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Impact of prescribed burning on soil organism communities in a *Pinus laricio* forest.

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Abstract

The objective of this preliminary study is to highlight the potential impacts of prescribed fire on soil organism communities in Pinus laricio forests, a species endemic to Corsica. For this purpose, a control plot, and a plot burned on 10th November 2020, were delimited in Bavella (South Corsica). The intensity of the burning was characterized using K-Type thermocouples at different depths in the soil. Soil organisms were collected with pitfall trap and Berlèse method, then identified to the order. Results show a decrease of all orders on the burned plot, with important potential of survival of the organisms in the soil, since heat transfer is weak (+10°C max at 3cm depth) and the burned surfaces heterogeneous. A rapid recolonization is indeed observed in the spring. The contribution of organic matter, minerals, and free ecological niches could encourage this phenomenon.

In order to better understand the heterogeneity of the plots and to highlight the specificities of Pinus laricio forests, a study at the sub-plot level is in progress, as well as an identification of organisms up to the family level.

1. Introduction

In the Mediterranean Basin, forest fires are a recurrent problem. Pines are particularly affected by wildfires, they account for a large proportion (> 2/3) of the total burned areas (Pausas and Vallejo 1999; Quézel and Médail 2003). In Corsica, the most represented pine species is *Pinus nigra* subsp. *laricio* (Poir.) Maire var. *corsicana* (Loudon) Hyl. The development of these ecosystems takes place between 900m and 1800m altitude (Gamisans, 1999); hard to reach and steeply sloping terrain make it difficult to manage and protect these sensitive habitats using mechanical methods. Reintroducing fire into ecosystems through prescribed burning (Fernández et al. 2013) is time saving and allows to circumvent logistical and cost constraints. It removes hazardous understory flammable materials and creates more spatial variability in the structure of the forest (Fulé et al. 2004). Some studies have provided answers on the resistance of *Pinus laricio* to prescribed burning (Cannac et al. 2007, Ferrat et al, 2021). However, the effects of these prevention techniques on the ecology of a forest soil have been little studied.

A cascade of trophic interactions between microorganisms, detritivores and predators (Hunter et al. 2003; Santonja et al. 2015) allows the decomposition of organic matter (Aubert et al. 2010), soil regeneration, and nutrient recycling.

Fire can change the physical nature of the soil (grain size, permeability), but also its chemical quality through ash input (mineralization of organic matter, nitrogen input, pH change ; Shakesby et al. 2015). These modifications can destabilize the balance of the environment, and influence the recovery of the communities of organisms living in the soil (Wikars and Schimmel, 2001).

This study has several objectives:

- A preliminary characterization of the soil organism communities in a *Pinus laricio* forest, little studied so far, under different types of micro-habitats.
- Characterization of prescribed burns intensity and heat transfer in the soil
- Highlight the potential impacts of prescribed burns on the soil fauna

2. Material and methods

The study was carried out in a pure stand of *Pinus laricio* located in Bavella, South Corsica, France (9.224334740328 ; 41.791482512769) at 1218 m above sea level. This forest, managed by the French Forest Office, has been thinned and pruned, leaving an important and heterogeneous amount of branches and trunks on the soil, with a consistent needle litter. Trees are about 30 years old, the average tree height and DBH are 12.72m and 18.12cm respectively. The understory is absent, the herbaceous layer is mostly represented by *Brachypodium pinnatum* (L.) P. Beauv. and the moss is present discontinuously. The slope is about 20% with a west aspect. The site is submitted to supramediterranean climate, with hot summers and mild winters (mean annual temperature : 10,1°C ; min : -7°C ; max : 26°C, 620 mm total precipitation in 2020).

The stand is divided into both 25 m² control (CP) and burned (BP) plots. Each plot is subdivided into 16 subplots of about 6.25 m².

The prescribed burning was carried out on 10th november 2020 by trained forest managers. Temperature measurements were performed for different fuel configuration (litter, branches and trunk from thinning residues) at the surface and at various depths (under litter and – 3 cm) in the soil using K-type thermocouples. Measurements of the different fuel biomass and surface (grass, litter and thinning residues) was realized before and after burning.

