Foothills Model Forest Chisholm-Dogrib Research Initiative
Year 1 Progress Report

Project title: Cumulative effects of wildfire and harvesting on the diversity and stability of saproxylic beetle assemblages

Applicants: T.P. Cobb[1], J.R. Spence[1], and D.W. Langor[2]

[1] Department of Renewable Resources
Faculty of Agriculture, Forestry & Home Economics
University of Alberta, 442 Earth Sciences Building
Edmonton, AB
T6G 2E1

[2] Natural Resources Canada
Canadian Forest Service
Northern Forestry Centre
5320 – 122 Street
Edmonton, AB
T6H 3S5

Project Contact: Tyler P. Cobb
Phone: (780) 492-6920
Fax: (780) 492-1767
Email: tcobb@ualberta.ca

Cumulative effects of wildfire and harvesting on the diversity and stability of saproxylic beetle assemblages

T.P. Cobb, J.R. Spence, and D.W. Langor

Background

In addition to industrial forest harvesting, disturbances, such as wildfire, continue to play a dominant role in shaping the forest landscape (Schneider 2002). Despite rigorous fire fighting and suppression efforts, large-scale wildfires still result in substantial economic losses to the forest industry. In Canada, for example, forest fires account for an average annual loss of 70 million m^3 of wood, which has an estimated value of $1 billion (Canadian Council of Forest Ministers 2000). These stark facts prompt some to speculate that there is no need to worry about maintaining a natural succession of post-fire communities, but the issue is more complicated than first meets the eye. Post-fire salvage logging is now commonly used to recover some of the economic value lost to fire. Few guidelines exist for the management of this practice because little is known about the ecological consequences of altering early post-fire successional habitats. In addition, the effects of combining wildfire with other forest disturbances, like harvesting, remain equally unclear. Thus, in order to achieve goals for biodiversity conservation and sustainable forest management, we need to know more about the individual and combined effects of wildfire and various harvesting practices on boreal forest communities.

In this study, we are exploring the individual and combined effects of fire and harvesting on saproxylic beetle assemblages. Saproxylic beetles are species that are associated with dead and decaying wood (Speight 1989), and previous research has demonstrated that many species in this group are particularly sensitive to forest disturbances (e.g., Siitonen and Martikainen 1994, Käila *et al.* 1994, Siitonen 2001). In northern Europe, for example, more than a thousand saproxylic beetle species are known to depend on coarse woody debris (CWD) (Ehnström 2001), and the loss of this substrate from managed stands has already resulted in the extirpation of several red listed species (Siitonen and Martikainen 1994). Moreover, several saproxylic species are also known to be pyrophilous which means that they are attracted to burned trees (Evans 1971, Holliday 1992) suggesting that this group may particularly sensitive to post-fire salvage logging.

Hypotheses

Our work is structured through pursuit of the following hypotheses:

- Natural disturbances (e.g., wildfire) affect stability (resistance, and resilience) of saproxylic beetle assemblages less than do anthropogenic disturbances (e.g., harvesting).

- The combined effects of forest harvesting and wildfire are cumulative.

• Wildfire and harvesting, alone or in combination, differentially affect key habitat parameters (e.g., amount of fine and coarse woody debris).

• A significant relationship exists between key habitat parameters and saproxylic beetle communities such that management of these parameters can be used to mitigate the effects of various harvesting procedures on saproxylic beetle communities.

Work Completed 2002-2003

Site selection and experimental design

During the summer of 2002, we set up a replicated, 2-factor (cover type vs. stand treatment), stand-level experiment in and around the ca. 120,000-ha Chisholm Fire that occurred 24 May to 4 June, 2001 near Chisholm, AB (ca. 200 km northwest of Edmonton). For this experiment, a total of 31 sites were selected from 5 stand treatment categories within spruce dominated (SP) and mixedwood (MX) forest cover types. The specific stand treatments are as follows:

1. Green (GRN) - 7 control sites, undisturbed by fire or harvesting in >100 years;
2. Burned (BRN) - 6 sites burned during the Chisholm fire;
3. Harvested (HAR) - 6 sites clear-cut logged in 2001;
4. Salvaged (SAL) - 6 sites burned during the Chisholm fire and then salvaged logged in 2001; and
5. Burned after harvest (BAH) - 6 sites clear-cut logged in 2001 and then burned during the Chisholm fire.

