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FIRE-SKIPS AND CARABID BEETLES OF NORTHERN ROCKIES: 'NATURAL LESSONS' FOR THE FOREST INDUSTRY

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ABSTRACT

Large-scale forestry and land-use activities may disrupt ecological and evolutionary processes and eventually alter original faunal community structure. Therefore, forest land-managers in recent years have been searching for more ecologically sound harvesting practices that may permit a sustainable timber flow. We studied ground beetles (Coleoptera: Carabidae) of 'fire-skips' in 15 and 35 year-old burned stands in the northern Rockies of western Alberta to explore how biodiversity is affected by fire. Our results indicate that fire-skips provide refugia for carabid beetles that are mature forest specialists, and promote their recolonization of burned areas. Skips may also sustain locally endemic beetle species. Forest specialist beetles are segregated based on the skip-size, although species-richness is not directly related to skip-size. Fire-skips are not only an integral landscape feature of these high-elevation pyrogenic forests, but are also important in structuring and maintaining late-successstional arthropod community structure. These findings support harvest strategies that maintain green-tree residual patches and suggest that the positioning and size distribution of such residual patches be further considered.

INTRODUCTION

A significant portion of the boreal and montane forest in Alberta is slated for timber harvest and artificial reforestation in the next 50-60 years (Pratt and Urquhart, 1994; Urquhart, 1998). Increasing forest development has caused widespread concern over the fate of the local biological communities that have emerged since the last glaciation. Wilson (1992) argues that biological diversity is the thin fabric of life that clothes an otherwise hostile and inhospitable environment. The complex web of ecological processes and patterns that exists today, is woven by the interactions of local organisms and their habitats over an evolutionary time. Present day forestry depends on the resulting sequestration of nutrients and its conversion into standing fiber biomass (trees).

Sensible and sustainable forestry should ensure that processes that produced today's economic bonanza of fiber are maintained and renewed through management. Because we know so little about the relevant processes, land managers are adopting a risk minimization strategy that seeks to maintain the biotic elements that characterize healthy, unharvested forests (see Spence *et. al.*, 1999). Under the 'natural disturbance paradigm', a fundamental organizing principle of the SFM-NCE, it is argued that faunal communities existing in our northern forests are adapted to disturbances such as fire, windthrow and pest outbreaks and therefore, their natural dynamics are resilient to such events. If harvesting can be made

equivalent to natural disturbance, the resulting landscape patterns could contribute to the conservation of biodiversity and the ecological processes within the forest.

The matter of emulation is being pursued by work such as the EMEND project (Spence *et. al.* and Volney *et. al.*, this volume). In order to understand fire-effects and key elements that can be emulated, we have studied ground beetles (Coleoptera: Carabidae) in natural burns and 'fire-skips' (residual patches of forest) of high elevation coniferous forests of the Rocky Mountains. We hypothesize that fire-skips act as habitat reserves for beetles specializing in old growth and mature forests, and promote natural recolonization of the burned forest. We chose carabids as our study organisms because they are well-known taxonomically, are abundant, could act as potential indicators (McGeoch, 1998) and are easily sampled in pitfall traps. Also, specific inferences about landscape distribution patterns can be made for many species because their natural history and microhabitat requirements are relatively well known.

Specifically, our research objectives were the following:

(1) To determine whether fire-skips act as habitat reserves for mature forest specialists;
(2) To elucidate possible edge effects between unburned and the burned forest, and fire-skips and the burned forest that are significant for our model taxa;
(3) To determine whether skip-size has any significant effect on the composition of the beetle fauna that inhabits them.

METHODS

Study Sites

We sampled a 15-year-old burn (Hat Creek Fire) in 1997 and a 35-year-old burn (Sheep Creek Fire) in 1998, both in the Weyerhaeuser Canada, Grande-Prairie-Grand Cache Forest Management Area. Both burns are located north of Grande Cache, southwest of Grande Prairie, in sub-alpine and lower montane zone, dominated by lodgepole pine, sub-alpine fir, black spruce and engelmann spruce. We compared results from two ages of recovering forest to provide data about the rates of change in species richness and abundance in fire-skips, the burned forest, and adjacent unburned forest. In each study area, 8 skips of varying sizes ranging from less than a hectare to 10 hectares were sampled.

Trapping Methods

Pitfall traps (Spence and Niemelä, 1994), set along transects were used to sample carabids. Sampling design was kept consistent for both the study areas. Transects were separated by 150-200m to insure independent samples. In each study area, two transects, each consisting of 6 traps separated by 50m were placed in the mature forest and the burned forest while variable number of traps were used in fire-skips depending on the skip size. To address edge effects, two transects of 11 traps each were placed in each study site. A trap was placed on the edge, one trap each at 5, 10, 20, 40 and 80m into the unburned forest and into the burn. Similarly, edges of 8 skips in each study site were sampled with traps placed in a similar geometric fashion into the burned forest and into the core of fire- skips. We also conducted vegetation sampling around each pitfall trap to assess habitat heterogeneity.

