

Chapter 5

VARIATION IN AERIAL ARTHROPOD ABUNDANCE AND TAXONOMIC RICHNESS WITH STAND STRUCTURE AND VEGETATION COMPOSITION IN THE OREGON COAST RANGE

INTRODUCTION

Aerial insects are important prey for several species of birds that breed in Pacific Northwest coniferous forests. Some aerial insectivores, such as swifts, swallows, and nighthawks, forage entirely on the wing, usually in open habitats or above the forest canopy. Other bird species, such as Hammond's flycatcher, western tanager, Townsend's solitaire, and Wilson's warbler, forage within or below the forest canopy by making brief sallies from perches to catch airborne insects. For species that use any type of aerial foraging strategy, stand structure may influence the suitability of foraging habitat. For example, open spaces within and below the canopy provide suitable foraging habitat for Hammond's flycatcher, western tanager, and Townsend's solitaire (Dowlan 2003b, Hagar 2003c, Nehls 2003). Commercial thinning harvests create such canopy openings in dense conifer stands, at least temporarily, and all of these species were more abundant in recently thinned than in unthinned 50-year-old Douglas-fir (*Pseudotsuga menziesii*) stands (Hagar et al. 1996, Hayes et al. 2003, Hagar and Howlin, submitted). Clearly, the configuration of open spaces and perch sites is an important aspect determining suitability of foraging habitat for these species, but availability of prey theoretically should be at least as important. Indeed, increases in the density of insectivorous birds have been associated with increases in the abundance of flying insect prey (Brush and Stiles 1986, Whitaker et al. 2000). However, the influence of forest structure on availability of aerial insect prey has not been well studied in western coniferous forests. A basic understanding of habitat characteristics that influence aerial arthropod abundance is prerequisite to assessing both their response and the response of their predators to changes in forest structure that result from management practices.

Forest overstory cover may directly influence the taxonomic composition and abundance of aerial arthropod prey. Some insect taxa may be most abundant in areas with high light intensity, while others may be correlated with foliage density in tropical forests (Koike et al. 1998). In temperate forests, insect species richness and diversity has been negatively correlated with canopy cover (Humphrey et al. 1999). A positive relationship between amount of light penetration through forest canopy and primary productivity was cited as a possible explanation for higher abundances of aerial insects in gaps than under forest canopies (Blake and Hoppes 1986). However, insect abundance in relation to canopy cover and gap size has not been well studied in temperate coniferous forests, providing little basis for prediction of the response of aerial arthropods to partial canopy removal such as thinning or group selection harvests.

Forest overstory conditions also have effects on the cover and composition of ground vegetation (Klinka et al. 1996, Bailey et al. 1998), which in turn may influence abundance of flying insects. Cover of vegetation, particularly deciduous shrubs, in the shrub layer of forests has been positively correlated with abundance of flying arthropods (Jokimaki et al. 1998) and fly diversity (Humphrey et al. 1999). In a western Oregon study, higher abundance of flying insects in commercially thinned young conifer stands than in similar unthinned stands may have been related to greater herbaceous cover in thinned than unthinned stands (Hagar 1992), but empirical evidence for this relationship was lacking. Cover of both herbaceous and woody ground vegetation in gaps may create suitable habitat for arthropods by minimizing negative effects of surface heat buildups and moisture deficits (Oliver and Larson 1990, Shure and Phillips 1991).

The relationship between the abundance of aerial arthropods and understory vegetation cover and composition may be particularly relevant to management of habitat for the Wilson's warbler. A predominance of flies and other winged insects in the diet of Wilson's warblers (Chapter 4) reflects the hover-gleaning and aerial fly-catching foraging strategy frequently used by this species (Bent 1963, Stewart et al. 1977). This strategy enables Wilson's warblers to prey on small, winged insects found on or near the tips of branches and twigs too small to support the weight of a perched

bird. Wilson's warblers are associated with deciduous vegetation in forest understory (Hagar 2003b), and have responded positively to commercial thinning in Pacific Northwest conifer forests (Muir et al. 2002). A greater abundance of Wilson's warblers in thinned than unthinned stands and their association with deciduous shrubs may be related to abundance of sedentary prey on shrub foliage (Chapters 2, 3, and 4), but it is not known if abundance of aerial arthropods also may be important.

Given the importance of airborne arthropods as prey for birds, I wanted to understand habitat characteristics that influenced their abundance in Douglas-fir forests in the Oregon Coast Range. Specifically, I addressed three questions: 1) Does abundance of aerial arthropods differ among stands with different management histories? 2) Do gaps created by group selection harvesting support higher abundances of aerial arthropod prey than the unharvested matrix surrounding the gaps? 3) Is abundance of aerial arthropod prey related to forest canopy cover and the cover and composition of understory vegetation? In the analyses, I focused on flies >3 mm in length and adult Lepidoptera, because they were prey for Wilson's warblers (Chapter 4) but were not adequately sampled by beating shrubs. I also was interested in total abundance of all airborne arthropods and all airborne arthropods >3 mm in length because these could represent coarse estimates of available prey for fly-catching bird species in general.

