

## Longer-term Effects of Selective Thinning on Carabid Beetles and Spiders in the Cascade Mountains of Southern Oregon

### Abstract

Within late-successional forests of the Cascade Mountains of southern Oregon, abundances of carabid beetles (Carabidae) and spiders (Araneae) from pitfall traps were compared between stands thinned 16-41 years prior and nearby unthinned stands. Species richness of both taxa were moderate for coniferous forests of this region, with 12 carabid beetle species and >120 spider species collected. No differences in total abundance or species richness were found between stand types for carabid beetles, although abundances of four of the six most common species differed significantly. *Pterostichus setosus*, the most abundant species collected, was significantly more abundant in unthinned stands, while *Omus cazieri*, *P. lama*, and *Carabus taedatus* were more numerous in thinned stands. In contrast, both total spider abundance and species richness were significantly higher in thinned stands. Hunting spiders within the families Lycosidae and Gnaphosidae, and the funnel web-building Dictynidae were captured more often in thinned stands while sheet web spiders within Linyphiidae and Hahniidae were more abundant in unthinned stands. The forest floor within unthinned stands was structurally more diverse than in thinned stands, but this did not lead to greater overall abundance or diversity of either carabid beetles or spiders.

### Introduction

Timber harvest over the past 150 years has greatly modified the structure of forestlands in the Pacific Northwest. Early- to mid-successional stands have replaced mature and old-growth forests over much of the landscape. While these younger stands provide high wood volume, they generally lack structural characteristics of mature forests, such as a multistoried canopy, large-diameter standing snags and downed logs, and a diverse assemblage of understory plant species and habitats (Franklin and Spies 1991). Concern for the survival of species dependent upon late-successional forests has resulted in the development and implementation of management plans emphasizing ecosystem integrity over much of western Washington, Oregon and central and northern California (Franklin 1993, McComb et al. 1993, Tuchmann et al. 1996). Management goals now emphasize protection and improvement of structural components critical to ecosystem function, while minimizing disturbance (USDA and USDI 1994). Within some stands, selective thinning is used to improve structural conditions and minimize the risk of wildfire. This is particularly important in stands where

low intensity wildfire, largely excluded through fire suppression, has played a role in maintaining stand structure. While efforts to conserve vertebrate species such as the northern spotted owl (*Strix occidentalis caurina*) have been high profile, much concern also exists for the long-term persistence of many other plant, fungi, and animal species, including arthropods (Moldenke and Lattin 1990, USDA and USDI 1994).

Understanding the effect of thinning on the forest floor arthropod community is of particular concern because of its role in nutrient cycling. Forest floor arthropods are diverse in both type and function, and include microbivores, fungivores, detritivores, herbivores, and predators. In terms of numbers and species diversity, this community is dominated by microarthropods, such as mites and Collembola, that primarily comprise the decomposing guild (Wallwork 1983, Seastedt 1984). Functionally, arthropod predators may be of primary importance as they can regulate populations of invertebrate consumers. Among arthropod predators, spiders and carabid beetles are particularly important because of their high abundance and ubiquitous distributions (Moulder and Reichle 1972, Turnbull 1973, Thiele 1977). Experimental manipulations of spider abundance have affected populations of fungivorous microarthropods, which in turn may influence rates of litter decomposition (Kajak 1997, Lawrence and Wise 2000). Spiders are also important predators

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of lepidopteran defoliators (Renault and Miller 1972, Mason and Paul 1988). Similarly, carabid beetles may be capable of influencing aphid (Chiverton 1986) and caterpillar (Reeves et al. 1983) populations.

Numerous studies have investigated the effects of timber harvesting on spiders and carabid beetles. Most have addressed conventional clear-cutting (McIver et al. 1992, Niemelä et al. 1993, Heliölä et al. 2001), or modifications of this practice, such as patch retention, and prescribed burning following cutting (Huhta 1971, Michaels and McQuillan 1995, Beaudry et al. 1997). Results from these studies vary, but they generally conclude that many species are affected by harvest treatments: some species increased in abundance while others decreased. These studies also show that arthropod communities change as forest succession progresses after cutting. In contrast, little work has considered how forest thinning influences litter arthropods. Because the impact of thinning on forest structure is likely less extreme than clear-cutting, it is possible that arthropods are influenced to a lesser degree as well. In a landscape scale study in Douglas-fir forests of western Oregon, Madson (1998) found no statistical differences in forest floor arthropods among old-growth, pole-sized (80 yr old) and thinned (thinned 9-23 yrs prior) stands, although, within site triads, a trend toward treatment differences was often seen. Further research is needed to better understand the short- and long-term influences of selective thinning on carabid beetle and spider faunas.