Traps were operated from June to August and were emptied approximately every 12 days. Samples were sorted, beetles pinned, labeled and identified to species-level using the available literature and reference collections at the Strickland Museum, University of Alberta and Northern Forestry Center in Edmonton.

Data Analysis

Species abundance data was standardized to 100 trap-days to account for different trapping effort in the three forest types. Rarefaction was used to estimate species richness in a way that controls for overall sample sizes (Krebs, 1989). Non- parametric tests (Mann-Whitney U test, Kruskall Wallis test) were used to compare differences in species abundance. Bray-Curtis similarity measures were used to compare carabid communities, and regression analysis was used to assess species- area relationship for fire-skips.

RESULTS AND DISCUSSION

Characteristics of 'fire-skips'

Fire-skips are cool, moist patches of forests left after a wildfire. In these high-elevation coniferous forests, skip overstories are dominated by fir and spruce and forest floor by mosses and *Equisetum*. Tree-coring in the Sheep Creek burn revealed that the average tree-age in the fire-skips is approximately 180 years with the oldest tree being over 300 years. In contrast, the average tree-age in the unburned forest is 70 years, suggesting that these fire-skips patches have survived at least one fire-cycle and are a non-random, semi-permanent part of the pyrogenic landscape. Hence, fire-skips are old-growth forests in the strictest sense.

Arthropod Community Structure

We collected about 2,000 carabids representing 31 species. In both the study areas, species richness was highest in the burns and lowest in the mature forest. Species abundance patterns, which generally followed the log-normal model, revealed that skips had the highest beetle abundance, followed by mature forest and burned forest. Species richness is highest in the burned areas because of influx of carabid species characteristic of open-habitats. However, low abundance of open-habitat species in the 15 year-old burn indicates that they are unable to establish large populations. Even in the forest habitat of the regenerating 35 year-old burn, open-habitat species are rare, but there has been extensive recolonization of the burn by the mature forest specialists. In contrast, in a study done by Niemelä *et. al.*, (1993) in low-elevation coniferous forests around Hinton, open-habitat specialists increased in abundance in regenerating stands, even 30 years after harvest, and mature forest specialists were virtually absent in the harvested blocks.

We used Bray-Curtis similarity indices to look at the overall community structure in all the forest types (Figure 1). Carabid communities in the fire-skips of the two different aged burns are most similar to each other, followed by those of the mature forest communities. This suggests that fire-skips are left in similar habitats by fires that occur in similar ecological zones. The faunal community of the 35 year-old burn is closer to the mature forest suggesting temporal recolonization from the mature forest. The beetle assemblage of the 15 year-old burn is least similar to the rest of the forest types and seems to reflect colonization of species with high dispersal ability from elsewhere on the landscape.

Mature Forest Specialists

We define mature forest specialists as species that have particular microhabitat requirements, are dominant in mature unburned forest (in this and other studies), and are negatively affected by disturbances (Spence *et. al.*, 1996). We expected such forest specialists would be absent in the15 year-old burn because of the recent disturbance, but expected to encounter some in the 35 year-old burn. *Calathus advena* and *Nebria crassicornis* fit the above criteria; they are present in the mature forest and are absent in the 15 year-old burn. Both of these species were also collected in the fire-skips in burns of

both ages. This suggests that fire-skips do act to some extent as habitat reserves for mature forest specialists that recolonize the burned areas by 35 years after disturbance.

Pterstichus empetricola, a northern parthenogenetic species, was found both in the skips and in the surrounding burned forest around the skips. Since this species was formerly thought to be restricted to high latitude cold habitats, its presence in the cool, moist fire-skips suggests that skips also act as reservoirs for species with highly specialized habitat requirements. Thus, populations surviving fire-associated disturbance in skips may be essential for recolonization of the burned forest.

Edge-Effects

Although there has been some research about invertebrate responses to harvest edges (Spence *et. al.*, 1996), the implications of natural edges between fire and unburned forest have not been well studied. We studied two types of edges: between the fire and the old-growth forest, and between the skips and the burned forest. Both of the forest specialists seem to recolonize little from the adjacent forest in the 15- year-old burn, instead, most of the recolonization seems to take place from the skips. This scenario changes in 35 year-old burn in which *N. crassicornis* seems to recolonize from the skips while *C. advena* primarily from the adjacent forest. Thus, both adjacent forest and skips play an important role in faunal regeneration of the burned forest with time.

