control" these plots and then the shrews moved into the "burned and twigs" (n = 4) and "burned and clear plots" (n = 3).

Post-fire recovery

The shrews that inhabited the pine forests before the fire were either killed during the fire or were forced to emigrate from the post-fire habitat owing to its destruction. Only in April 1991, one and a half year after the fire, the first shrew was trapped. From January 1992 shrews were trapped regularly, first only in the "burned control" and the "burned and clear" plots, and from April 1992 also in the "burned and
Fig. 1. – Histogram of total trapped shrews, *Crocidura suaveolens* in relation to maximal and minimal ambient temperatures measured in the afternoon (maximum) and during the night (minimum). Ambient temperature data were used only for nights when shrews were trapped.

Fig. 2. – Histogram of total trapped shrews, *Crocidura suaveolens* in relation to maximal and minimal relative humidity measured in the afternoon (minimum) and during the early morning (maximum). Relative humidity data were used only for nights when shrews were trapped.
twigs" plots. In 1993 a shrew population was established and its abundance was relatively high (Fig. 3). A total of 110 individuals were trapped in this study, out of them 39 were recaptured. Less than 5% mortality was observed throughout the study period.

![Graph of shrews caught per session](image)

**Fig. 3.** Number of shrews, *Crocidura suaveolens* trapped per session (in a total of 750 traps) during a period of three months each) under three different treatment regimes ("burned", "burned and twigs", and "burned and clear") in an East Mediterranean pine forest recovering from fire on Mount Carmel, Israel, between the years 1990 and 1994.

The mean numbers of shrews trapped under each treatment, taking into account trapping efforts, and a comparison with those of unburned plots, are given in Table 3.

In the first one and a half year after the beginning of the study, shrews were trapped in the unburned control plots, in number almost five times higher than in the burned plots, but this result was not significant (Table 3). No differences in the number of shrews trapped were found among the three burned plots in the last one and a half year of the study.

**TABLE 3.** Mean number of shrews trapped in different treatments during the first 1.5 years post-fire and the following 1.5 years. Each trapping session (n=7) comprised three months trappings.

<table>
<thead>
<tr>
<th></th>
<th>Unburned forest</th>
<th>Burned control</th>
<th>Burned and clear</th>
<th>Burned and twigs</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 1991 - July 1992</td>
<td>0.92</td>
<td>0.17</td>
<td>0.19</td>
<td>0.2</td>
<td>2.22*</td>
</tr>
<tr>
<td>August 1992 - January 1994</td>
<td>0.83</td>
<td>0.68</td>
<td>0.71</td>
<td>0.27*</td>
<td></td>
</tr>
<tr>
<td>t-test value</td>
<td>3.34**</td>
<td>2.26</td>
<td>3.51**</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*0.01 < p < 0.05;
**0.001 < p < 0.01;
ns - not significant;
*No data available for the unburned forest.
study. However, marked differences (3-5 times) were noted in the numbers of trapped shrews in each treatment between the two half periods of the study (Table 3). A two-way ANOVA indicated that the number of trapped shrews was significantly different according to time since fire, while the three treatments were not significantly different (Table 4).

In the burned control plots, shrews were found to correlate positively with the height of vegetation such as *Pinus* \( (r = 0.99, n = 4, p < 0.05) \) and *Cistus* \( (r = 0.96, n = 4, p < 0.05) \) plants, but they were found to be negatively correlated with the height of *Cistus* \( (r = 0.95, n = 4, p < 0.05) \) in the burned and clear plots.

The correlations between shrews and rodents existing in the same plots demonstrated a positive relation with *Apodemus mystacinus* \( (r = 0.62, n = 15 \) trapping sessions, \( p < 0.05) \) in the unburned plots. A positive correlation was detected with *Gerbillus dasyurus* \( (r = 0.68, n = 15, p < 0.01) \) in "burned and twigs ", while a negative correlation was detected in these plots with *Mus macedonicus* \( (r = -0.57, n = 15, p < 0.05) \).

**TABLE 4.** - Two-way ANOVA for the effects of the time of the trapping session (each session comprises three months' trappings between April 1990 and January 1994) and the treatment (see methods) on the weighted number of trapped shrews in a post-fire ecosystem in Mount Carmel, Israel.

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>R-square</th>
<th>F value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete Model</td>
<td>13</td>
<td>0.69</td>
<td>3.81**</td>
</tr>
<tr>
<td>Trapping</td>
<td>11</td>
<td></td>
<td>4.46**</td>
</tr>
<tr>
<td>session</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>2</td>
<td></td>
<td>0.22ns</td>
</tr>
</tbody>
</table>

**DISCUSSION**

**General biology**

The natural diet of *C. suaveolens* includes mainly snails, earthworms, insects and other arthropods (Atallah 1977). Due to their low body mass they have a high body mass specific metabolic rate. The resting metabolic rate (RMR) recorded for this species was 2.55 ml O$_2$/g.h., which is about 10% higher than the expected for its body mass (Mover et al. 1986). However, Vogel (1976, 1980) points to the fact that in Crocidurinae shrews RMR is lower than in Soricinae (see also Nagel 1994).