STUDY SITES

I sampled aerial arthropods in a subset of the study sites described in Chapter 2 (sites 1, 2, 5, and 6 in Fig. 2.1), chosen to represent a range of variability in understory structure. I used two pairs of young thinned and unthinned stands (Mary's Peak and D-Line), and two unmanaged, mature stands each paired with stands of the same age that had been partially harvested with a group selection method (hereafter referred to as GS stands), for a total of eight stands. The young stands (thinned and unthinned) regenerated naturally following clear-cut harvesting and were 55 - 65 years old. A

single age cohort dominated the overstory, with very few large trees and well-decayed snags (<1/ ha) persisting from previous stands. Unthinned stands were in the stem-exclusion stage of forest development (Oliver and Larson 1990), and were characterized by a dense, uniform overstory of Douglas-fir, and a sparse understory. Clumps of tall shrubs, mainly vine maple (*Acer circinatum*) and oceanspray (*Holodiscus discolor*), that occurred in unthinned stands tended to be scattered, and were primarily composed of a few tall stems with sparse foliage. Thinned stands had been thinned to uniform spacing 19 – 27 years prior to this study. Residual tree densities were typical for standard thinning operations meant to optimize timber yield. In other words, the goal of thinning at the time it was performed did not include the fostering of structural and biological diversity. In contrast, GS stands were part of an experiment to assess wildlife response to alternatives to clear-cutting aimed at maintaining biodiversity in managed forests (Chambers et al. 1999). In these 120-year-old stands, one-third of the volume was removed in 0.2-ha circular patches. All sites were located in forests dominated by Douglas-fir on the east side of the Oregon Coast Range, in the Western Hemlock Vegetation (*Tsuga heterophylla*) forest zone (Franklin and Dyrness 1988). Regional climate is characterized by mild, wet winters and dry summers.

METHODS

Sticky traps were intended to capture aerial insects that are potential prey for fly-catching birds and consisted of a 46- x 46-cm piece of hardware cloth coated with tanglefoot insect trap, stapled to the top of a 2.4-m long wooden stake driven into the ground. Thus, traps sampled insects approximately 2 m above ground. In each of the eight stands, ten traps were haphazardly placed within 10 – 25 m of mist-net locations, where birds were captured to sample diets (see Chapter 4). In the GS stands, five traps were placed in gaps, and five in adjacent forested matrix.

Aerial arthropods were sampled at the same trap locations during two periods in 2000: (1) 6 June to 4 July, and (2) 12 – 31 July. Trapped arthropods were identified in

the field seven days after traps were placed. Arthropods >2 mm in length were identified to the lowest possible taxonomic level in the field and measured to the nearest mm. Arthropods >10 mm in length and those we were unable to identify in the field were removed from traps, mounted on index cards, and identified in the laboratory. I did not attempt to identify arthropods <2 mm in length. Used screens were replaced with fresh ones at the beginning of the second sampling period.

Methods of vegetation sampling

I ocularly estimated overall cover of live vegetation and cover of deciduous vegetation within a 5-m radius of each trap in four height classes: <1.5 m, 1.5- to 4 m, 4.1- to 15 m, and >15 m. Height classes were based on approximate natural breaks in the vegetation. Most herbs and low shrubs fell into the lowest height class; tall shrubs were represented by the 1.5- to 4 m class, and the highest classes represented mid- and overstory cover, respectively.

Data Analysis

I assumed that the number and taxa of arthropods caught on each screen trap represented the local abundance and community composition of aerial arthropods. Therefore, I summed the number of arthropods on each trap within each sampling period to derive an index of abundance. I calculated this abundance index for three arthropod categories: all arthropods, all arthropods >3 mm in length, and Diptera >3 mm in length. I summed the number of orders and families on each trap within each sampling period to derive two indices of taxonomic richness. I assumed that each trap location was independent because individual arthropods respond to microsite characteristics (Schowalter 2000), causing variation in arthropod communities within a stand. Therefore, each screen trap represented an experimental unit ($N = 80$).

I used analysis of variance (ANOVA) to test the null hypotheses that mean abundance of the three categories of arthropod prey did not differ among stand conditions and between matrix and gap plots within the GS stands only. I included an interaction term for sampling period because arthropod abundance can fluctuate over

the time period represented by my sampling effort, introducing variability in the data. I log-transformed the response variables to meet the statistical assumptions of normally distributed residuals with constant variance.

