The influence of forest thinning on the landscape pattern of arthropod diversity in headwater riparian zones

A.R. Moldenke & C. Ver Linden, Department of Entomology, OSU

Research at four BLM Density Management Sites in western Oregon has documented that the terrestrial forest-floor component of headwater riparian zones is a hot-spot of arthropod diversity (Moldenke, unpub; Progar & Moldenke, 2 mss in prep.). Soil-associated arthropod diversity in the terrestrial zone immediately adjacent to the stream was nearly twice that of the upland forest floor (>25m from the riparian vegetation). Nearly all of the species characteristic of the upland forest floor occurred in equal or higher relative abundances in the immediate riparian zone; 50% of the species occurring in the riparian zone were restricted to the riparian zone. These studies supplement similar results for mammals in the Andrews Experimental Forest.

Moldenke and Progar (submitted mss) have suggested that this terrestrial riparian zone has significantly higher densities of arthropods from most functional guilds, leading to the hypothesis that headwater riparian zones provide the highest priority vertebrate habitats relative to available arthropod food resources. This broader concept also involves the arthropod fauna on shrubby vegetation as well as emergent aquatic insects from the stream itself (Miller & Hammond, 1998, 1999 & unpub.; Chen 1999 and unpub.). Nakano & Murakami (2001) have shown that in Japanese forests the diets of aquatic fish consist heavily of terrestrial insects and the diets of terrestrial birds consist heavily of aquatic insects (between 25-50% invertebrates from the opposing habitats); it is likely that the same phenomenon occurs here in the Pacific Northwest as well. Terrestrial arthropod production may play a significant role as prey in aquatic systems. Therefore it is important to document how arthropod biomass is distributed across the landscape mosaic and to what extent vertebrate predator (bird, bat and amphibian) distribution and activity could be controlled by this factor.

Tree harvest of any kind sets in motion a poorly understood cascade of predictable ecological process changes; the magnitude of these changes depends upon the degree of tree harvest. Most of the scientific information on these changes comes from classic clear-cut studies, which though no longer directly relevant, provides a useful background on which to evaluate thinning experiments (studies of Gray, Griffith et al.). Overlooking the immediate disturbance-related impacts, during the first post-cut decade, the major effects of tree removal are known to be: (1) an increase in water-availability at rooting depth due to tree root death and (2) a decrease in litter/humus moisture due to increased evaporation. It is unclear what overall effect these somewhat contrasting changes would produce on soil-inhabiting arthropods in areas subject to thinning. If thinning significantly affects arthropod density and diversity, it could subsequently result in altered vertebrate populations.

The question at these Density Management sites is whether the pulse of disturbance (i.e., thinning) is sufficient to be detected throughout the ecosystem on groups of taxa only very indirectly related to the canopy trees themselves. If that disturbance has profound effects, then the challenge is to identify appropriate indicator taxa and to document how they respond to both the altered abiotic (e.g., temperature, solar radiation) and biotic (e.g., microbial activity, root respiration) ecosystem regulators. We propose to monitor arthropod diversity and abundance at 3-4 Density Management Sites during 2002. Since current studies by Chan have shown little detectable microclimatic effects in light-thins, we do not expect any system-wide effects on arthropod or vertebrates densities (and will not attempt to document any). Heavy-thins have shown the greatest microclimatic effects, hence we expect to document changes in both arthropod and vertebrate densities there. Chan's results demonstrate little effect of moderate thinning, unless it occurs within 30m of the stream channel. If thinning does significantly affect arthropod density and diversity, it will subsequently inescapably result in altered vertebrate populations.

