Collembolan Succession and Stump Decomposition in Douglas-fir

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Introduction

Coarse woody debris (CWD) is now recognized as an important component of terrestrial ecosystems. Logs account for a major part of the CWD in virgin forests, but stumps assume this prominence in most second-growth stands. Here they provide an array of ecological functions including sites for moisture retention, N fixation, ectomycorrhizal activity, seedling of crop trees, and habitats for vertebrates and invertebrates (Setälä and Marshall 1994). Intensive forest management alters the physical nature of forests and may threaten biological diversity (Boyle 1992), especially through monoculture, whole-tree logging, slash burning, and de-stumping. The simplified ecosystem thus formed may retard nutrient cycling. Also, pests might benefit from reduced predator numbers and diseases could thrive in the absence of the fauna that consume pathogenic bacteria and fungi. Collembola, often considered members of the Apterygota or wingless insects, are among the most abundant and ubiquitous groups of soil arthropods. A few collembolan species feed on living prey, but the majority consume a host of organic materials, including dead and decaying animal and plant matter, bacteria, algae, and fungi. Collelmbola are therefore important in nutrient cycling and in controlling plant pathogens. The chronosequences provided an opportunity to study the natural succession of collembolan species during stump decomposition and allowed examination of the micro- and macro-habitat factors that affect collembolan distribution.

Methods

Three chronosequences near Victoria, BC, were selected (see Setälä and Marshall 1994): Site 1 or Greater Victoria Watershed South (plots 3, 5, 6, 8), Site 2 or Greater Victoria Watershed North (plots 11, 12, 14,15), and Site 3 or Koksilah (plots 21, 22, 23, 24). The numbering of the plots at each site follows Trofymow et al. (1997) and represented regeneration (REG), immature (IMM), mature (MAT) and old-growth (OLG) forest seres, respectively. Stumps were randomly selected and represented three stages of decomposition: stage I (sound stump wood), stage II (moderately decayed), and stage III (most of the wood soft and spongy). Stumps were sampled with a metal soil-corer and collembolans and nematodes were extracted by dry and wet funnel methods, respectively. Sampling was done in the fall, winter, and spring. Chemical analyses included the following: gravimetric moisture, total %N by modified Dumas combustion, total %C by LECO CR-12 carbon system, total P by wet oxidation and an autoanalyser, and microbial biomass by substrate induced respiration (SIR). Data analyses, mostly for decay stages II and III, included ANOVAs, canonical correspondence analysis (CCA), detrended Correspondence analysis (DCA) and various similarity indices (Setälä and Marshall 1994; Setälä et al. 1995).

Results and Discussion

No significant differences were observed between samples collected in different seasons, i.e. during fall, winter, and spring. The number of individuals was significantly smaller ($P = 0.001$) in the regeneration (REG) stand than in the forested stands (IMM, MAT, and OLG) (Table 1). The number of species per sample (not per sere) was also significantly smaller in the REG sere ($P < 0.05$). Of the 72 species found, many were not

TABLE 1. Collembolan numbers and species per sample (150 cm^3) and total number of species per sere.

	Number of Individuals				Number of species			
Site	REG	IMM	MAT	OLG	REG	IMM	MAT	OLG
1	34	119	80	76	32	37	41	45
2	72	128	164	115	34	38	40	39
3	50	119	134	140	30	31	39	33
Mean	52	122	126	110	32	35	40	39
Total number of species per sere					46	49	54	54

collected in the REG sere, but these were mostly represented by small numbers and low frequency in other seres. The majority of the species with a frequency over 50% (no. samples with a sp./total no. samples x 100) were either positively correlated with stand age or were ubiquitous. *Vertagopus alpa*, *Hymenaphorura coklei* and *Folsomia stella* tended to be abundant in OLG seres, whereas *Anurophorus septentrionalis* and *Ballistura libra* were characteristic of the REG seres. Most of the species (63.8%) were common to all sites; Renkonen's and Morisita's similarity indexes as well as DCA analysis showed that the greatest dissimilarity was between the two earliest forest successional stages of a particular site. DCA also indicated a clustering of the fauna into 'seral communities' along a line corresponding to forest succession. DCA showed that macrohabitat factors (stand age and study site) were the most important ones affecting species distribution. However, within a season, CCA ordination indicated that dominant species were positively correlated with %C, but negatively correlated with %N, %P, numbers of nematodes, and microbial biomass, suggesting that the collembolans, being heterotrophs, were not directly related to the first four factors. The microbial biomass:collembolan biomass ratio in stump wood was 21 in the forested seres. The values for the regeneration seres were substantially higher and tended to decrease with increasing stage of decomposition, giving 780, 111, and 74 for decay stages I, II, and III, respectively. The negative correlation between dominant collembolan species and microbial biomass, and the low microbial:collembolan biomass ratio compared to those for coniferous forest soils, were attributed to rapid turnover of microbes and excessive grazing on fungi by Collembola. An average well-decayed stump in the forested stands contained 48 800 specimens or about 799 843 specimens m^{-3}, giving a population density comparable to that in the soil. This large collembolan population will affect microbial populations and nutrient dynamics during stump decay. The reduction of Collembola in the REG sere most likely resulted from slash-burning, changes in fungal composition, and greater exposure to extreme weather conditions. We estimated that about 40 years would be required after clearcutting before the collembolan population regains the general characteristics of those in old-growth forests.

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