The objective of this study was to determine the longer-term effects of selective thinning of late-successional forests on carabid beetles and spiders in the Cascade Mountains of southern Oregon. To do this, we characterized habitat differences and compared abundances of these arthropods within stands thinned 16-41 years prior to adjacent unthinned stands.

## Methods

### Study Site

The study area was located within the Medford Resource Area, Bureau of Land Management, of the Cascade Mountains of southern Oregon. Sites were located within a 10 km radius of 42° 07', 122° 26'. Elevation ranged from 1092-1556 m.

Dominant overstory trees varied slightly among sites, but were primarily white fir (*Abies concolor* Lindl. ex Hildebr.) or Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), but also included sugar pine (*Pinus lambertiana* Dougl.), ponderosa pine (*Pinus ponderosa* Dougl. ex. Laws.), and incense-cedar (*Libocedrus decurrens* Torr.). Climate is affected by continental conditions of the Great Basin to the east and the wetter oceanic influences to the west, leading to cold, moist winters and hot, dry summers. Mean annual precipitation is 86.9 cm (recorded at Howard Prairie Reservoir, ca. < 8 km from closest site; 1392 m elevation;), with 69.6% falling November-March, largely in the form of snow. Mean monthly temperatures range from -2.0°C (January) to 16.4°C (July). The flora and fauna are diverse, with many taxa endemic to the region; this community is heavily influenced by climate, topography, geology and biogeographic history.

Eight pairs of stands within late-successional stages (forest seral stages that include mature and old-growth age classes (USDA et al. 1993)) were chosen for study. Each pair consisted of a thinned stand and an adjacent, or nearby, unthinned stand. Thinned sites were generally selectively harvested for the purpose of overstory reduction, mortality salvage or commercial thinning. Thinning first occurred between 16 and 41 years prior to this study. Two sites had been thinned on two occasions. While some large diameter trees were harvested from most stands, all sites still contained large trees, as well as numerous snags and much downed coarse wood material. For ecosystem management purposes, thinned sites were still classified as late-successional forest (USDI 2000). Paired sites were contiguous (separated by a road) in all cases but two; both of these sites were separated by less than 1.5 km. Paired sites were similar in terms of stand age, elevation, aspect and slope.

### Arthropod Sampling

Arthropods were collected using pitfall traps. Each trap consisted of a 1-liter plastic bucket (14 cm diameter opening) fitted with a metal funnel and a 0.24 liter canning jar, partially filled with ethylene glycol (50% solution), placed beneath the funnel to catch and preserve arthropods falling into the traps. Trap buckets were buried in the ground with their tops placed flush with the level of the forest floor and covered with a 25 cm x 25 cm plastic rain cover, suspended with

nails, 5 cm above the trap. Within each of the 16 stands, 10 traps were placed along transects at 30 m intervals. Transects generally ran along terrain contours and were placed no closer than 30 m from a site boundary. Traps were placed no closer than 0.5 m to a standing or downed tree >10 cm in diameter.

Pitfall traps were open during six 2-week intervals over the course of the study: 7–21 June; 21 June–6 July; 19 July–2 August; 2–17 August; 30 August–13 September, and; 13–27 September. Occasionally traps were lost due to disturbance by wildlife or livestock. Samples from disturbed traps were discarded and traps were reset for collection during the following trap period. The analysis focused on adult beetles within the family Carabidae (ground beetles) and adult spiders (all families). Specimens within each of these groups were identified to the species or morpho-species level. Voucher material was deposited in the USDA Forest Service, Western Forest Insect Collection (Oregon State University, Corvallis, OR).

#### Measurements of Environmental Variables

Habitat features measured included canopy cover, basal area, vegetative ground cover, downed wood debris, and litter and duff depth. During August 2000, measurements of each of these variables were made on 3.59 m radius plots (ca. 1/4000 ha) centered at each of the 160 pitfall trap locations used in the study. Canopy cover (%) was based on the average convex spherical densiometer measurement taken at the four cardinal directions around the plot center (Strickler 1959). Basal area was determined using a 10-factor prism. Ground cover included shrubs and herbs. The amount of ground covered by each of these two groups was estimated to fall within one of the following categories: 0%, <1%, 1–5%, 5–25%, 25–50%, 50–75% and 75–100%. A line transect was established along a random direction across the diameter of each plot to measure downed wood. Four size classes of downed wood were established (<0.6 cm, 0.6–2.5 cm, 2.5–7.6 cm and >7.6 cm diameter) and counts of individual pieces that intersected the transect were made using an incremental size gauge. Litter and duff depth were each measured at two points along each line transect, 1.8 m from the center in each direction. Litter is defined as freshly fallen needles and leaves, generally intact and loosely scattered on the forest floor. Duff is defined as the packed, dark colored fermentation and humus

layer found beneath the litter layer, and extends downward to the level of mineral soil. Needles and twigs within duff are often fragmented and bound by fungal mycelia.

