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Effects of winter fire on spiders

MARCO MORETTI
Swiss Federal Research Institute WSL, Sottostazione Sud delle Alpi, PO Box 57, CH-6504 Bellinzona, Switzerland (marco.moretti@wsl.ch)

Abstract
"Fire and biodiversity" is a much-discussed topic based on research in different countries under varying environmental conditions and fire regimes. Nevertheless, until now, no research has been carried out on faunal post-fire biodiversity in winter fire-prone ecosystems such as deciduous forests on the south-facing slopes of the Alps. The basic objectives of this study were to analyse the effects of single and recurring fires on spider communities and their subsequent diversity. Epigeic spiders were used as bioindicators to describe the ecological response of chestnut forest-floor habitats to winter fires in Southern Switzerland. Overall, 143 spider species were sampled from April to September using pitfall traps at both post-fire and intact chestnut coppice sites. Approximately 30% of the species found were present exclusively in burnt sites (compared with only 7% found exclusively in intact areas). These results suggest that post-fire succession was initiated by surviving individuals. No dominant pioneer species were observed in the burnt sites. Changes in communities were observable only within the first two years after a single fire, whereas changes persisted in areas with recurring fires. In the latter case, communities were characterised by the eudominance of a single species *(Pardosa saltans)* and by an increase in species richness. The presence of species strongly associated with particular fire regimes indicates a wide-mosaic structure of environmental and microclimatic conditions at the epigeic level, with a predominance of xeric conditions. Evidence was found that major silvicultural projects implemented before and during the early 1950's, combined with an intense fire history, have played an important role in the development of the spider communities in the chestnut forest of the Southern Alps.

Key words: forest fires, fire ecology, post-fire succession, fire regime, fire frequency, time elapsed since last fire, fauna, biodiversity, Southern Switzerland

INTRODUCTION

Fire is an important environmental factor in many ecosystems throughout the world. However, few studies have examined the impact of fires over periods exceeding 10-15 years (Huhta 1971; Merrett 1976), and little is known about longer-term effects of fire on spider communities. A further limitation of existing work is that most have been carried out in fire-prone regions (e.g. Mediterranean shrub-land, steppe, savanna, boreal forest, etc.) or in specific fire-climax ecosystems; much less is known about the role of fire in other ecosystems, such as temperate forests.

Our study concentrates on the impact of fire on spider communities in chestnut forests of the Southern Alps. Fires are frequent in these forests, but occur mainly during the dormant period between December and April (Conedera et al. 1996). The following objectives were pursued:
(i) analysis of the effects of single and recurring fires on spider diversity over a 25 year period,
(ii) identification of the species most affected by fires, both positively and negatively, and

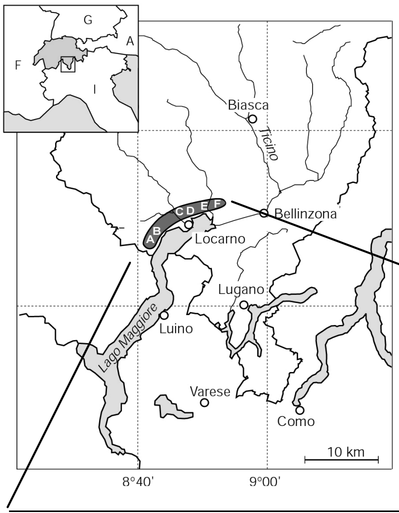

Fig. 1. Location of the study area (dark shading) on the southern slope of the Alps (Ticino, Switzerland) and the sampling design. A-F: six sectors of the study area in which a total of 26 study sites were selected; n: number of chosen study sites among the categories of fire regime.

Categories of fire regime	Description	n
Unburnt (= control)	Sites without fires for the last 30 years	6
Freshly burnt	Sites where sampling started 1-2 weeks after the fire	2
Single fire	Sites which have burnt only once within the last 30 years	8
Repeated fire	Sites which have burnt 3-4 times within the last 30 years	10

(iii) analysis of the ecological response of forest-floor habitats to wildfires using epigeic spiders as bioindicators.

The current project is part of a wider research program on the effects of wildfire on invertebrates and is supported by the WSL Swiss Federal Research Institute (Switzerland).