* *Note that sites were simply not available for two stand treatment categories outlined in the original proposal (double burn and burned after harvest 1998) and have consequently been removed from the design.*

Site selection was conducted using forest inventory maps followed by extensive ground verification and was completed by 30 May 2002. For each stand treatment category, we chose 3 sites in each of the two cover types. An additional GRN MX site was added to increase the range of natural variability for the control treatment. Wherever, possible sites were selected in conjunction with the soil-nutrient study being conducted by Dr. Barb Kishchuck (Canadian Forest Service) and the bryophyte study being conducted by Mike Simpson (University of Alberta) to facilitate the pooling of resources with respect to data collection as outlined in the original proposal. The exact locations of all sites and overlap with these other two projects are given in Table 1.

Beetle sampling

At each site, we established one permanent sample plot (Fig. 1). Saproxylic beetles were sampled from June 1, 2002 to August 30, 2002 using window traps (196 total) placed on standing trees (or snags), downed logs, or stumps. Total sampling effort was 14,048 trap-days which resulted in the total collection of 9,818 beetles. Initial sorting and cleaning of these samples was completed by February 2003 and species level identification is currently underway. So far approximately 10% of the total this collection has been identified and has yielded 61 species from 15 different families (Appendix A).

Preliminary analysis of total beetle abundances (Fig. 2) revealed significant differences between stand treatments (2-way ANOVA; $F_{4,161} = 17.96$, $p < 0.001$) with harvested sites having the highest abundance, while the effect of cover type ($F_{1,161} = 0.96$, $p = 0.329$) and the interaction between cover type and stand treatment ($F_{4,161} = 0.491$, $p = 0.742$) were not significant. Diversity and species composition data will not be calculated until all specimens are identified.

Environmental Variables

Collection of all environmental data was completed by mid September 2001 and is currently being analyzed. Detailed field surveys were conducted to determine the amount of coarse (>5 cm diameter) and fine (<5 cm diameter) woody debris, understorey plant species richness, % vegetative cover, % litter, and % bare ground. In addition, max/min temperature, soil moisture, and precipitation were measured at all sites on a biweekly basis. Ultimately, these data will be used to assist in interpretation of variation in beetle species abundances as well as provide a backdrop to assist with the interpretation of information obtained by the other FHMF-funded studies being conducted in the area (Table 1).

Coarse Woody Debris:

Mean volume of coarse woody debris (CWD, Fig. 3) was estimated for each site through a collaborative effort with Dr. Barb Kishchuck (CFS). Specifically, we recorded the diameter and length (or height) for all pieces found within two 5m - radius plots centred on 2 of the 4 window trap stations at each site (Fig. 1). Each piece (n = 1479) was categorized by species, type (log, stump, or snag), decay class (1-7) and burn class (1-4) in order to characterize the CWD across stand treatments and forest cover types (Table 3). Detailed descriptions of each of these categories are given in Table 2. Although analyses of these data are not yet complete, BRN sites had the largest volume of CWD regardless of forest cover type as a result of the large number of snags created by the fire. In addition, the proportion of CWD in advanced stages of decay (decay classes 5-7) was greater in GRN, SAL, and BAH sites compared to BRN and HAR sites. Exactly what influence this pattern has on saproxylic beetle assemblages is yet to be determined.

Fine Woody Debris:

In addition to CWD, we also obtained stand-level estimates of the amount of fine woody debris (FWD, Fig. 4). These estimates were obtained by collecting all pieces of small (< 5 cm diameter) woody debris found within a 0.5m X 0.5m frame that was tossed a random distance and direction from the center of each plot (Fig. 1). These samples were then dried to a constant mass at 70ºC (~2weeks) and then weighed. In general, the effect of stand treatment was significant (2-way ANOVA; $F_{4,83} = 23.293$, $p < 0.001$), while there were no differences between cover types ($F_{1,83} = 0.919$, $p = 0.341$) and the interaction between stand treatment and cover type was not significant ($F_{4,83} = 0.366$, $p = 0.832$). The strong stand treatment effect can be explained by the large amount of slash (logging debris) left after harvest in the HAR sites. Interestingly, the amount of FWD in HAR sites was greater than the amount found in SAL or BAH sites suggesting that this substrate may have been consumed by the fire.