#### Data Analysis

Prior to analysis, it was necessary to standardize arthropod capture rates within stands because of occasional trap loss associated with animal disturbance. Standardized trap catches for each stand on each date were calculated by multiplying the average number of arthropods per undisturbed trap by the total number of traps initially established within each site (10 traps/site). Standardized totals for each site on each of the six collection dates were then combined for statistical analyses. All species of carabid beetles and all families of spiders comprising more than 3% of the total number of individuals collected were analyzed statistically. Spiders were analyzed at the family level because 1) a single species often dominated a family numerically, 2) species within a family generally belong to the same feeding guild, and 3) we were most interested in determining whether broad functional differences existed between treatments. Species richness of carabid beetles and spiders was also compared.

Statistical comparisons between thinned and unthinned stands were made for arthropod abundances and habitat variables using Wilcoxon's Signed-Ranks Test for paired comparisons (Sokal and Rohlf 1981). Parametric analyses were not performed because transformations generally failed to yield residual distributions consistent with underlying assumptions of the tests (Sabin and Stafford 1990). Statistical significance was set at  $P = 0.05$  before the research began.

## Results

### Carabid beetle abundance

A total of 4,914 carabid beetles from 12 species were collected in thinned and unthinned stands over the course of the study (Table 1). Numerically, three species dominated the samples, comprising 82.1% of the total: *Pterostichus setosus* (34.5%); *Scaphinotus r. rugiceps* (29.4%), and; *P. herculeanus* (18.2%). *Omus cazieri*, *P. lama*, and *Carabus taedatus* were also relatively common (6.5, 4.5 and 4.5 %, respectively). These six species were abundant enough to analyze statistically.

TABLE 1. Total abundance of carabid beetles collected in pitfall traps within thinned and unthinned late-successional stands in the Cascade Mountain Range of southern Oregon.

Species	Thinned		Unthinned		Total	
	Number	Stands <sup>a</sup>	Number	Stands <sup>a</sup>	Number	Blocks <sup>b</sup>
<i>Amara conflata</i> LeConte	3	2	1	1	4	0
<i>Carabus taedatus</i> Fabricius	184	8	35	7	219	7
<i>Harpalus opacipennis</i> Haldeman	2	1	0	0	2	0
<i>Notiophilus sylvaticus</i> Eschscholtz	7	5	2	2	9	2
<i>Omus cazieri</i> van den Berghe	281	6	40	5	321	5
<i>Pterostichus herculeanus</i> Mannerheim	373	8	520	8	893	8
<i>Pterostichus inanis</i> Horn	5	3	21	3	26	2
<i>Pterostichus lama</i> (Menetries)	167	8	55	8	222	8
<i>Pterostichus melanarius</i> (Illiger)	1	1	0	0	1	0
<i>Pterostichus setosus</i> Hatch	422	5	1272	7	1694	4
<i>Scaphinotus rugiceps rugiceps</i> (Horn)	770	8	675	8	1445	8
<i>Zacotus matthewsii</i> Leconte	54	3	24	6	78	3
Total	2269		2645		4914	

<sup>a</sup> Number of stands within treatment in which one or more individuals were collected.

<sup>b</sup> Number of blocks (a pair of thinned and unthinned stands) in which one or more individuals were collected in both thinned and unthinned stands.

Combined, the remaining six species comprised 2.4% of the total. The total number of carabid beetles collected in thinned and unthinned stands was 2,269 and 2,645, respectively. *S. r. rugiceps*, *P. herculeanus* and *P. lama*, were found in all 16 stands while *P. setosus* was found in 12 stands. All 12 species were collected in thinned stands and 10 species were found in unthinned stands. Two uncommon species, *Harpalus opacipennis* and *P. melanarius*, each represented by a single individual, were collected in thinned stands.

Significant differences in abundance between thinned and unthinned stands were found for four of the six species analyzed (Table 2). *O. cazieri*, *P. lama* and *C. taedatus* were more abundant in thinned stands, while *P. setosus* was collected more often in unthinned stands. No treatment difference was found for *S. r. rugiceps*, *P. herculeanus* and total Carabidae. Similarly, no difference in species richness was found between thinned and unthinned stands.

### Spiders

In total, 3695 adult spiders were collected from 22 families and more than 120 species (Table 3). Within each family, one, or sometimes a few, species were numerically dominant. The eight most common families (relative abundance followed by

TABLE 2. Mean ( $\pm$  SE) abundance per stand type and results of statistical comparison of carabid beetles in pitfall traps within thinned and unthinned late-successional stands in the Cascade Mountain Range of southern Oregon.