METHODS

Study area

The study region is located along a uniform, south-facing slope (450-850 meters a.s.l.) in Canton Ticino (46°09′ N, 08°44′ E) (Fig. 1). The forest is dominated by chestnut (*Castanea sativa* Mill.) coppices, situated on acidic substratum, corresponding to the *Phyteumo betonicifoliae-Quercetum castanosum* association (Ellenberg & Klötzli 1972; Keller et al. 1998). The climate is mild with humid summers and relatively dry winters. Average annual rainfall is 1800 mm. The mean annual temperature is 11°C (1°C in January and 22°C in July).

Sampling was based on a 'space-for-time substitution' (Pickett 1989), and 26 individual study sites were chosen. The sites were similar to each other in aspect, slope and soil, but differed in terms of fire frequency and time elapsed since last fire. The Wildfire Database of Southern Switzerland (Conedera et al. 1996) was the principal source of information on the regional fire history over the past 30 years (1968-1997). The sites were classified according to fire regime (Fig. 1).

Sampling methods and data analysis

Epigeic spiders were sampled using pitfall traps (plastic beakers, ∅ 15 cm) with an overhead roof for rain protection (Uetz & Unzicker 1976; Obrist & Duelli 1996). The traps were filled with 2% formaldehyde solution and soap was added to reduce liquid surface tension. Three pitfall traps were installed on each of the 26 study sites (totaling 78 traps), and were emptied on a weekly basis from March through

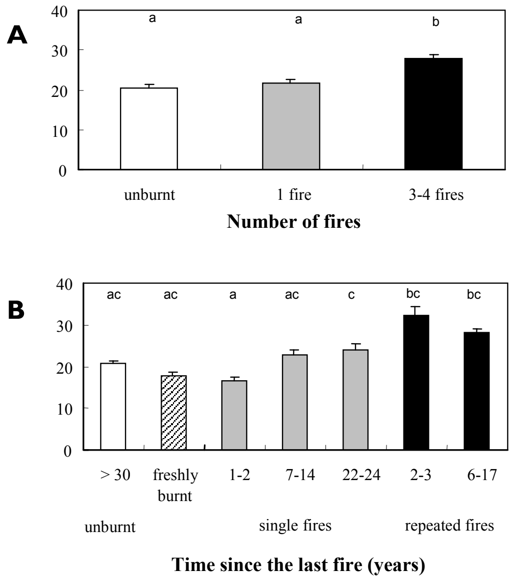

Fig. 2. Spider species richness (mean ± SE) grouped in classes of **(A)** 'fire frequency' (ANOVA F = 30.69, P < 0.001) and of **(B)** 'time elapsed since the last fire' (ANOVA, F = 19.14, P < 0.001). Bars with different letters are significantly different (P < 0.05; ANOVA with subsequent Scheffé post-hoc test).

September 1997 (28 sampling periods in all). The distance between traps was never less than 10 m. All adult spiders were classified into species using standard keys (i.e. Heimer & Nentwig 1991) and the nomenclature followed Platnick (1989). Specimens of each species were deposited in the Natural History Museum of Lugano.

In order to describe the response of forest habitats to fire, the study focused on the abundance of species, post-fire succession of dominant and subdominant species, and analysis of post-fire successional species strongly associated with particular fire regimes (differential species).

RESULTS

Species richness

A total of 143 spider species and 10196 individuals were collected. Of these, 64 species (46% of the total) were represented by less than 5 individuals, and 39 species (28%) were observed at only one study site.