Soil fauna was sampled prior to burning, then one week and 4 months after burning, using pitfall traps positioned on all subplots. Pitfall traps allow the study of all organisms present in the litter and humus (macrofauna and mesofauna). Spot corings (5cm*5cm*5cm) in different micro-habitats (moss, moss + litter, litter) followed by extraction with Berlèse (Berlèse, 1905) were also performed just before, and after burning, then one month post-burning, in order to study the mesofauna of humus and soil. Collected organisms are quantified and identified to order.

3. Results

The maximum temperatures were recorded at the litter surface (674–1007 °C), and the average flame residence time (duration of exposure to temperatures > 300 °C) was in the range of 25–173 s. The heat was very little transferred from the litter to the humus (+ 10.08 °C maximum). A typical example of temperature evolution is presented in Figure 1 for litter and branches configurations.

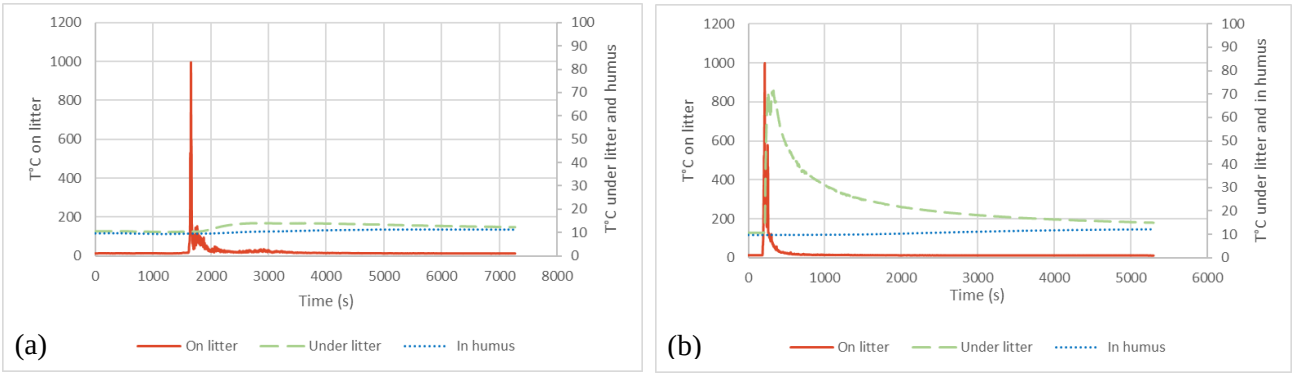

Figure 1- Temperature monitoring at different depths during prescribed burning, (a) under litter and (b) under a pile of branches.

90% of the litter, and particles smaller than 3mm (branches, herbaceous stratum) were heterogeneously removed by the burning. In contrast, larger diameter particles were not removed (Figure 2).