Species	Thinned Mean ( $\pm$ SE)	Unthinned Mean ( $\pm$ SE)
<i>Carabus taedatus</i>	24.0 (7.6) <sup>a</sup>	5.0 (2.1) <sup>b</sup>
<i>Omus cazieri</i>	36.3 (12.3) <sup>a</sup>	5.1 (2.5) <sup>b</sup>
<i>Pterostichus herculeanus</i>	48.8 (19.0) <sup>a</sup>	69.7 (16.8) <sup>a</sup>
<i>Pterostichus lama</i>	22.9 (8.3) <sup>a</sup>	7.3 (1.7) <sup>b</sup>
<i>Pterostichus setosus</i>	53.9 (29.7) <sup>a</sup>	184.2 (54.8) <sup>b</sup>
<i>Scaphinotus r. rugiceps</i>	99.1 (48.9) <sup>a</sup>	94.9 (18.3) <sup>a</sup>
Total carabid beetles	294.3 (77.5) <sup>a</sup>	372.5 (65.0) <sup>a</sup>
Species richness	7.3 (0.6) <sup>a</sup>	6.9 (0.4) <sup>a</sup>

Means followed by the same letter were not significantly different (Wilcoxon's Signed-Ranks Test for paired groups,  $P < 0.05$ ).

the dominant species) were: Lycosidae (37.2%; *Pardosa dorsalis*), Gnaphosidae (14.4%; *Zelotes fratris*), Linyphiidae (12.3%; numerous moderately common species), Hahniidae (7.5%; *Cryphoea exlineae*), Thomisidae (6.9%; *Xysticus pretiosus* and *X. montanensis*), Cybaeidae (5.5%; *Cybaeus* new sp. #2), Antrodiaetidae (4.2%; *Antrodiaetus*

TABLE 3. Total abundance and feeding guild placement of the 25 most abundant spiders collected in pitfall traps within thinned and unthinned late-successional stands in the Cascade Mountain Range of southern Oregon.

Spider family and species	Feeding guild <sup>a</sup>	Thinned		Unthinned		Total	
		Number	Stands <sup>b</sup>	Number	Stands <sup>b</sup>	Number	Blocks <sup>c</sup>
<b>Agelenidae</b>		<b>26</b>		<b>49</b>		<b>75</b>	
<i>Novolena intermedia</i> (Ch. & Gert.)	funnel web	18	6	48	8	66	6
<b>Amaurobidae</b>		<b>59</b>		<b>47</b>		<b>106</b>	
<i>Callobius paynei</i> Leech	hackled band	49	6	33	6	82	6
<b>Antrodiaetidae</b>		<b>91</b>		<b>65</b>		<b>156</b>	
<i>Antrodiaetus pacificus</i> (Simon)	trap door	80	8	55	7	135	7
<i>Atypoides gertschi</i> Coyle	trap door	11	3	10	5	21	2
<b>Cybaeidae</b>		<b>91</b>		<b>111</b>		<b>202</b>	
<i>Cybaeus</i> new sp. #1	funnel web	14	3	41	4	55	3
<i>Cybaeus</i> new sp. #2	funnel web	76	7	70	8	146	7
<b>Dictynidae</b>		<b>92</b>		<b>43</b>		<b>135</b>	
<i>Blabomma</i> new sp #2	funnel web	71	7	30	7	101	6
<b>Gnaphosidae</b>		<b>383</b>		<b>150</b>		<b>533</b>	
<i>Haplodrassus eumis</i> Chamberlin	nocturnal running	51	7	19	5	70	5
<i>Micaria pulicaria</i> (Sundevall)	nocturnal running	36	6	20	6	56	5
<i>Zelotes fratris</i> Chamberlin	nocturnal running	137	8	87	8	224	8
<i>Zelotes josephine</i> Pl. & Sh.	nocturnal running	79	6	4	1	83	1
<i>Zelotes puritanis</i> Chamberlin	nocturnal running	20	5	0	0	20	0
<b>Hahniidae</b>		<b>68</b>		<b>209</b>		<b>277</b>	
<i>Cryphoea exlineae</i> Roth	sheet web	58	4	209	6	267	4
<b>Linyphiidae</b>		<b>190</b>		<b>265</b>		<b>455</b>	
<i>Ceratinella ataskae</i> Ch. & Ivie	sheet web	8	3	15	5	23	3
<i>Ceratinops inflatus</i> (Emerton)	sheet web	12	6	15	6	27	5
<i>Incestophantes mercedes</i> (Ch. & I.)	sheet web	17	7	31	5	48	5
<i>Linyphantes pualla</i> Ch. & Ivie	sheet web	12	6	15	6	27	5
<i>Neriene litigosa</i> (Keyserling)	sheet web	9	6	11	4	20	4
<i>Pityolyphantes brachygynus</i> Ch. & I.	sheet web	19	7	10	5	29	5
<i>Tenuiphantes zelata</i> (Zorsch)	sheet web	38	7	58	7	96	7
<i>Walckenaeria bifida</i> Millidge	sheet web	21	5	17	4	38	3
<b>Lycosidae</b>		<b>922</b>		<b>454</b>		<b>1376</b>	
<i>Alopecosa kochii</i> (Keyserling)	diurnal pursuit	46	8	14	7	60	7
<i>Pardosa dorsalis</i> Banks	diurnal pursuit	874	8	439	8	1313	8
<b>Thomisidae</b>		<b>147</b>		<b>108</b>		<b>255</b>	
<i>Xysticus montanensis</i> Keyserling	diurnal ambush	94	7	24	6	118	5
<i>Xysticus pretiosus</i> Gertsch	diurnal ambush	43	7	81	8	124	7
<b>Species not listed</b>		261		185		446	
<b>Total spiders collected</b>		2154		1541		3695	