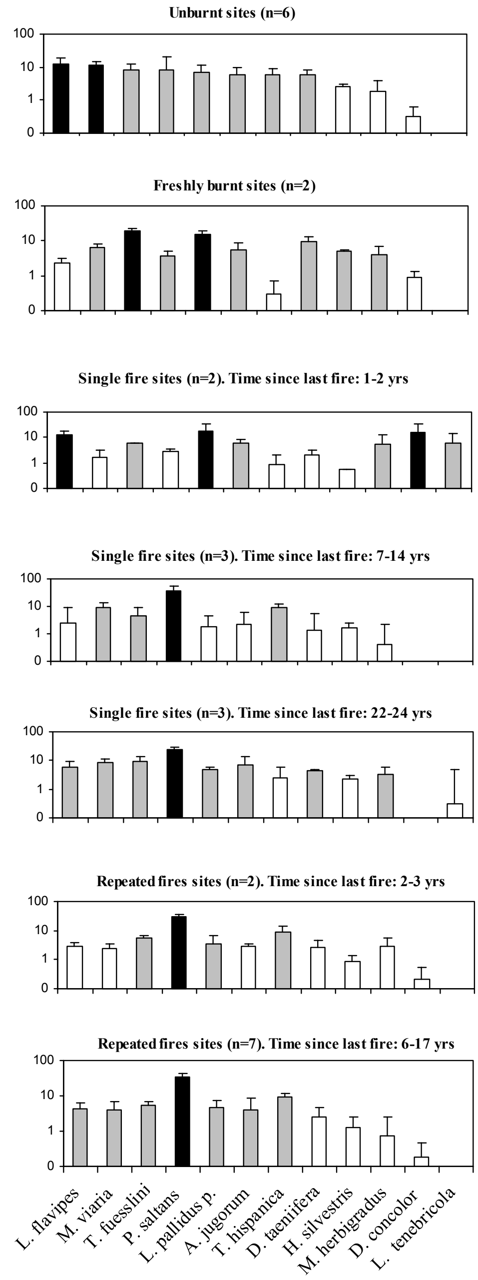

Fig. 3. Relative dominance (%) of spider species at study sites belonging to different classes of fire-regimes. Dominant species (>10%; black bars), subdominant species (3.2-9.9%; grey bars) and recedent species (<3.2%; white bars). The species follow the dominance gradient of the unburnt sites.

Table 1. Number and percentage of species associated with particular fire regimes and of those which were found in all types of study sites. For each category of fire frequency six study sites were selected (except for the two only freshly burnt sites available).

	Control n = 6	Freshly burnt n = 2	Single fires n = 6	Repeated fires n = 6
Exclusive species of the unburnt sites	8 (7%)			
Exclusive species of the burnt sites		1 (1%)		
			20 (16%)	
				43 (35%)
		7 (6%)		
Species which were found in all types of study sites	64 (52%)			

Species richness at single fire sites was similar to values encountered at unburnt sites, while at repeated fire sites, species richness was found to be significantly higher (Fig. 2A). Elapsed time since the last fire had a considerable effect on the number of species found. At freshly burnt sites the number of species decreased but changes were not significant (Fig. 2B). On the other hand, in instances of single fires, this initial decrease was followed by a gradual increase, leading to a significantly higher number of species after 22-24 years. At repeated fire sites, there were no significant trends in species richness with respect to the time elapsed since the last fire.

Species structure of the community

Fig. 3 summarises some important differences in dominant and subdominant species composition in relation to fire regime. On unburnt sites, *Lepthyphantes flavipes* and *Microneta viaria* were the dominant species (dominance > 10%), and *Tegenaria fuesslini, Pardosa saltans, Lepthyphantes pallidus, Amaurobius jugorum, Trochosa hispanica* and *Dasumia taeniifera* were subdominant (dominance 3.2-9.9%). On freshly burnt sites, *Lepthyphantes flavipes* and *Microneta viaria* decreased considerably, while *Tegenaria fuesslini* and *Lepthyphantes pallidus* became the dominant species. *Lepthyphantes flavipes* continued to be dominant 1-2 years after a single fire, and *Lepthyphantes pallidus* and *Dyplostyla concolor* increased considerably in abundance, while the number of *Microneta viaria* declined sharply during this period. After 7-14 years, *Pardosa saltans* became strongly dominant at many single fire sites (dominance > 32%). In contrast, on recurring fire sites, *Pardosa saltans* became the dominant species after only 2-3 years, and remained dominant for 6-17 years.

Differential species

Table 1 shows that approximately 30% of all recorded species were found exclusively on burnt sites. The analysis yielded a mean number of 43 species (35%) confined exclusively to repeated fire sites, compared with only 8 species (7%) found exclusively on unburnt sites; 64 species (52%) showed no differences in distribution. Some of the species which were strongly associated with particular fire regimes are listed in Table 2.

DISCUSSION

There have been numerous studies on the effects of fire on epigeic and soil fauna. They vary greatly in sampling methods and other factors such as habitat conditions, time of study, fire regime and size of burnt areas. Consequently, caution is necessary when making direct comparisons between the present and past studies.

As far as the post-fire succession of spiders is concerned, in contrast to Huhta (1971), Merrett (1976), Schaefer (1980), and Koponen (1993, 1995), no evidence was found of pioneer species colonising study sites for limited periods after a fire. Although the abundance of dominant and subdominant species of unburnt sites decreased after a fire, most of them maintained an impor-

Table 2. Species and number of sampled individuals associated with particular fire regimes. For each category of fire frequency, six study sites were selected (except for the two only freshly burnt sites available).