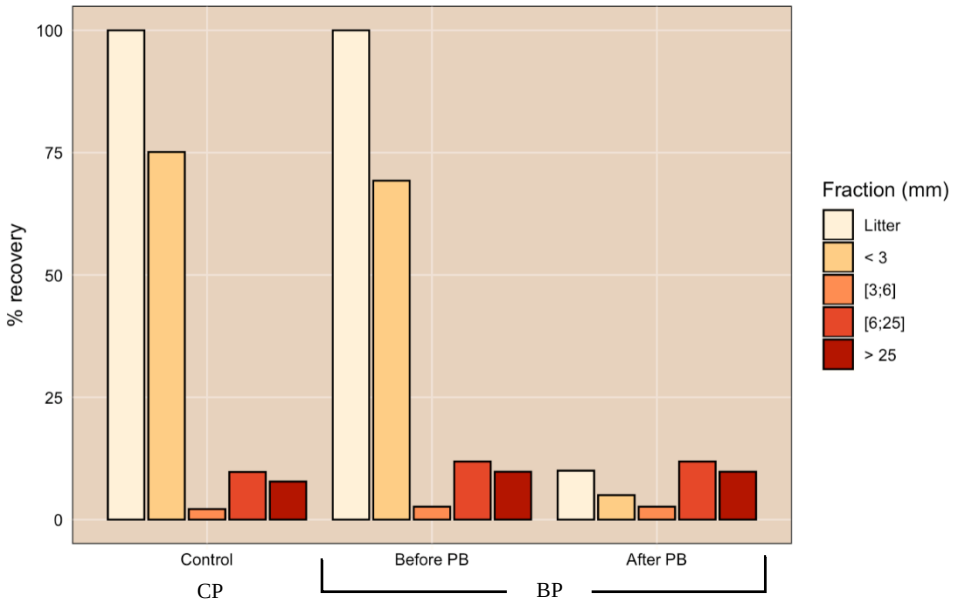

Figure 2- % plot coverage by fuel type (<3: particles less than 3mm in diameter; [3;6]: particles between 3mm and 6mm in diameter; [6;25]: particles between 6mm and 25mm in diameter; >25: particles greater than 25mm in diameter), before and after burning

20 different orders were identified within pitfall traps, all periods and all plots combined. Whatever the plot, Acari, Collembola, Diptera and Coleoptera always represented more than 80% of the total number of organisms (Figure 3). The Shannon index (Shannon & Weaver, 1949) was initially 2.15 for BP and 2.46 for CP. Abundance in the subplots was highly variable, from from 56 to 283 organisms for BP and 30 to 144 organisms for CP.

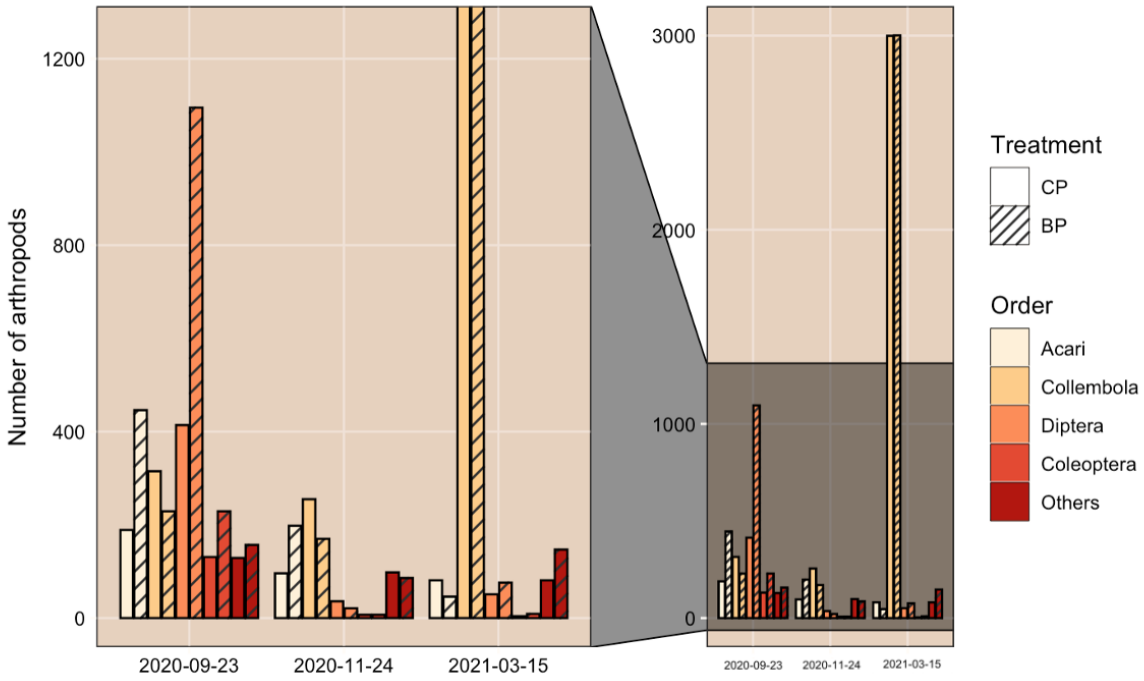

Figure 3- Total count for each order at different dates, collected by Pitfall traps (16 orders with less than 5% total count on all plots, all dates combined, were grouped in "Others")

On 09/23/2020, BP counted 2156 organisms, against only 1178 for CP. This difference can mainly explained by the abundance of diptera and acari, which are 1095 and 446 respectively for BP, and 414 and 189 for CP.