<sup>a</sup>Feeding guild placement based on Post and Riechert (1977), McIver et al. (1992) and Uetz et al. (1999).

<sup>b</sup>Number of stands within treatment in which one or more individuals were collected.

<sup>c</sup>Number of blocks (a pair of thinned and unthinned stands) in which one or more individuals were collected in both thinned and unthinned stands.

*pacificus*) and Dictynidae (3.6%; *Blabomma* new sp. #2). Linyphiidae was by far the most species-rich family with over 45 species, followed by Gnaphosidae (17 species) and Salticidae (8 species). However, many of the Linyphiids were rare, with fewer than 10 individuals collected for 36 species. Many common species were widespread among stands, as 17 of the 25 most abundant species were collected in 12 or more of the 16 stands (Table 3). Only 6 of the 25 common species were found in less than 10 stands.

Significant differences in abundance between thinned and unthinned stands were found for four of the eight spider families analyzed (Table 4). Linyphiidae and Hahniidae were more common in unthinned stands while Gnaphosidae and Dictynidae were more numerous in thinned stands. The abundance of Lycosidae did not differ significantly between stand types, but more were collected in thinned stands than in unthinned stands on seven of the eight comparisons. Total spider abundance was also significantly greater in thinned stands. No differences were found for Thomisidae, Cybaeidae and Antrodiaetidae. Species richness was significantly higher in thinned stands than in unthinned stands, with on average, 39.5 and 30.8 species collected in each stand type, respectively.

TABLE 4. Mean ( $\pm$  SE) abundance per stand type and results of statistical comparison of spider families collected in pitfall traps within thinned and unthinned late-successional stands in the Cascade Mountain Range of southern Oregon.

Family	Thinned Mean ( $\pm$ SE)	Unthinned Mean ( $\pm$ SE)
Antrodiaetidae	12.3 (2.4) <sup>a</sup>	8.7 (1.3) <sup>a</sup>
Cybaeidae	11.7 (4.6) <sup>a</sup>	15.3 (4.0) <sup>a</sup>
Dictynidae	11.8 (1.7) <sup>a</sup>	5.9 (1.6) <sup>b</sup>
Gnaphosidae	50.7 (6.4) <sup>a</sup>	19.6 (4.5) <sup>b</sup>
Hahniidae	9.2 (4.0) <sup>a</sup>	27.8 (7.9) <sup>b</sup>
Linyphiidae	25.1 (4.1) <sup>a</sup>	36.2 (5.4) <sup>b</sup>
Lycosidae	121.0 (20.5) <sup>a</sup>	60.1 (11.6) <sup>a</sup>
Thomisidae	18.8 (2.7) <sup>a</sup>	14.3 (1.6) <sup>a</sup>
Total spiders	282.9 (27.5) <sup>a</sup>	206.4 (20.0) <sup>b</sup>
Species richness	39.5 (2.3) <sup>a</sup>	30.8 (1.5) <sup>b</sup>

Means followed by the same letter were not significantly different (Wilcoxon's Signed-Ranks Test for paired groups,  $P < 0.05$ ).

## Habitat Attributes

Thinned stands differed structurally from unthinned stands for five of ten variables measured (Table 5). Canopy cover, basal area, counts of wood debris < 0.6 cm diameter and wood debris 0.6 - 2.5 cm diameter, and duff depth were all significantly greater in unthinned sites than in thinned sites. No statistical differences were found for shrub and herb cover, wood debris 2.5 - 7.6 cm and > 7.6 cm diameter, and litter depth.