Clustering of edge assemblages according to Bray-Curtis Similarity indices showed that all habitat edges in the 15-year-old burn were similar (Graph 2). The carabid assemblages of skip edges of the 35 year-old burn clustered closest to the edges of the 15-year-old burn, suggesting that these assemblages retain their integrity with time. Burn and forest edges of the 35-year-old burn clustered out together suggesting that with time these edges break-down and become more permeable.

Species-Area Relationship

There is no overall relationship (p-value = 0.27, d.f. = 15) between carabid species richness and skip size. Contrary to predictions that commonly flow from Island Biogeography Theory (MacArthrur and Wilson, 1967), species richness does not increase with the size of the skips. However, our data suggests that mature forest specialists are segregated based on the skip size. *Calathus advena*, the dominant mature forest specialist was found mainly in the smallest skips, while *Nebria crassicornis* was restricted to the largest skips. The abundance of these two species are negatively correlated, suggesting that the hypothesis that inter-specific interactions like competition or intraguild predation are intensified in these areas (see Currie *et. al.*, 1996 for evidence of such effects in carabids).

CONCLUSIONS & RECOMMENDATIONS

Results from this preliminary analysis of our data suggest implications for forest management. Clearly, our results show that fire-skips are important biotic storehouses of mature forest specialists and old-growth species. Skips also promote faunal recolonization of the burned forest areas by terrestrial insects. A surprising finding is that carabid species are segregated in fire-skips, based on skip size. Thus, it appears that wet patches of forests of varying size left on harvested blocks will allow survival of forest beetle species and may promote eventual recolonization of regenerating blocks. In view of the contrast between the results presented here and those of Niemelä *et. al.*, (1993), more work should be done to understand why harvested blocks are not recolonized in the latter study. For high elevation forests of the Alberta foothills region, the present study clearly suggests that a significant

proportion of wet forest patches dominated by fir and spruce within a surrounding pine forest matrix could be profitably left as reserves for forest invertebrates.

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Figure 1. Cluster analysis of Bray Curtis similarity index for carabid communities of fire-skips, burned forest and the unburned mature forest. '15' refers to the 15-year-old study site and '35' refers to the 35-year-old study site.

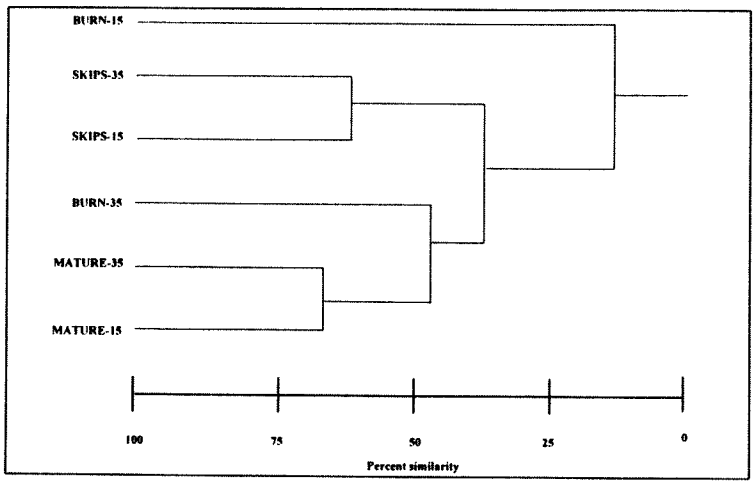
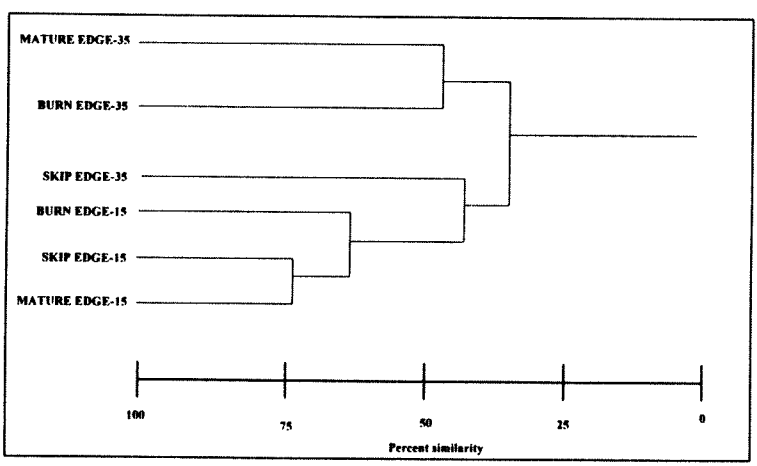


Figure 2. Cluster analysis of Bray-Curtis measures of percent similarity for carabid communities collected at skip/burned forest edges and mature/burned forest edges in 15 and 35 year-old burned forest.



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