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FACTORS INFLUENCING BROWN CREEPER (*CERTHIA AMERICANA*) ABUNDANCE PATTERNS IN THE SOUTHERN WASHINGTON CASCADE RANGE

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Abstract. During the spring of 1984, we sampled arthropods in three young (65–80 years old), three mature (105–130 years old), and three old-growth (375 years old) forest stands in the western hemlock zone of the southern Washington Cascade Range. Crawl traps, designed to collect arthropods crawling upwards on the bark surface of tree boles, and flight traps, designed to catch arthropods alighting on tree boles, were installed on 45 live Douglas-fir trees. Brown Creeper abundance was correlated significantly and positively ($P < 0.01$) with the abundance of spiders (6–11 mm) estimated from the crawl traps. Spiders were found in all six creeper digestive tracts we examined. Spiders of all sizes and soft-bodied arthropods (≥ 12 mm) were the only arthropod variables that were significantly and positively associated with bark furrow depth, which is highly correlated with tree diameter. A quantitative method for estimating bark surface area as it changes with diameter, height, and bark furrow depth was designed to evaluate how arthropod abundances differed with changes in bark structure. We discuss the limitations and usefulness of these arthropod sampling methods.

Key Words: Tree trunk arthropods; Douglas-fir trees; Brown Creepers; bark surface features.

Several species of bark-foraging birds use some tree species and sizes disproportionately as foraging substrates (e.g., Jackson 1979; Morrison et al. 1985, 1987; Lundquist and Manuwal, this volume). Differential use of foraging substrates may partly be attributed to the composition and availability of arthropods (Jackson 1979), which vary in response to the suitability of microclimatic conditions created by bark structure (Jackson 1979, Nicolai 1986).

Characteristics of tree-trunk bark differ both interspecifically (Travis 1977) and intraspecifically with respect to tree size and age (Jackson 1979). In the western hemlock zone, southern Washington Cascades, Douglas-fir (*Pseudotsuga menziesii*) trees have the most rugose bark structure of any tree species and the furrow depths become substantially deeper as the trees increase in diameter. In both old-growth and second growth forest stands of the western hemlock zone, the trunks of large Douglas-fir trees (≥ 50 cm at diameter breast height) are the only substrates used disproportionately as foraging sites by Brown Creepers (*Certhia americana*) during spring and winter (Lundquist and Manuwal, this volume). Brown Creepers typically begin foraging at the base of a tree and proceed up the bole searching for prey.

Our study was designed primarily to determine the degree of association between Brown Creeper and arthropod abundance on Douglas-fir trunk surfaces in three forest age classes. We also evaluated the association between arthropod abundance and changes in bark structure. To achieve these objectives, we designed a method for calculating the bark surface area of tree boles by measuring bark furrow depth. In this paper we compare the arthropod survey techniques we employed.

STUDY AREA AND METHODS

We worked in the U.S. Forest Services' Wind River Ranger District, in coniferous forest stands of the southern Washington Cascade Range. Our study sites were in the low elevation western hemlock zone (Franklin and Dyrness 1973), where western hemlock (*Tsuga heterophylla*) is the primary regenerating tree species in old-growth forest stands. Stands selected for this study originated from natural disturbances and had no silvicultural treatments applied throughout their development. The nine study sites comprised three young (65–80 years old), three mature (105–130 years old), and three old-growth (all 375 years old) forest age classes. Elevations ranged from 420 to 710 m.

Douglas-fir and western hemlock were the most abundant tree species in all forest age classes. Western red cedar (*Thuja plicata*), Pacific yew (*Taxus brevifolia*), western white pine (*Pinus monticola*), and several true fir species (*Abies* spp.) were present in varying amounts in the old-growth stands. The common deciduous tree species included big-leaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), and black cottonwood (*Populus tricocarpa*). Specific details of the plant associations and stand structure of forests in the western hemlock zone are found in Topick et al. (1986).

The annual temperature regime is considered moderate, and most of the precipitation, averaging about 154 cm annually, occurs from October through May. Summers are typically dry and warm (Topick et al. 1986).

Brown Creeper abundance

We counted Brown Creepers by using the variable circular plot (VCP) method (Reynolds et al. 1980). Twelve permanent VCP stations were established at