TABLE 5. Summary of habitat variables measured in thinned and unthinned late-successional stands in the Cascade Mountain Range of southern Oregon.

Habitat variable	Thinned Mean ( $\pm$ SE)	Unthinned Mean ( $\pm$ SE)
Canopy Cover (%)	57.2 (8.1) <sup>a</sup>	81.4 (4.6) <sup>b</sup>
Basal Area (m <sup>2</sup> /ha)	4.6 (0.2) <sup>a</sup>	7.4 (0.3) <sup>b</sup>
Shrub cover (%)	2.0 (0.1) <sup>a</sup>	1.8 (0.2) <sup>a</sup>
Herb cover (%)	3.0 (0.1) <sup>a</sup>	2.6 (0.2) <sup>a</sup>
Wood < 0.6 cm diam (pieces)	132.5 (9.3) <sup>a</sup>	199.5 (9.9) <sup>b</sup>
Wood 0.6 - 2.5 cm diam (pieces)	31.5 (2.4) <sup>a</sup>	44.3 (2.8) <sup>b</sup>
Wood 2.5 - 7.6 cm diam (pieces)	4.4 (0.5) <sup>a</sup>	4.0 (0.4) <sup>a</sup>
Wood > 7.6 cm diam (pieces)	1.0 (0.2) <sup>a</sup>	1.3 (0.2) <sup>a</sup>
Duff depth (cm)	2.1 (0.2) <sup>a</sup>	3.0 (0.2) <sup>b</sup>
Litter depth (cm)	1.1 (0.1) <sup>a</sup>	1.4 (0.1) <sup>a</sup>

Means followed by the same letter were not significantly different (Wilcoxon's Signed-Ranks Test for paired groups,  $P < 0.05$ ).

## Discussion

Based on activity patterns detected by pitfall traps, carabid beetle and spider populations within late-successional forests thinned 16-41 years prior differed considerably from those in unthinned stands, although abundances of many taxa were similar. Overall, the total number and species richness of carabid beetles did not differ significantly between thinned and unthinned stands, but total spider abundance and richness was significantly greater in thinned stands compared to unthinned stands. Thinning did not affect all carabid beetles and spiders in the same way, as some taxa within each group were more abundant in thinned stands while others were more abundant in unthinned stands. Although little information exists regarding short- or longer-term effects of selective thinning on forest litter arthropod communities,

these results generally concur with other studies that have shown that timber harvesting leads to changes in the abundance and diversity of carabid beetles and spiders (Jennings et al. 1986, McIver et al. 1992, Niemelä et al. 1993, Michaels and McQuillan 1995, Beaudry et al. 1997, Heliölä et al. 2001).

### Carabid Beetles

In general, the composition of the carabid beetle community within both thinned and unthinned stands appears typical of conifer forests of the southern Cascade Mountain Range. Both stand types contained relatively large numbers of *S. r. rugiceps*, *P. herculeus*, *P. lama*, and *Z. matthewsii*, all species commonly found in forest habitats in this region (Parsons et al. 1991, Brenner 2000). Two species relatively abundant in this study, *O. cazieri* and *P. setosus*, are previously known from only a few locations in mountains of southwestern Oregon (Hatch 1951, van den Berghe 1994, J. R. LaBonte, personal communication). Each of these two species was also relatively abundant in a mixed conifer forest 25 km west of the current study area (Niwa and Peck 2002), suggesting that within this poorly studied region, each may be abundant within a small geographic range.

Thinned stands were sufficiently different from unthinned stands to result in significant differences in the abundance of four of the six most common species. Three species, *O. cazieri*, *P. lama* and *C. taedatus*, were significantly more abundant in thinned stands than in unthinned stands. Known habitats of the tiger beetle, *O. cazieri*, include mixed conifer stands (Niwa and Peck 2002) and pine forest with an open understory (van den Berghe 1994). Niwa and Peck (2002) found *O. cazieri* to be equally abundant within unburned stands and those having experienced prescribed underburning. *P. lama* is found in a wide range of forest habitats throughout much of western North America. While it occurs in more open habitats, including forest clearcuts and edges, and in mesic-to-xeric open and closed canopy coniferous forests (Lindroth 1961-1969, Kavanaugh 1992, J. R. LaBonte personal communication), it was also found to be the second most abundant carabid beetle collected in non-riparian old-growth forest in Cascade Mountains of central Oregon (Brenner 2000). *C. taedatus* is widespread throughout western North America, from Alaska

and the Yukon south to New Mexico, and east to Quebec (Bousquet and Laroche 1993). As with most species of *Carabus*, it is also found in open habitats with low or sparse vegetation (Lindroth 1961-1969, Parsons et al. 1991).