Organisms decreased by 78% after the prescribed burning in BP (482 organisms on 11/24/2020), and only by 58% in CP plot.

In spring, both plots had a similar population of organisms (3279 for BP and 3216 for CP), with a very low diversity (Shannon index of 0.64 for BP and 0.54 for CP).

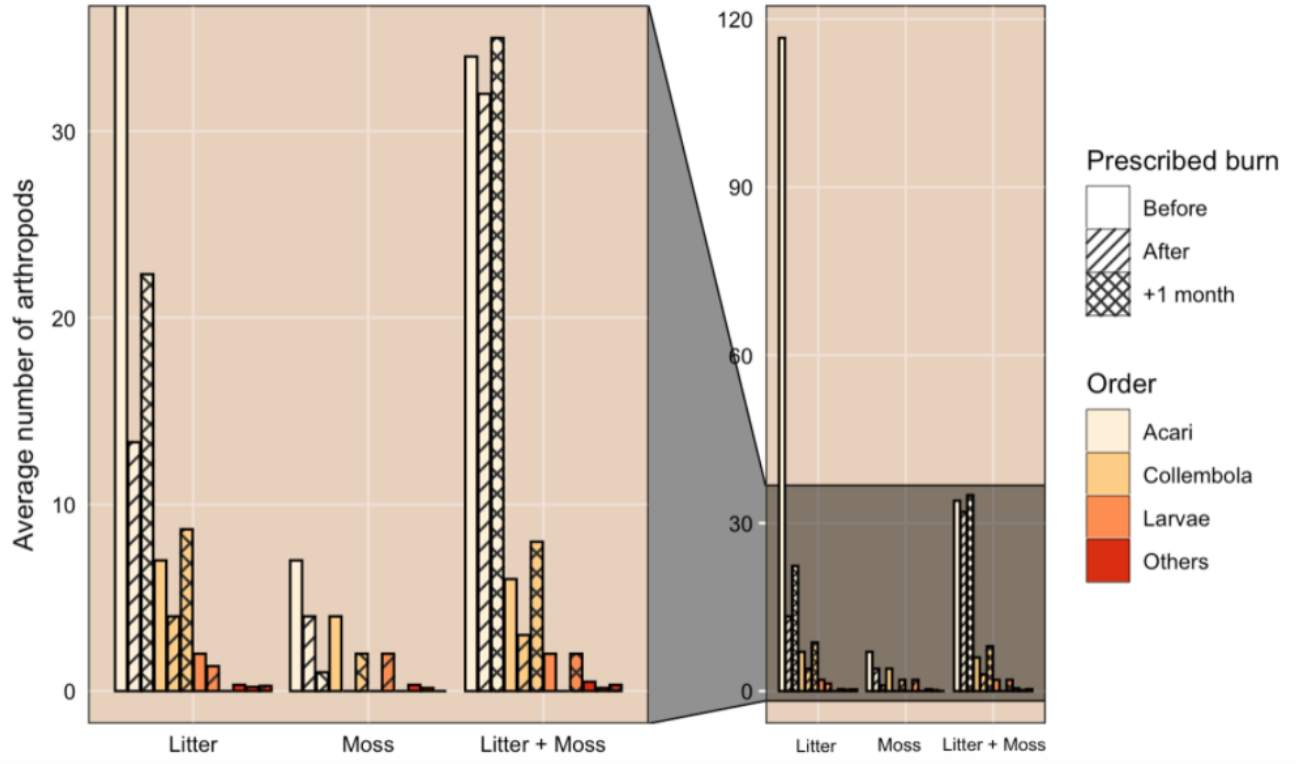

Figure 4- Distribution of mesofauna in the soil of Pinus nigra laricio ecosystems, according to microhabitat type, before and after prescribed burning.

Berlese sampling allowed to highlight the presence of 8 orders in the soil, all types of micro-habitat included. Litter had the highest total population, with an average of 130 organisms, compared to 45 in litter+moss, and 13 in moss, before burning.