I used an information-theoretic approach to selecting the “best” model from a set of pre-defined candidate regression models (Burnham and Anderson 2002) to explain variation in aerial arthropod response variables as a function of vegetation cover. I used this method to explain variation in five response variables: abundance of all arthropods, abundance of arthropods >3 mm, abundance of Diptera >3 mm, ordinal richness and family richness. I modeled each response variable separately for each sampling period. Candidate models were selected from the variables describing overall cover and deciduous cover in each of the four height categories. I examined plots of predictor versus response variables and log-transformed variables that appeared to have non-constant variance. Variables that did not conform to statistical assumptions following transformation were not used in analyses. Strongly correlated variables were not included in any of the candidate models. I included a null model in the set of candidates to ensure the final model performed better than a model based solely on average arthropod abundance or taxonomic richness. The model with the lowest Akaike Information Criteria (AIC) score was considered the “best” in the set if it met assumptions of constant variance and normal distribution of residuals. For each of the remaining models in the set, I calculated Δ as the difference between the AIC score of the best model and that of the model under consideration. Models within 2 Δ units of best model were considered equally plausible as long as they met model assumptions. I calculated the Akaike weight (w_i) to evaluate the strength of evidence supporting the best models. Models with w_i values close to 1 are more plausible than those with values close to 0 (Burnham and Anderson 2002).

Because adult Lepidoptera were captured on only 22% of the screen traps, multiple regression could not be used to model the association between their abundance and vegetation cover. Instead, I used ANOVA to test the hypothesis that the mean percent cover at traps where adult Lepidoptera were caught did not differ from that at

traps where they were not caught for three cover variables: total vegetation cover <4 m, cover of woody deciduous shrubs <4 m, and total vegetation cover >4 m.

I compared overall vegetation cover at the three lowest height categories between gap (N=10) and matrix plots (N=10) within the GS stands using ANOVA. By definition, gaps did not have any overstory cover in the highest height category.

RESULTS

Thirteen orders of arthropods were identified from the 18,492 specimens captured on screen traps. The order Diptera dominated the collection numerically, representing 42% of all captures (Table 5.1). Coleoptera was the second most abundant order. Both Diptera and Coleoptera were captured on 99% of the traps. Eighty percent of the arthropods captured were ≤ 5 mm in length. Arthropods <3 mm in length composed 49% of the sample.

Differences in ordinal and family richness among stand conditions depended on the sampling period ($P_{\text{interaction}} < 0.001$, ANOVA; Fig. 5.1). During the early sampling period, the average number of orders / trap was significantly greater ($P < 0.001$, least squares means test) in thinned stands than in any of the other stand types (Fig. 5.1A), while the number of families was higher ($P < 0.02$, least squares means test) in GS and thinned stands than in mature and unthinned stands (Fig. 5.1B). During the later sampling period both ordinal and family richness was highest in GS and lowest in unthinned stands, but lower in thinned relative to mature stands.

Differences in abundances of all arthropods and arthropods >3 mm among stand types did not vary with sampling period ($P_{\text{interaction}} \geq 0.18$, ANOVA). For aerial arthropods of all sizes, median abundance was 1.6 to 2.1 times lower in unthinned stands than in the other three stand types ($P \leq 0.007$, least squares means test; Fig. 5.2A). For aerial arthropods >3 mm, median abundance was 1.8 to 2.6 times higher (approximately 24 – 38 arthropods/trap) in mature and GS stands than in young thinned and unthinned stands ($P < 0.001$, least squares means test). Abundance in thinned stands

averaged 25% greater than in unthinned stands (Fig. 5.2B), but this difference was not statistically significant.

Table 5.1. Frequency of occurrence of arthropods on 155 sticky traps and total numbers of captures by taxonomic group in Douglas-fir stands in the Oregon Coast Range, 2000. Only arthropods >2mm in length were identified to order.