Understorey Plant Species Richness and Ground Cover:

Mean plant species richness (Fig. 5) was estimated for all sites during a single visit to each site (21 July to 8 Aug, 2001) by identifying all understorey plant species found within four 1m X 1m plots located 25m apart around the center of the main sampling plot (Fig. 1). Where possible, plant species were identified in the field using keys provided in Johnson *et al*. (1995), whereas others needed to be dried and pressed for later identification. Mean understorey plant species richness (Fig. 5) varied significantly among stand treatments (2-way ANOVA; $F_{4,114} = 22.504$, $p < 0.001$) and between forest cover types ($F_{1,114} = 13.769$, $p < 0.001$), but there was no significant interaction between these two main effects ($F_{4,114} = 1.636$, $p = 0.170$). This result was due to the fact that plant species richness in GRN sites was greater than in all other stand treatments and was also consistently greater in MX sites than in SP sites.

Within these same 1m X 1m plots we estimated the percentage cover by vegetation, litter, and bare ground (Fig 6). Although statistical analysis of these data have not yet been completed, patterns for these parameters were similar in MX and SP forest cover types, but differed between stand treatments. In general, the amount of bare ground was highest in BRN, SAL, and BAH sites, while the amount of vegetative cover was greatest in GRN sites and the amount of litter was greatest in HAR sites.

Soil Moisture and Precipitation

The amount of soil moisture (Fig. 7) and precipitation (Fig. 8) at each site were recorded during biweekly visits to each site. Soil moisture estimates were obtained by collecting a 35 cm^3 core of mineral soil and then recording the mass of that sample before and after drying to a constant mass at 70°C. Mean %soil moisture was estimated as the proportion of the total sample mass made up of water and varied significantly among stand treatments (2-way ANOVA; $F_{4,157} = 18.460$, $p <0.001$) and between forest cover types ($F_{1,157} = 6.947$, $p = 0.009$). Soil moisture (Fig. 7) was greatest in GRN and HAR sites and the lack of a significant interaction between stand treatment and forest cover type ($F_{4,157} = 0.791$, $p = 0.533$) indicated that soil moisture was generally greater in MX sites than in SP sites.

The amount of precipitation (Fig. 8) was recorded at each site using standard rain gauges mounted 1m off the ground on a stake at each site. Specifically, we found a significant stand treatment effect (2-way ANOVA; $F_{4,118} = 3.697$, $p = 0.007$), but no forest cover type effect ($F_{1,118} = 0.003$, $p = 0.957$) or interaction ($F_{4,118} = 0.879$, $p = 0.479$). HAR sites generally received more precipitation than the other stand treatments, but patterns of precipitation and soil moisture were not the same suggesting that that moisture retention differed between sites.

Temperature
We recorded maximum and minimum temperatures during biweekly visits to all sites using max/min thermometers mounted 1m off the ground on the north side of a stake at the center of each plot (Fig. 1). By subtracting the minimum recorded temperature from the maximum, we were able to monitor differences in temperature ranges at each site (Fig. 9). In general, GRN sites had significantly lower temperature ranges than all other stand treatments during the summer months which resulted in a significant stand treatment effect (2-way ANOVA; $F_{4,118} = 8.792$, $p < 0.001$). However, we found no significant difference between forest cover types ($F_{1,118} = 1.237$, $p = 0.268$) and no significant interaction between forest cover type and stand treatment ($F_{4,118} = 0.840$, $p = 0.502$). These results suggest that undisturbed sites may be buffered against the larger temperature fluctuations found in disturbed sites.

Collaboration and Integration
Several other investigations were initiated through collaborative efforts and funding from Canadian Forest Service, University of Regina, Sustainable Forest Management Network, and the Natural Sciences and Engineering Research Council (NSERC). Through a collaboration with Dr. Barb Kishchuck (CFS), we initiated a replicated mesocosm experiment aimed at identifying the importance of feeding activity of larval saproxylic beetles on burned coarse woody debris for soil nutrient input. This experiment involved manipulating the abundance of larva of the white-spotted pine sawyer, *Monochamus scutellatus* (Coleoptera: Cerambycidae) on burned spruce bolts (10cm diameter, 50cm long) held within screened enclosures at BSP1 (Table 1). Set up of this experiment was completed by July, 2002 and initial log masses, and soil samples were obtained. Soil samples will be collected again in July 2003 to examine changes in C, N, P, Mn, Mg, Ca, Fe, and pH and relate these changes to larval beetle abundance.