	Species	**Control** (n = 6)	**Freshly burnt** (n = 2)	**Single fires** (n = 6)	**Repeated fires** (n = 6)
Selected exclusive species of the burnt sites	*Walckenaeria furcillata*				**5**
	Haplodrassus signifer				**6**
	Zora silvestris				**7**
	Trochosa terricola				**35**
	Zelotes erebeus				**14**
	Episinus truncatus			**2**	**4**
	Cercidia prominens			**1**	**5**
	Trichoncus cf. sordidus			**1**	**32**
	Hahnia ononidum		**4**		**10**
	Meioneta gulosa		**1**	**1**	**28**
Selected species which 'profit' from the fire	*Poecilochroa conspicua*	1		2	**4**
	Alopecosa pulverulenta	2		1	**7**
	Centromerus sellarius	1		3	**8**
	Walckenaeria mitrata	1			**11**
	Zelotes apricorum	1		4	**19**
	Zodarion gallicum	14		6	**25**
	Micaria fulgens	6		5	**79**
	Callilepis nocturna	1	1	1	**11**
	Gnaphosa bicolor	9	2	7	**35**
	Hahnia helveola	14	14	31	**29**
	Xerolycosa nemoralis	7	10		**43**
	Zora spinimana	4	2	2	**43**
	Pardosa saltans	262	13	260	**996**
Selected species 'affected' by fire	*Ballus chalybeius*	**24**		2	9
	Coelotes mediocris	**75**		11	50
	Tapinocyba maureri	**105**	1	55	4
	Lepthyphantes flavipes	**214**	8	80	132
	Micronetа viaria	**217**	22	105	138

tant position in the community. One possible explanation for the in situ survival of many species is that fires do not usually burn the fuel uniformly (Marxer & Conedera 2000), leaving some pockets under stones, logs, or surface tree roots where individuals of many species can survive (Huhta 1971; Merrett 1976; Riechert & Reeder 1972). It seems possible that post-fire succession is mainly determined by altered habitat conditions and through post-fire environmental variations at the epigeic level (Pyne et al. 1996).

On the whole, spider communities of single fire sites tended to return to the pre-fire species composition and structure over a relatively short period (within approximately 7 years). This is especially true for the Linyphiidae, a family characteristic of intact forests (Uetz 1975, 1979; Bultman & Uetz 1982; Leclerc & Blandin 1990). The rapid recovery is probably due to resprouting of chestnut stools (Delarze et al. 1992; Hofmann et al. 1998) resulting in accelerated restoration of the litter layer.

In fire ecosystems resident communities are sometimes significantly different from those in surrounding unburnt areas, enhancing biodiversity in the region as a whole. In ecosystems where fires are frequent, spider and other arthropod communities seem to be adapted to recurrent events of low to medium intensity (e. g. Riechert & Reeder 1972; Force 1981; Weaver 1985; Siemann et al. 1997; York 1998). Nevertheless, Springett (1976) and York (1998) pointed out that in frequently burnt dry sclerophyll forests of Australia, many native forest species are lost and may be replaced by species associated with more open habitats.

In our study, the species strongly associated with particular fire regimes (differential species), especially those found almost exclusively in frequently burnt sites, are characterized by being able to live under a wide diversity of environmental conditions, ranging from humid to extremely xeric habitats. On the other hand, no 'forest species' was lost. This diversity could be explained in terms of an increase in habitat structural heterogeneity, where characteristic elements of both sparse and dense vegetation occur in close proximity, providing a rich mosaic of microclimatic conditions. This heterogeneity provides a wide range of microhabitats capable of supporting a large number of species. In fact, most of the species found exclusively on burnt sites are associated with open, dry conditions such as grasslands and exposed rocky habitats (Maurer & Hänggi 1990; Hänggi et al. 1995).

In conclusion, our results show that spider communites of unburnt sites in Southern Switzerland are mainly dominated by litter-dwellers. Species richness of sites that have experienced only a single fire is generally similar to that of unburnt sites. On the other hand, sites with recurring fires tend to have larger numbers of species and a characteristic species composition which differs from that of unburnt and single fire sites. However, the relatively high abundance of *Pardosa saltans* in intact forests shows that communities present in fire-free forest sites, which have not burnt for at least 30 years, are pre-adapted to disturbance. This confirms the hypothesis that spider communites in chestnut forests of the Southern Alps have been strongly conditioned by fire history and human activites such as coppicing. From the paleo history of fire we know that in Southern Switzerland this kind of disturbance has existed since the Neolithic period (Tinner et al. 1998).

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