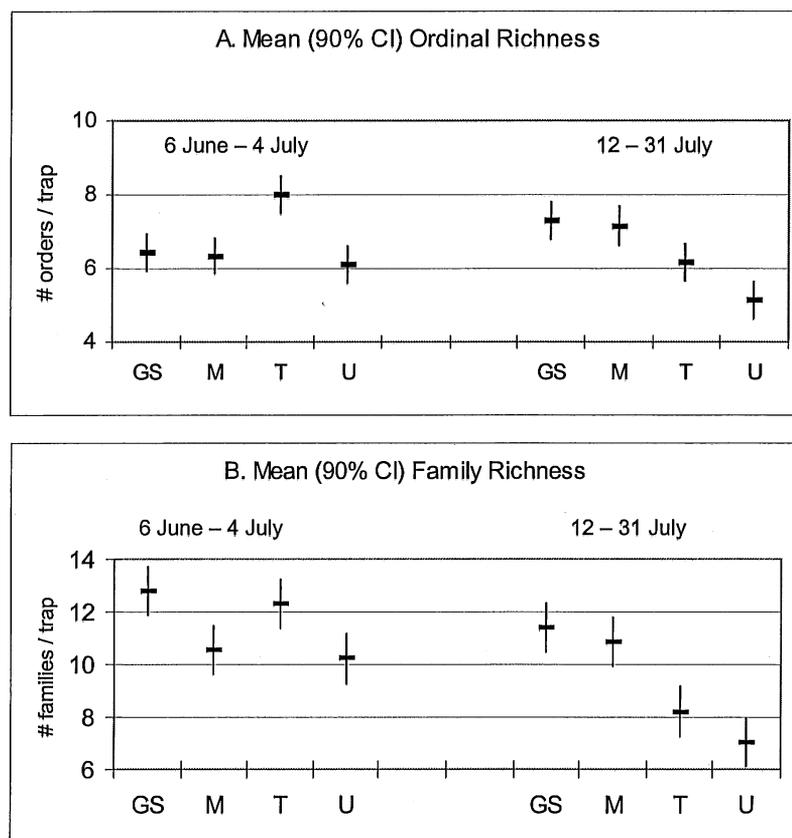
Arthropod Taxa	Frequency of occurrence ¹	total #	% of total
Diptera	0.99	7774	0.420
Coleoptera	0.99	1912	0.103
Hymenoptera	0.92	745	0.040
Psocoptera	0.45	480	0.026
Araneida	0.74	269	0.015
Homoptera	0.54	165	0.009
Hemiptera	0.39	117	0.006
Neuroptera	0.38	86	0.005
Lepidoptera - Adults	0.22	42	0.002
Lepidoptera - Larvae	0.09	16	0.001
Plecoptera	0.05	12	0.001
Tricoptera	0.05	10	0.001
Ephemeroptera	0.05	9	0.000
Opiliones	0.01	2	0.000
Unknown >2 mm in length	0.04	11	0.001
Unknown <2 mm in length	0.72	6842	0.370

¹ Number of traps on which taxa was recorded / 155 total traps

Differences in abundance of flies >3 mm among stand conditions depended on sampling period ($P_{\text{interaction}} < 0.008$, ANOVA; Fig. 5.3). During Period 1, median abundance was 2.8 to 8.4 times higher in mature than in any other stand condition ($P < 0.10$, least squares means test). Abundance was 2.1 to 4.7 times higher in GS stands than in thinned and unthinned stands ($P < 0.03$, least squares means test). Median fly abundance was 2.25 times higher in thinned than unthinned stands ($P = 0.02$, least squares means test). Overall median fly abundance was 3.7 times lower during sampling

Period 2 compared to Period 1. Within Period 2, median abundance in GS stands was 1.8 to 4.7 times higher than in any other stand condition ($P < 0.08$, least squares means test).

Fig. 5.1. Mean (90% confidence intervals) number of arthropod (A) orders and (B) families per trap in four stand conditions (GS = Group Selection harvest, M = unmanaged mature, T = young, commercially thinned, U = young, unthinned), during two sampling periods, Oregon Coast Range, 2000.



Within GS stands, ordinal richness was greater in gaps than matrix plots ($P=0.02$, ANOVA); traps in gaps had on average 0.3 to 1.8 (90% CI) more orders than traps in matrix (mean difference = 1.05 orders/trap). Average number of families/trap did not differ between gap and matrix plots ($P=0.12$, ANOVA). Total abundance of all sizes of arthropods did not differ between gap and matrix plots during the first sampling period, but was almost three times greater in gaps than in matrix locations during Period 2 ($P=0.001$, ANOVA; Fig. 5.4). Arthropods >3 mm in length were almost twice as abundant in gap as in matrix plots regardless of sampling period ($P=0.008$, ANOVA; Fig. 5.5). Abundance of arthropods >3 mm was 1.9 times greater during Period 1 than Period 2 ($P=0.03$, ANOVA). Similarly, flies >3 mm were more than twice as abundant in gap (median = 34/trap, 90% CI: 21, 54) as in matrix plots (median = 15/trap, 90% CI: 9, 24; $P=0.04$, ANOVA), but about half as abundant during Period 2 (median = 15/trap, 90% CI: 9, 24) compared to Period 1 (median = 33/trap, 90% CI: 20, 53; $P=0.06$, ANOVA; data not graphed).

Regression models explained 12 to 31% of the variation in abundance of the arthropod prey categories that I analyzed, and 8 to 28% of the variation in family and ordinal richness (Table 5.2). Associations between response variables and understory cover (≤ 4 m from forest floor) were uniformly positive. Deciduous understory cover explained the most variation for every response variable in at least one of the sampling periods. Except for abundance of Diptera during Period 1, responses were negatively associated with mid- and overstory cover (>4 m).