Relative to terrestrial arthropods specifically, thinning is predicted to have ecosystem effects both through an altered microclimatic regime and through an altered food base (ignoring localized immediate disturbance effects of being killed or having the soil compacted, which, under certain circumstances, could have significant long-lasting effects). The principal microclimatic effects should be expressed primarily through changes in soil moisture. Progressive opening of the canopy will have diametrically opposed effects on the topmost several inches of soil versus the soil at rooting depth (see Figure 1). Increasing insolation and exposure will dry the upper soil layers after the initial added debris left from thinning has decomposed; this process will be accentuated by any mechanical scarification of the insulating litter layer, as well as by the progressive decrease in the litter layer for perhaps as long as a decade (until annual leaf-drop once again equals the former rate). Even though ambient temperature at 1m height differs by only 1-3^{o}C between thinned and unthinned stands (see Chan, in prep.), soil surface temperatures in heavily thinned stands should greatly exceed that of the control stand (and the increase will be proportional to the degree of canopy removal – as soon as canopy cover reestablishes, the temperature effect on soil microbial activity will disappear). Increased soil surface temperatures will accelerate evaporation and limit surface soil microbial activity earlier in the annual drying cycle. It is the indirect effect upon the soil microbial community that will drive any significant long-term response of arthropod density and total biomass.

Deeper in the soil, at rooting depths, canopy removal should increase soil moisture significantly, since less water will be evaporated by transpiration through the tree roots. Although there may ultimately be a subsequent flush of shrubby or herbaceous vegetation, this will not significantly reduce the difference attributable to the killed trees for several years. Therefore, microbial activity should continue longer into the dry season in the moister rooting zone. Slightly elevated temperatures due to increased insolation should increase microbial activity in the rooting zone in canopy removal sites as well.

Levels of organic matter that can serve as a resource base for soil microbial activity will change as well. Most decomposition in the litter layer is fungal-based since the lack of nitrogen requires fungal hyphae to bring nitrogen to the surface. Fungal activity will be greatly increased after thinning due to the enormous volume of leaves and fine twigs added to the litter (fungi can import water to the litter from below through their hyphal connections and hence will not be slowed by a progressive litter dehydration). After the first flush that removes the labile nutrients, the rate of fungal decomposition in the litter layer will continue at a decreased level for many years until the litterfall from the newly expanding canopy equals the rate of pre-thinning litterfall.

At rooting depth, the sudden death of most of the tree roots will have an enormous effect. Most root material is not labile and will ultimately feed an enormous multi-year (decadal?) increase in non-mycorrhizal fungal activity. The mycorrhizae in small gaps, or where ericaceous shrubs abound, will retain their viability (work of Amaranthus, Perry, Griffith) but switch from primarily mycotrophic to degradative functions. One way or another, the enormous increase in rooting zone soil organic resources in thinned stands should be causally related to either an enormous increase in arthropod fungivores, predators, or both. Such postulated logarithmic increases in arthropod abundance and biomass should provide a nutritional basis for increased vertebrate activity in these thinned stands as well.

Therefore, any responses to thinning by terrestrial arthropods are proposed to be the indirect result of microclimatic shifts and are a direct link to population levels of resident vertebrates (which are either primarily insectivorous, or predators upon other insectivores). As such, this study should provide a mechanistic link between the microclimate studies of Chan and the vertebrate population studies of Olson. In order to coordinate with the forest island integrity studies of Olson & Wessell, we will focus our arthropod studies on two fronts – transects across the riparian zones into the forest proper (to document the efficacy of buffering) and transects between leave islands and the largest gaps (to test for a foodweb link between thinning and vertebrate abundance).

The primary emphasis of this study of soil-dwelling arthropods is on their trophic relations and how they might act as intermediaries between altered microclimatic regimes and vertebrate population levels. However, the biodiversity aspect is important as well. Coordination with Wessell will document the extent of faunal change between control and thinned stands. The trophic effects of arthropod biomass are undoubtedly transitory, however, the effects of altering the species composition of the forest floor community may be long-lasting. Approximately 50% of the species of arthropods that inhabit the forest floor are restricted to disturbed habitats (Moldenke, unpub; McIver, Parsons & Moldenke, 1994). Very little is known about the response of these species to different levels of thinning. It is known that many of these species which establish during disturbance are able to persist for long times under the forest canopy and hence thinning patterns may have long-lasting landscape level effects on the diversity of forest invertebrates.