The mean body mass of shrews trapped during the winter months was higher than that of those trapped during the spring (Table 2). This difference is a result of the population structure, which in spring includes young shrews while in winter it consists only of old individuals. This result is in agreement with those of Hellwing (1971), where it was noted that reproductive activity in this species takes place throughout the year but is at its highest during spring, between March and May.

Shrews of this species may be caught at any time of the day or night, but a peak in their activity is noted in the late afternoon and early evening (Harrison and Bates
1991). The results of the present study show that maximal captures of shrews was recorded between maximal T<sub>r</sub> of 20-30 °C recorded in the afternoon and minimal T<sub>r</sub> of 15-20 °C during the night (Fig. 2). The lower critical point in this species is at 28 °C, (Mover et al. 1986). The low activity at low as well as at high ambient temperatures, may possibly be a result of the relatively long torpor durations described in this species under such thermal conditions (Mover et al. 1986). Due to the high metabolic rate it may be assumed that water turnover is also high. The results of this study show that maximal abundance is noted at nights with relatively high humidity (Fig. 2). Both these results can explain the high dependence of shrew activity on seasonality.

Post-fire recovery

The recovery of a post-fire forest is presumably through succession, where the present study reveals the appearance of a secondary consumer - the shrew in a post-fire resilience. As insectivores, shrews can be used as bioindicators for habitat quality.

Individuals of the lesser white-toothed shrew C. suaveolens are common among the small mammals inhabiting the natural East Mediterranean pine forests on Mount Carmel. Their low metabolic rates relative to other shrew species, on the one hand and the short-term oscillations of metabolic rates and body temperature on the other seem important adaptations for saving energy (Mover et al. 1986, 1994) and may explain their wide distribution in Israel. Fire in such a habitat will result in the destruction of the shrew populations. The first small mammal species to reestablish its populations in the post-fire habitat are granivorous rodents (Quinn 1986). On Mount Carmel three granivorous rodent species were trapped in the early stages of post-fire recovery: Meriones crassus, Gerbillus dasyurus and Meriones tristrami (Izhaki et al. 1993; Haim 1993; Haim and Izhaki 1994). Prolonged disappearance of shrews from post-fire habitats have been reported for south African pine forests (Kern 1981; Rowe-Rowe and Lowry 1982). Similar results were also reported from Mediterranean cork oak forest (Fons et al. 1993). Therefore, the appearance of the shrews in the post-fire habitat can be considered as a secondary stage in the resilience of the forest to fire. In this stage, the omnivorous Palaeartic Apodemus species also returned to the post-fire habitat, while M. macedonicus populations were declining (Haim and Izhaki 1994). This is further supported by the negative correlation described between the shrews and M. macedonicus in the "burned control" and "burned and twig plots". This change in small mammal populations may result from the increase of invertebrates in the habitat during this period (Broza et al. 1993).

In the study plots on Mount Carmel, shrews were trapped regularly from January 1992, over two years after the fire. This is similar to results described for Crocidura russula, from a post-fire pine forest habitat in the Montserrat Massif (Arrizabalaga et al. 1993). However, Fons et al. (1993) reported that in a post-fire cork oak (Quercus suber) habitat, the common European white-toothed shrew, C. russula, had established a population already one year and a half after the fire. The shorter time needed for shrews to return to the post-fire habitat in the cork oak forest may be due to differences in habitat quality, suggesting a quicker recovering for the cork oak forest.

C. suaveolens was found to be territorial and the size of territories suggested by Churchfield (1990) was 8 meter in diameter. Therefore, from the results of our study it may be assumed that individuals which showed a long distance movement are nomad. This feature probably characterizes individuals that did not establish yet a definite territory. These individuals cross different treatments during their movements, thus at this stage of post-fire forest recovery, the treatments seem to be less important.
The lesser white-toothed shrew C. suaveolens is abundant in northern Israel in a wide variety of habitats. According to Atallah (1977) they take refuge in rock piles and do not construct burrow systems. Therefore, the positive correlation in the "burned control" plots with the height of vegetation is reasonable as this factor may help them deal with the environmental climatic changes. Further studies are needed to explain the negative correlation which was found between shrew abundance and Cistus height in the "burned and cleared" plots. The relatively long recovery duration of Pinus and Cistus from seeds (Ne'eman 1993) may explain the relatively long time for the recovery of the shrew populations, as the plantation may not only serve as a food source for the prey of the shrews but also moderate extreme abiotic conditions in the habitat. Furthermore, our results suggest that time since fire, rather than different treatments, forms the main factor governing the rate of shrew recolonization in post-fire East Mediterranean pine forest.

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