Adult Lepidoptera were captured at 43.5% (37 of 85) of the screen trap plots during both sampling periods combined. Cover of deciduous shrubs <4 m and cover of all vegetation <4 m was significantly greater ($P < 0.10$, ANOVA) on plots where adult Lepidoptera were captured than where they were not captured. Cover of deciduous vegetation <4 m was estimated to be on average 12.8% greater at traps where adult Lepidoptera were caught (mean = 58.5%, 90% CI: 49.1, 67.9) than where no adult Lepidoptera were caught (mean = 45.7%, 90% CI: 37.4, 53.9). Cover of all vegetation <4 m was estimated to be on average 14.3% greater at traps where adult Lepidoptera were caught (mean = 98.2%, 90% CI: 90.2, 106.2) than where no adult Lepidoptera

were caught (mean = 83.9%, 90% CI: 76.9, 91.0). A difference in overstory cover (>4 m) was not detected between plots with and without Lepidoptera ($P = 0.55$, ANOVA).

Cover of vegetation differed significantly between gap and matrix plots within GS stands for three height categories (Fig. 5.6). Cover in the lowest layer (<1.5 m) was greater in gaps than matrix by an average of 24% ($P = 0.007$, ANOVA). Cover from 1.5 – 4.0 m was greater in matrix plots by an average of 18% ($P = 0.034$, ANOVA). Cover above 4.0 m also was greater in matrix than gap plots ($P < 0.001$, ANOVA).

Figure 5.2. Comparison of mean number of captures on sticky traps (90% confidence intervals) for A) all sizes of arthropods, and B) arthropods >3 mm in four stand conditions (GS = Group Selection harvest, M = unmanaged mature, T = young, commercially thinned, U = young, unthinned), Oregon Coast Range, 2000.

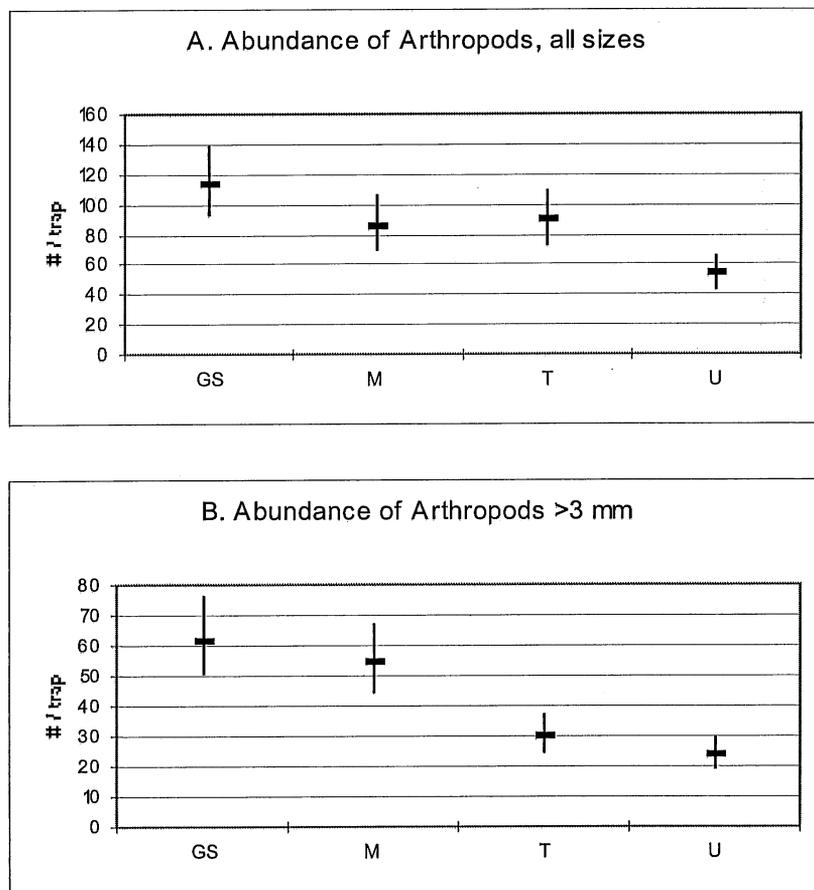


Figure 5.3. Comparison of mean number of captures (90% confidence intervals) of **flies** on sticky traps, during two sampling periods in four stand conditions (GS = Group Selection harvest, M = unmanaged mature, T = young, commercially thinned, U = young, unthinned), Oregon Coast Range, 2000.