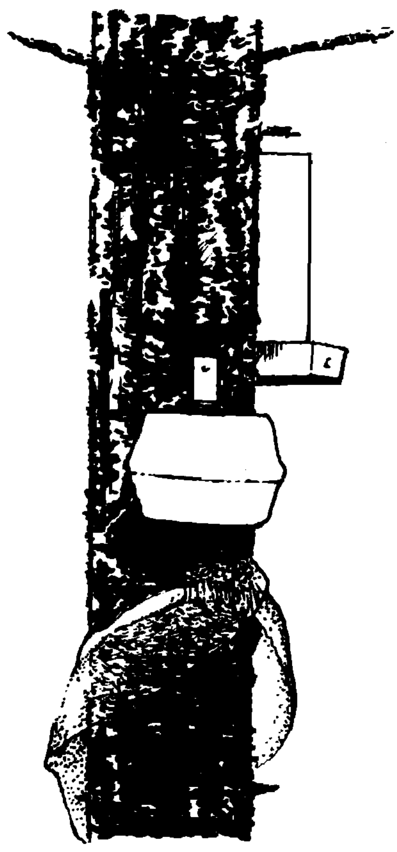

FIGURE 1. Arthropod traps as they were installed on the trunks of 45 Douglas-fir trees in nine forest stands of the southern Washington Cascades. The crawl trap consisted of three basic parts: a removable collecting tray, a cover, and a netting girdle. The flight trap (to the upper right) consisted of a 30 × 30 cm^2 piece of plexiglass suspended by wire clips in a 36 × 7.5 × 5 cm plastic tray.

150-m intervals along a rectangular transect within each stand. Six censuses were conducted in each stand from 25 April to 30 June 1984. We avoided conducting surveys on days with precipitation or high winds. All visual and aural bird detections were recorded for a period of 8 min at each count station. A 1-min pause time followed our arrival at a count station to allow for resumption of normal bird activity. We recorded the estimated horizontal distance from the observer at the plot center to the birds detected. Abundance estimates of Brown Creepers were calculated with the program TRANSECT (Laake et al. 1979) as described by Burnham et al. (1980). Creeper abundances are expressed as birds/40 ha.

Tree abundance

All trees were counted in circular plots centered at each VCP count station. Each tree was identified to species and assigned to one of four size classes measured at diameter breast height. Trees 1–10, 11–50, and 51–99 cm were counted in 0.05 ha plots, and trees ≥100 cm were counted in 0.20 ha plots.

Arthropod sampling

We sampled arthropods from the bark surface of five Douglas-fir tree trunks in each of nine forest stands. All sample trees were within a size range (diameter measured at breast height) known to be average for forest stands of that age class (T. Spies, pers. comm.). We randomly selected five of the 12 VCP bird count stations that had been established in each stand, and within a radius of 25 m of the count station centers one tree was randomly selected on which to install the traps.

Two types of arthropod traps were attached to each tree bole at 1.5 m from the ground. One trap was designed to collect arthropods crawling upward on the bark surface. It consisted of a removable collecting trap, a cover, and a netting girdle (Fig. 1). The netting girdle was attached around the circumference of the tree and followed the contours produced by the bark furrows. The girdle acted as a funnel for arthropods climbing upward on tree trunks by guiding them into the collecting tray. For specific details of the materials, design, and installment, see Moeed and Meads (1983).

The other trap was designed to collect air-borne arthropods that alighted on the tree bole. This flight trap consisted of a 30 × 30 cm^2 piece of plexiglass suspended by wire clips in a 36 × 7.5 × 5 cm plastic tray (Fig. 1). These traps were attached to tree boles by two nails located in the back of the tray, and the tray had two small holes at each end (located 1 cm from the bottom and covered with mesh) to prevent overflow from rainfall.

We began collecting samples from the crawl traps on 9 May 1984 and from the flight traps on 16 May 1984, and collected samples from both traps weekly through 1 August 1984. We collected 165 flight trap samples and 195 crawl trap samples from each forest age class. A total of 495 samples was collected from the flight traps and 595 samples from the crawl traps. Antifreeze was used in the collecting trays of all traps to capture and preserve arthropods, which were removed from the antifreeze and stored in vials containing 70% alcohol.

Bark structure and area

We recorded several measurements on each of the trees sampled for arthropods and on 16 additional (randomly selected) trees in each of the nine forest stands to evaluate changes in bark structure in relation to tree diameter and bark furrow depth. The following measurements were made at diameter breast height on each tree bole: (1) four bark furrow depth measurements equally spaced around the tree bole, (2) tree bole circumference without accounting for furrow depth, and (3) bark circumference taking into account the larger area produced by the depth of bark furrows. We took the last measurement by molding electrical wire around the tree to conform to the contours produced by furrows. Measuring the length of the stretched wire then equaled the circumference of the tree at diameter breast height, accounting for bark furrow depth.

Prey composition

We collected two Brown Creepers from stands in each of the three forest age classes in June. All were shot from the trunks of live Douglas-fir trees after watching them feed. The entire digestive tract was extracted immediately and stored in 70% formaldehyde.

Data Analysis

Arthropod classification and abundance

We sorted, counted, and classified to Order and Family the arthropods from each sample. All insects were grouped into one of six categories defined by exoskeleton condition (hard or soft) and body length: small (1–5 mm), medium (6–11 mm), and large (≥12 mm). The longest insect measured was 27 mm. Spiders were grouped into the same size classes defined above but maintained as separate variables. Size classes were determined by examining the frequencies of individuals measured lengthwise from several randomly chosen samples. Our categorization was based on the assumption that there may be constraints imposed by the morphology of the Brown Creepers' bill for obtaining or ingesting very large arthropods or those with very hard exoskeletons.