Acari were in the majority, representing between 91% (litter) and 54% (moss) of the population in the samples (Figure 4). Next came the Collembola, representing between 5% (litter) and 31% of the total population. The remaining orders were very poorly represented (araneae, coleoptera, thysanoptera, hymenoptera, hemiptera and myriapoda).

The average population of the litter micro-habitat showed a decrease of 84% just after the burn. This decrease was mainly due to the loss of acaris, whose population decreased by 89%. The other orders weree present in too small numbers to show a difference in abundance.

The litter+moss microhabitat showed only a slight decrease of 20% in abundance after the burn. Moss was the poorest environment, with a very low number of organisms before the burn (13 organisms). This number decreased by 46% after the burn.

No difference in the distribution of organisms between the control and burned plots were noted. Pitfall traps and Berlèse samples showed the same trends: a decrease in total abundance after burning.

4. Discussion

Pinus laricio is a Corsican endemic species, its ecosystem is very poorly characterized.

The two types of trapping used in this study provide a preliminary overview of the communities of organisms living in these forests. The orders identified seem to fit very well with the descriptions given for the Mediterranean forests (Mantoni et al. 2020; Samain et al. 2019).

Precribed fire seems to cause a significant decrease in the population of organisms (78% for pitfall traps and 50% for Berlèse). This decrease is much greater than the one observed in the control plot (CP), which is only due to a seasonal effect. As a matter of fact, the average temperatures of November did not exceed 9°C on the pass of Bavella, which slows down biological activites (Mòron-Rios et al. 2010).

Thus, fire does not eliminate all organisms, either locally or at the plot level. Temperature measurements may partially explain these results. Indeed, the surface temperature during burning reached a maximum of 1007°C, which is totally incompatible with the survival of litter organisms. Heat transfer to the soil remained very low, since no more than a 10°C increase was measured. This demonstrates the insulating and protective power of the soil for organisms that live deeper than 3cm, which is the case for many species (acari, collembola, larvae of few Diptera and Coleoptera). Moreover, soil microarthropods can resist temperatures up to 40°C (Malmstrom, 2008) thanks to their cuticule (Moretti et al., 2006). Our finding follows the results of Uotila and Levula, 2011, who showed that the impact of fire on soil is relatively low due to its high insulating capacity.

The study of Berlèse, sampled in entirely burned areas, shows that not all microhabitats react in the same way to the passage of fire. Acari decreased in numbers under the "litter" habitat, composed of combustible pine needles. This could be explained by the fact that soil-dwelling organisms tend to occupy the surface layers of the environment. However, several studies have demonstrated the ability of microarthropods to escape deep into the soil (Certini, 2005; Gongalsky et al., 2012). The remaining organisms may have used this ability to protect themselves from the heat stress of passing through the burn. The low impact on other microhabitats (moss and moss + litter) could be explained by stronger insulation in these areas, it may be interesting to confirm this hypothesis with additional sampling.

Another important aspect of this study, which must be taken into account in the analysis of soil populations, is the evidence that BP did not burn completely during prescribed burning. The plot had about 10% unburned area. Auclerc et al. (2019), demonstrated the importance of both endogenous (i.e., surviving species) and exogenous species in recolonizing the disturbed environment. In this study, the heterogeneity of burning (a mosaïc of burned and unburned areas) could allow a very rapid recolonization of fire-affected areas, which happen to be an available ecological niche, and a source of organic matter and minerals of interest for organisms.

This recolonization is already evidenced by the spring samples (+680% in BP), wich is similar to the seasonal increase of CP (due to the recovery of biological activity, especially for springtails, whose number goes up to 3000). It must be noted that BP had almost twice the number of CP in the initial state and that this level has not yet been found.

This preliminary study clearly shows the difficulty of highlighting the effect of a prescribed burning on the dynamics of soil arthropod populations, as the heterogeneity of the plots and the conduct of a fire are important. A further study at the scale of subplots will allow to better define the heterogeneity of the plots. An identification of the organisms to the family will also highlight the specificities of *Pinus laricio* forests. Finally, to complete the study, sampling of different soil strata, treated with the Berlèse instrument, could allow a better understanding of the degree to which they are impacted by heat transfer.

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