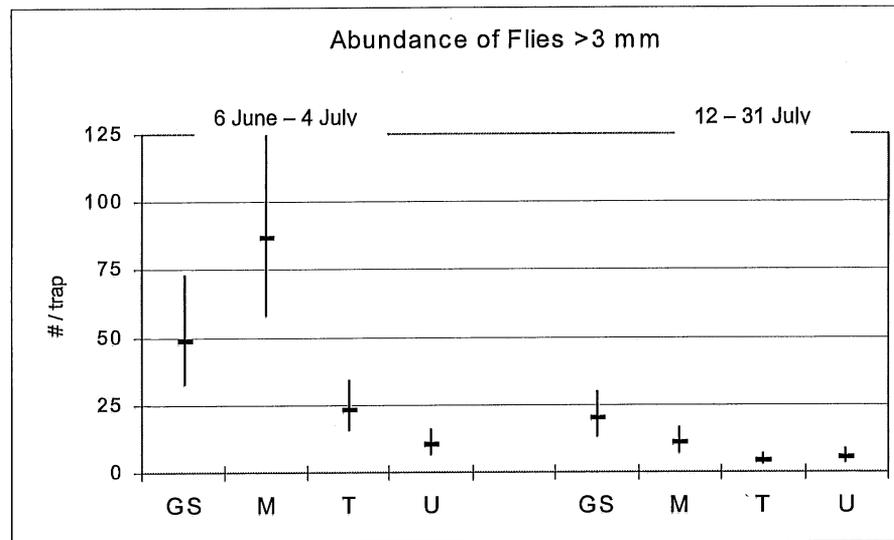


Figure 5.4. Comparison of median number of captures (90% confidence intervals) of **all arthropods** on sticky traps in gaps and matrix of group selection stands during two sampling periods in the Oregon Coast Range, 2000.

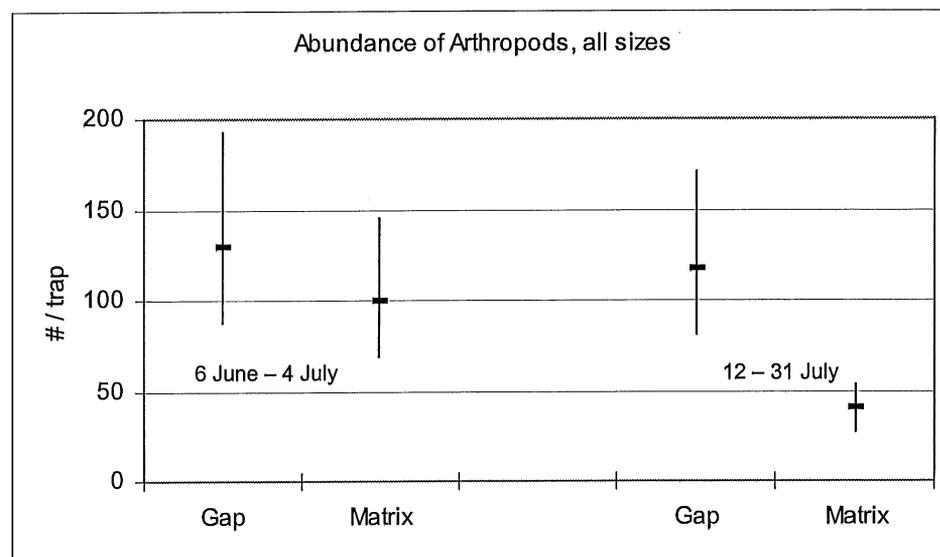


Figure 5.5. Comparison of median number of captures (90% confidence intervals) of arthropods >3 mm on sticky traps between gap and matrix plots averaged over two group selection stands and sampling periods in Oregon Coast Range, 2000.

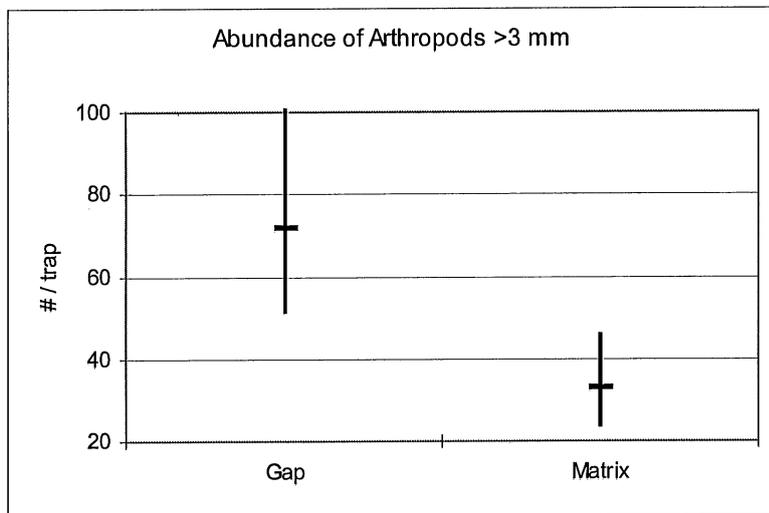


Figure 5.6. Comparison of average vegetation cover (95% confidence intervals) in three height categories between gap and matrix plots in two group-selection stands in the Oregon Coast Range.