*Pterostichus setosus*, the most abundant species collected, was the only carabid beetle found to be significantly more abundant in unthinned stands. Habitat requirements for this species are poorly known, but collection sites prior to this study include a dense, closed canopy mature western red cedar (*Thuja plicata*) and fir (*Abies* sp.) forest (J. R. LaBonte personal communication) and previously burned mid-successional mixed conifer stands (Niwa and Peck 2002).

The similarity in species richness between thinned and unthinned stands suggests that thinning has affected carabid beetle composition much less than clearcutting. For comparison, in 80-100 year old spruce-dominated forests in Finland, Heliölä et al. (2001) found 31 species of carabid beetle in clearcut stands and 16 species in adjacent uncut forest. Similarly, Niemelä et al. (1993) found an average of 26 species in stands regenerating after clear-cutting (< 9 years) and an average of 15 species in four different types of mature stands. In these studies, higher species richness in clearcuts was largely due to an influx of open-habitat species, such as those within the widespread and species-rich genera *Amara* and *Harpalus*, which generally favor more open and dry conditions (Lindroth 1961-1969). In our study, *Amara* and *Harpalus* were only rarely collected (4 and 2 individuals, respectively), suggesting that existing structural differences between thinned and unthinned stands were not great enough to support these species. It is possible that forest succession within thinned stands had advanced to a stage in which it is no longer favorable for these open habitat species to exist in large numbers.

### Spiders

The spider fauna was generally representative of forest habitats, being dominated by the Lycosidae, Gnaphosidae, Linyphiidae, Hahniidae, and Thomisidae (Bultman and Uetz 1982, McIver et al. 1992, Muzika and Twery 1997). Overall, two families of running spiders, Lycosidae and Gnaphosidae, were slightly more numerous than all other spiders combined. Part of their numerical dominance in our pitfall traps, however, may be due

to their active style of hunting. Because running spiders generally pursue their prey throughout the forest floor, they are more likely to be collected in pitfall traps than are more sedentary spiders, such as web-building and trap door spiders. More sedentary spiders are often trapped while searching for mates or during dispersal.

Thinned stands supported more lycosid and gnaphosid hunting spiders and the funnel web building Dictynidae than unthinned stands, illustrating the preference that these spiders have for more open forests. McIver et al. (1992), comparing the succession of litter spiders following clear-cutting, also found Lycosidae and Gnaphosidae to be most abundant in open stands, being common in young clearcuts (herb- and shrub-dominated) while being rare in older, tree-dominated stands. Our results were less extreme, however, as both families were also relatively common in unthinned stands. Both *P. dorsalis* and *Z. fratris*, the dominant species within the families, have a wide range of environmental tolerances and are not limited to forested habitats (Dondale and Redner 1990, Platnick and Dondale 1992, Glesne 1998). In contrast, McIver et al. (1992) found the Dictynidae to be considerably more numerous in closed canopy stands than in young clearcuts, although they were about one-half as abundant in old-growth stands than in 22-31 year-old tree-dominated stands. Responses of different species of *Blabomma* within each of the studies may have contributed to this difference.

Conditions within unthinned stands led to greater abundance of sheet-web building spiders within the Linyphiidae and Hahniidae, although many members of these two families were also relatively common in thinned stands. Many species within these two families are small spiders that build webs within forest floor litter or low growing vegetation. The greater amount of litter in unthinned stands may have provided more favorable habitat for these spiders. McIver et al. (1992) also found linyphiid spiders to be more abundant in closed canopy sites than in more open sites, but a single species of Hahniidae was generally similar in abundance across forest successional stages.

Higher spider species richness in thinned stands indicates the existence of more favorable conditions for a greater number of species than in unthinned stands. This pattern was widespread among families and hunting styles. Of the 22

families collected, 12 were more species-rich in thinned stands while only 3 were more diverse in unthinned stands. The species-rich Linyphiidae contributed little to this pattern, with 34 species collected in thinned stands and 31 trapped in unthinned stands. Most likely, a variety of spiders commonly found in more open habitats moved into the thinned stands. Unfortunately, little is known about habitat preferences for many of the species collected.

#### Influence of Habitat Structure

The structure and complexity of the forest floor undoubtedly influences the composition of spider and carabid beetle communities. Litter, wood debris and vegetation are all likely to be important because they provide a 3-dimensional substrate in which a variety of microhabitats exist. This vertical array of microhabitats has been suggested to influence the relative abundance and diversity of both spiders (Uetz 1975, 1979, Bultman and Uetz 1982) and carabid beetles (Heliölä et al. 2001). Each contributes to fine scale complexity, and may provide places from which to hide from predators, stalk prey, or for spiders, attach webs (Edgar 1969, Schaefer 1978, Polis and McCormick 1986, Uetz 1991, Wagner and Wise 1996). In general, however, our results do not support the prediction that greater habitat complexity leads to greater abundance and diversity of carabid beetles and spiders. Although more duff and small pieces of woody material (< 2.5 cm diam.) were found in unthinned stands compared to thinned stands, only a few taxa were more abundant in unthinned stands.