In addition, we also assisted with the development of summer research projects for two undergraduate students: Mr. Iain Phillips (University of Regina) and Ms. Andrea Dechène (University of Alberta). Mr. Phillips' project examined the influence of edge habitat created by post-fire salvage logging on ground beetle assemblages, while Ms. Dechène's project (funded by an NSERC Summer Undergraduate Studentship) compared saproxylic beetle assemblages between standing and fallen burned timber. All three projects are expected to continue in the 2003 field season.

Future Work
In addition to continuing beetle species identifications, collection of saproxylic beetles will continue in 2003 to monitor recovery of this community after each disturbance treatment. Field work for the 2003 season is already underway as window traps were set up April 23-26, 2003.

Both Mr. Phillips and Ms. Dechène have been re-hired to assist with the 2003 field work and will continue to work on their respective projects. However, both projects will be expanded to build on the results of the 2002 field season. Mr. Phillips' project will be expanded to include the edge effects of harvesting as well as those created by salvage logging. Ms. Dechène's project will include a life history study of a poorly understood, pyrophilous, ground beetle (*Sericoda quadripunctata*, Coleoptera: Carabidae) which was found in large numbers in the BRN and SAL sites in 2002.

As part of our ongoing collaboration with Dr. Barb Kishchuck (CFS) and Mike Simpson (UofA), we will assist with the development of an experiment to examine the effects of mosses and saproxylic species on the decomposition rate of woody debris. Discussions surrounding the details of this experiment are currently underway.

Research Goals:

<u>Short-term:</u>

Based on relationships between saproxylic beetles and key habitat parameters such as amounts of woody debris, we will provide informed recommendations for silvicultural and/or harvest manipulation that minimize the impact of post-fire salvaging on saproxylic species composition and diversity.

<u>Long-term:</u>

This research will provide much needed insight into the effects of multiple disturbances such as wildfire and forest harvesting on the stability of boreal forest communities. Such knowledge will become increasingly important as our demand for forest resources increases under various scenarios of global change.

Literature Cited

Canadian Council of Forest Ministers. 2000. State of Canada’s forests: Forests in the new Millennium. Canadian Forest Service, Natural Resources Canada, Ottawa, ON.

Ehnström, B. 2001. Leaving dead wood for insects in boreal forests – suggestions for the future. Scandinavian Journal of Forest Research Suppl. **3**:91-98.

Evans, W.G. 1971. The attraction of insects to forest fires. Proceedings of the Tall Timbers Research Station, Tallahasse, FL.

Holliday, N.J. 1992. The carabid fauna (Coleoptera: Carabidae) during postfire regeneration of boreal forest: properties and dynamics of species assemblages. Canadian Journal of Zoology **70**:440-452.

Johnson, D., Kershaw, L., MacKinnon, A., and Pojar, J. 1995. Plants of the Western Boreal Forest and Aspen Parkland. Lone Pine Publishing, Edmonton, AB, Canada.

Käila, L., P. Martikainen, P. Punttila, and E. Yakovlev. 1994. Dead trees left in clear-cuts benefit saproxylic Coleoptera adapted to natural disturbances in boreal forest. Biodiversity Conservation **6**:1-18.

Pedlar, J.H., Pearce, J.L., Venier, L.A., and McKenney, D.W. 2002. Coarse woody debris in relation to disturbance and forest type in boreal Canada. Forest Ecology and Management **158**:189-194.

Schneider, R.R. 2002. Alternative Futures: Alberta's Boreal Forest at the Crossroads. The Federation of Alberta Naturalists and The Alberta Centre for Boreal Research, Edmonton, AB, Canada.

Siitonen, J. 2001. Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. Ecological Bulletins **49**:11-42.

Siitonen, J. and P. Martikainen. 1994. Occurrence of rare and threatened insects living on decaying *Populus tremula*: a comparison between Finnish and Russian Karelia. Scandinavian Journal of Forest Research **9**:185-191.

Speight, M.C.D. 1989. Saproxylic invertebrates and their conservation. Council of Europe Publication, Strasbourg.

Stelfox, J.B. (Editor). 1995. Relationships between stand age, stand structure, and biodiversity in aspen mixedwood forests in Alberta. Jointly published by Alberta Environmental Centre (AECV95-R1), Vegreville, AB, and Canadian Forest Service (Project No. 0001A) Edmonton, AB, Canada.