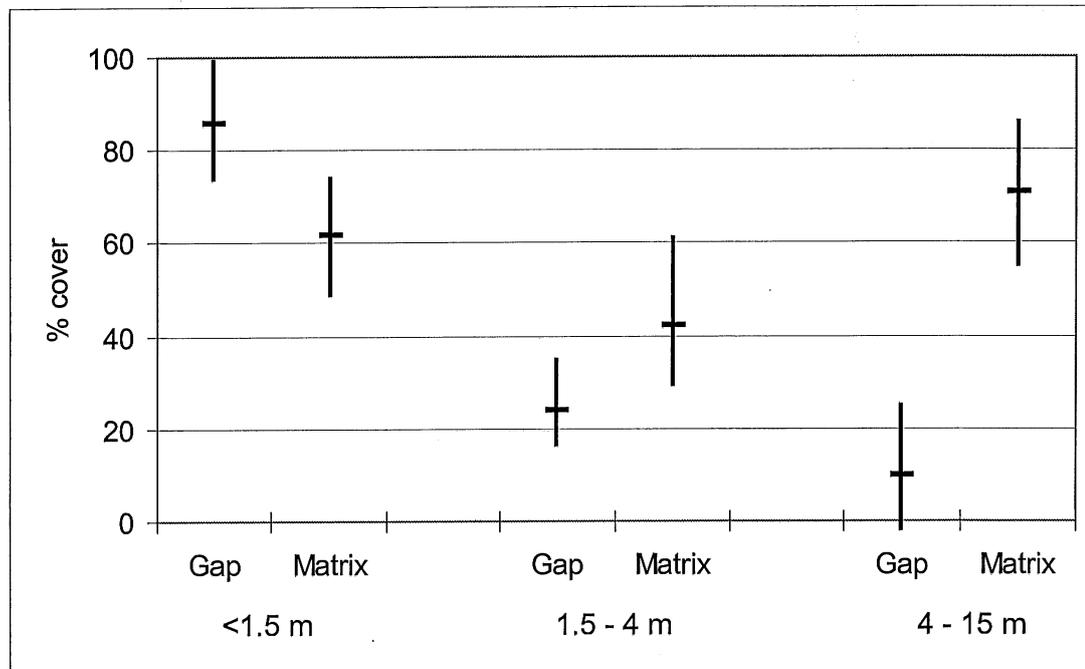


Table 5.2. Best models for explaining variation in abundance of aerial arthropod prey as a function of habitat variables in Douglas-fir forests, Oregon Coast Range. Potential values of Akaike Weight range from 0 to 1, with greater values indicating stronger evidence in support of the best model.

Response	Model Variables	Parameter Estimate	Akaike Weight	Adjusted Model R ²
Arthropods, All Sizes				
Period 1	log (vegetation cover 4 - 15 m)	0.802	0.97	0.14
Period 2	deciduous cover \leq 4 m vegetation cover \geq 4 m	0.009 -0.005	0.99	0.31
Arthropods >3 mm				
Period 1	log (deciduous cover <1.5 m)	0.319	0.83	0.12
Period 2	deciduous cover \leq 4 m vegetation cover \geq 4 m	0.009 -0.004	0.92	0.25
Diptera >3 mm				
Period 1	log (deciduous cover <1.5 m)	0.481	0.67	0.12
Period 2	deciduous cover <4 m	0.012	0.57	0.15
Ordinal Richness				
Period 1	log (vegetation cover 4 – 15 m)	-0.286	0.34	0.08
Period 2	log (deciduous cover <1.5 m)	0.598	0.46	0.21
Family Richness				
Period 1	log (vegetation cover 1.5 – 4 m)	0.132	0.72	0.11
Period 2	deciduous cover <4 m)	1.005	0.60	0.28

DISCUSSION

Taxonomic richness and abundance of aerial arthropods varied among stands with different silvicultural histories and were associated with amount and composition of cover in different vertical strata of forest vegetation. Cover of deciduous shrubs in particular was important in explaining variation in the abundance of several arthropod groups (Table 5.2), and was greater in thinned and GS stands than in mature and unthinned stands (Chapter 2). Within GS stands, the greater cover of vegetation within 1.5 m of the forest floor in gaps was associated with greater abundance of aerial arthropods in gaps relative to matrix. Some arthropods that birds catch on the wing may be dispersing, but many may be associated with local vegetation, using it for feeding, resting, or hiding. For example, Lepidoptera are particularly important prey for many songbirds, and the adults are commonly consumed by fly-catching bird species (Beaver and Baldwin 1975; Chapter 4). A diversity of understory vegetation may benefit some species of Lepidoptera that use different host plants during phytophagous larval stages than during nectivorous adult stages (i.e., some butterflies; Opler et al. 1995). Other actively flying insects that are prey for insectivorous birds also may be influenced by local plant community characteristics. Wilson's warblers preyed on cantharid and mordellid beetles, which are common on flowers (Borror et al. 1989). Pollinating insects, including members of the orders Hymenoptera and Diptera also were prey for warblers and flycatchers (Chapter 4). The light-rich environment of gaps may provide more flowers for pollinators and nectarivores than the shaded matrix. Similarly, plants in the understory of thinned stands may produce more flowers than those under a more closed canopy (Harrington et al. 2003).