Proposed Methods:

Site-selection—We propose to conduct this study at four BLM Density Management sites in western Oregon. Green Peak, Keel Mounatin and Callahan Creek are proposed due to available pre–treatment data for arthropods. However, the unique unreplicated design at Callahan Creek makes it less suitable, and would be dropped if the study were constrained by time or funds. The fourth proposed site is Delph Creek, which may be valuable as a demonstration area due to its proximity to Portland, OR. Also, Green Peak, Keel Mountain and Delph Creek provide an opportunity to integrate ongoing studies by Chan, Olson and Wessell.

With Chan, the challenge is to test whether the pre-/post-thin changes in microclimate that he has measured are sufficient to drive an ecosystem response or whether they are 'trivial'. With Olson's amphibians, if there is going to be a predictable long-lasting effect of thinning, it is far more likely (in our judgement) to be determined by a change in food availability, than in any minor change in microclimate during a time of year when the amphibians are not active anyway. With Wessell, we have the chance to actually see what the effect of openings and island diameters has on the persistence of forest-interior species; the arthropod biodiversity component of her study would not be possible without our collaboration.

If time and funding permits, this design will result in two sites in the Cascade Range (KM,DC) and two in the Coast Range (GP, CC); this is significant since previous work of Madson (M.Sci. thesis, 1997) at the "John Bailey Density Management Sites" demonstrated that the arthropod community was fundamentally more diverse in the Coast Ranges than in the Cascade Range.

Pitfall Trap Sample Design—Samples will be taken along 5 transects perpendicular to stream-flow at each site. At each site there are comparable control unthinned streams and streams with a 1 site-potential tree height riparian buffer in moderately thinned stands. Along each transect sample sites will be:

the riparian (hyporheic) zone
at the interface between the true upland forest floor and the riparian zone
in the upland forest within the riparian buffer
and at several distances within the thinned upland forest.

Sample Frequency—The soil fauna will be sampled by pitfall traps, emergence traps and Berlese funnels, which span the range of arthropod mobilities and jointly should effectively monitor the density of most of the soil fauna (Moldenke, 1994). Samples will be collected monthly from April to October. Most of the equipment is already available and will not have to be purchased.

More in-depth sampling of the microbial community correlated with the arthropods will occur at Green Peak where there is the possibility of contrasting the effect of: (1) three different riparian buffer widths within the moderate thinning and (2) gaps and leave-islands. Invertebrate activity will be examined relative to 3 environmental descriptors (soil saturation, soil microbial respiration, and soil organic matter) during bi-weekly sampling during the spring and summer seasons when moisture availability would be expected to be most variable. Soil microbial respiration will be directly measured by soda lime technique, since this rate is the regulatory link between temperature/moisture and arthropod activity. Equipment for the soda lime studies is available from previously-funded Density Management studies. Soil moisture will be assessed gravimetrically; this process will require employing a work-study student during the subsequent fall to process samples and to perform microbial biomass measurements. Soil temperature measurements will be taken with temperature probes already bought by Chan as part of this study. The in-depth portion of the research will be designed specifically to integrate with the sampling design of Stephanie Wessell.

Soil Microbial Sample Design—Samples will be taken to maximize the predicted environmental differences. Rates will be contrasted between control stands (& leave islands), moderate thin, heavy thin and the centers of the largest gaps.

BUDGET

Salaries:	
Moldenke (0.50 FTE for 6 months)	10,000
(0.25 FTE for 2 months)	1,600
Ver Linden (0.50 FTE for 6 months)	7,500
(0.25 FTE for 2 months)	1,400
Work study student (fall 2002)	2,000
	22,500
Benefits (@ 49% exclusive of student)	10,250
Field Supplies	
Travel (Gas/car rental)	550
Pitfall Equipment	50
Archiving supplies	350
Berlese equipment	50
Emergence traps	250
Soil respiration	350
Soil moisture & temperature	500
Soil organic matter	50
	2,150
Overhead (USGS rate for OSU @ 15%)	5,385
TOTAL BUDGET	40,285

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