Microclimatic conditions on the forest floor, such as soil and litter moisture, humidity, and temperature, may also influence spider and carabid beetle abundance. Canopy closure is likely the most important variable influencing microclimate, as it strongly influences the amount of solar radiation and precipitation reaching the forest floor, as well as affecting wind speed and desiccation rates. Canopy closure was considered to be an important factor influencing spider community development over forest successional stages following clear-cutting (McIver et al. 1992). Forest floor depth may also be important, particularly for carabid beetle eggs and larvae, which generally reside within the soil, duff, and litter, as it insulates from extremes in temperature (Thiele 1977). Uetz (1979) suggested that temperature variation on

the forest floor was a primary factor influencing spider species richness during late summer when temperature stress was greatest. Although canopy cover was significantly lower in thinned stands than in unthinned stands, our results suggest that microclimatic conditions were not extreme enough to decrease the abundance and diversity of carabid beetles and spiders.

#### Associations with Late-successional Forests

Some species of both carabid beetles and spiders have been found to be closely associated with late-successional forests. Niemelä et al. (1993) considered 10 of 53 carabid species within lodgepole pine – white spruce stands of central Alberta to be mature forest specialists. Similarly, McIver et al. (1990) considered two species of Linyphiidae, one Antrrodiaetidae, and one Theridiidae to be characteristic of old-growth and mature second growth forests. The current emphasis on ecosystem management of late-successional forests in the Pacific Northwest underscores the importance of determining the extent to which these arthropods are associated with mature forests. For carabid beetles, two species collected in our study, *Z. matthewsii* and *N. sylvaticus*, have been cited as being closely associated with late-successional forests in western Washington and Oregon, and central and northern California (USDA and USDI 1994). In our study, *Z. matthewsii* was not rare in either forest type, with 54 of 78 individuals collected in thinned stands. *Notiophilus sylvaticus*, a species specialized to prey on small arthropods such as Collembola and mites (Hengeveld 1980), was rarely collected, with only nine individuals trapped, seven of which were from thinned stands. Although our study area represents only a small portion of the range of these species, it indicates that older thinned stands are able to support these carabid beetles as well as adjacent unthinned stands.

A general lack of understanding of habitat requirements for most forest spiders makes it difficult to determine how closely each taxon is associated with late-successional forests. We collected five species that have been closely associated with late-successional forest habitat (USDA and USDI 1994). Although none of these species were common in our sites, two species, *Callobius serverus* (Amaurobidae) and *Tachygyna vancoverana* (Linyphiidae), were considerably more abundant

in unthinned stands than in thinned stands (12 and 2, and 11 and 2 individuals, respectively). *Linyphantes pualla* (Linyphiidae) abundance was similar between stands (12 in thinned and 15 in unthinned sites). *Neon reticulatus* (Salticidae; 3 and 3 in thinned and unthinned, respectively) and *Theridion sexpunctatum* (Theridiidae; 0 and 3 in thinned and unthinned, respectively) were rare in both stand types. Considering only the 25 species represented by 20 or more individuals, none were restricted to unthinned sites. *Cryphoeca exlineae* (Hahniidae) was most strongly associated with unthinned sites (3.6 times more in unthinned sites), but 61 individuals were collected in thinned sites. Similarly, *Cybaeus* new sp. 1 (Cybaeidae) was 2.9 times more abundant in unthinned sites (41 and 14 individuals) followed by *Novolena intermedia* (Agelenidae) (2.7 times more abundant in unthinned sites; 48 and 18 individuals).

In conclusion, late-successional stands thinned 16-41 years prior supported at least as many individual carabid beetles and spiders, and were at least as species-rich, as nearby unthinned stands. However, numerous individual taxa of both carabid beetles and spiders differed in abundance between stand types indicating that changes in forest structure did influence some groups. In light of these results, it is important to note that the thinning treatment did not remove all large trees, and thinned stands are still considered by land managers to have structural integrity characteristic of late-successional forests. It is possible that if thinning would have removed more, or all large trees, the response of these arthropods would have been more dramatic. Furthermore, the relatively long period of time that passed since thinning took place likely resulted in stand succession that reduced the impact of the initial thinning treatment. For example, secondary growth of trees within gaps formed after tree harvest would have increased canopy cover, reducing microclimatic influences on the arthropod community.

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