Structural and species diversity of vegetation correlates positively with the variety of habitats and resources available for invertebrates (Schowalter 1995, Lawton 1983, Southwood et al. 1979). Therefore, it is not surprising that taxonomic richness of arthropod prey increased with cover of understory vegetation. Furthermore, the relationship between vegetation and availability of habitats for arthropods may explain why taxonomic richness was consistently lowest in young unthinned stands, which are

relatively simple in structure and plant species composition (Muir et al. 2002, Bailey and Tappeiner 1998). In contrast, consistently high taxonomic richness of aerial arthropods in GS stands may have been related to high plant and structural diversity characteristic of this stand type (Chambers 1996). Old-growth Douglas-fir forests also typically have high structural and plant diversity (Spies 1991, Spies and Franklin 1991), which has been associated with arthropod diversity (Schowalter 1995), although not for airborne arthropods in particular. In my study, richness of arthropod groups was not consistently higher in mature relative to young and GS stand types, but it did appear to be more stable throughout the season (Fig. 5.1). Prey diversity may be an important attribute of prey availability for birds because higher diversity may equate with more foraging opportunities for more species of birds. The positive association between taxonomic richness of aerial prey and cover of deciduous shrubs that I found may contribute to a positive relationship between deciduous shrubs and bird species richness (Muir et al. 2002; Willson and Comet 1996a, 1996b).

All measures of abundance of aerial arthropod prey that I analyzed were positively associated with cover of understory vegetation. Development of understory vegetation can be profuse in naturally created gaps (Franklin and Spies 1991). Partial removal of the overstory by thinning or group selection also can promote development of understory vegetation by increasing the availability of light and other resources. On my study sites, greater abundance of aerial arthropods corresponded with greater cover of understory vegetation in small (0.2 ha) gaps relative to matrix, and in thinned compared to unthinned young stands (Chapter 2). Cover of deciduous shrubs was a particularly important correlate for all measures of aerial prey abundance and diversity. The abundance of both aerial (Jokimaki et al. 1998) and sedentary arthropod taxa (Chapter 4) in temperate coniferous forests has been positively correlated with deciduous shrubs. In coniferous forests in western Oregon, 57% of all lepidopteran species richness and 69% of the abundance of moths are associated with hardwoods (Hammond and Miller 1998). The positive correlation that I found between cover of deciduous shrubs and Lepidoptera captures is consistent with this pattern. Herbs and grasses also support a significant proportion of Lepidoptera species in western Oregon

(31%; Hammond and Miller 1998) and have been positively associated with arthropod abundance in general (Blenden et al. 1986). Thinned Douglas-fir stands support greater species richness and abundance of herbs and grasses than unthinned and old-growth stands (Bailey et al. 1998).

Microenvironmental characteristics, including temperature and moisture, influence the abundance and activity of aerial arthropods and are mediated by vegetation. Because insects are poikilotherms, a minimum temperature is required for flight, but the small size of most insects makes them vulnerable to desiccation. Thus, forest gaps may provide habitats where elevated light and temperature promotes activity of flying insects while vegetation minimizes the negative effects of heat buildups and moisture deficits. A tradeoff likely exists between gap size and the ability of surrounding vegetation to mediate temperature and humidity (Shure and Phillips 1991). Furthermore, the larger a gap becomes the more likely that the spatial distribution of flying insects will be influenced by wind (Whitaker et al. 2000). Gaps in the forest canopy large enough to increase insolation to the understory, but small enough to be undisturbed by wind may be ideal foraging habitat for insectivores that use sallying maneuvers to capture aerial prey because they support concentrations of flying insects near perches. Natural treefall gaps, such as those in old-growth Douglas-fir stands, and gaps created by partial harvesting, as in the thinned and group selection stands that I sampled, seem to fit these criteria.

In conclusion, the abundance of aerial arthropod prey for birds was positively associated with forest understory cover, particularly of deciduous vegetation. Understory cover, in turn, is influenced by forest management practices that manipulate overstory cover. Small gaps in the canopy of commercially thinned stands, and larger gaps created by group selection harvests appear to promote conditions favorable to aerial arthropods and some of the insectivorous bird species that prey on them.