To evaluate differences in the types of arthropods collected in each trap, we calculated dry weight biomass of arthropods by body condition (spiders were included in the soft-bodied estimates) and calculated Pearson correlations between weight and abundance for each arthropod category identified.

We calculated Spearman Coefficients of rank-order correlation to examine the various associations of abundance (e.g., creeper and arthropod abundances) or relationships (arthropod abundance and bark furrow depth) being investigated. In most analyses, correlation coefficients were derived using stand level abundance estimates, and the sample sizes equaled nine. We used nonparametric rank-order correlations because we have only indices of abundance, which represent ordinal scale data (Zar 1984:3). All data sets were analyzed using SPSS (Nie et al. 1975).

Estimates of arthropods calculated from crawl traps are expressed as numbers per m^2 of bark surface area, and those from flight traps as numbers per 30 cm^2 (the area encompassing the plexiglass plate).

Bark surface area

To estimate arthropod abundance from the crawl traps, we calculated the bark surface area, including furrow depth sampled under the traps, to express arthropod abundance per unit area.

We used tree circumference, without measures of bark furrow depth, as an independent variable (X), and bark circumference including bark furrow depth as the dependent variable (Y) in two least squares regression models to generate slope and intercept coefficients. One model used measurements taken on 120 trees in young and mature stands (referred to as second growth); the other used measurements taken on 60 trees in old-growth stands. A BASIC computer program was written to calculate the bark surface area of Douglas-fir trees at any given diameter and height. The program incorporated both the slope and intercept coefficients produced by our linear regression models, and taper curve coefficients derived for second and old-growth Douglas-fir trees in British Columbia (D. Briggs, pers. comm., Kozak et al. 1969). Area of bark surface was calculated at 0.5-m intervals to account for changes in diameter and furrow depth.

Spider abundance and bark surface area

Bark surface area encompassing the lower two-thirds of the tree bole was calculated for representative young, mature, and old-growth Douglas-firs. The upper one-third of the tree bole was not included in the analyses because pronounced taper and the presence of limbs introduces additional and less predictable error into bark area calculations (D. Briggs, pers. comm.). We calculated the number of medium (6–11 mm) spiders occurring on a bole (daily and weekly) based on their abundances in the crawl traps. We used spiders of this size because their abundance was correlated most positively and significantly with creeper abundance. We assumed that spider abundance did not vary with height on a bole. We have no quantitative estimate of spider distribution and abundance with tree height so the degree to which this assumption is violated is unknown. The abundance of spiders (6–11 mm) per tree size was used only for considering the potential energy to be derived by creepers from foraging on trees of various sizes.

RESULTS

The probability of incurring Type I errors increases when numerous simple correlations are computed. We attempted to lessen the chance of incurring those errors by focusing only on those correlations significant at the $P < 0.01$ level.

Weekly arthropod abundance and biomass ($N = 13$) were significantly correlated ($r = 0.84$, $P < 0.01$) from the crawl traps only. Of the correlations between bird and arthropod abundances (Table 1), creeper abundance was significantly and positively correlated with the abundance of medium (6–11 mm) spiders measured in the crawl traps only. Brown Creeper abundance was correlated positively with very large (≥100 cm dbh) Douglas-fir trees ($r_s = 0.73$). No significant correlations were found between the abundance of creepers and any other tree species.

The correlation between tree diameter and bark furrow depth was highly significant ($r = 0.92$, $P < 0.0001$). Bark furrow depth was correlated significantly with the abundances of small ($r_s = 0.35$, $P < 0.01$), medium ($r_s = 0.77$, $P < 0.001$), and large spiders ($r_s = 0.66$, $P < 0.001$), and soft-bodied large arthropods ($r_s = 0.49$, $P < 0.001$).

Because of the low sample size ($N = 6$), we have only a qualitative assessment of prey capture by Brown Creepers. Spiders were present in the digestive contents of all six creepers and one creeper also contained numerous spider eggs. Unidentified larvae and pupae of the order Lepidoptera were found in three creepers, and soft-bodied adult arthropods of the orders Diptera

TABLE 1. Spearman Coefficients of Rank-Order Correlation Measuring the Degree of Association between Brown Creeper (Birds/40 ha) and Arthropod Abundance. Arthropods Were Sampled from 9 May through 1 August 1984 in Nine Forest Stands of the Southern Washington Cascade Range

Arthropod variables	Trap type	
	Crawl	Flight
Spiders		
Small (1–5 mm)	−0.18	0.68**
Medium (6–11 mm)	0.82***	0.49
Large (≥12 mm)	0.14	−0.27
Soft-bodied types		
Small (1–5 mm)	−0.63**	0.07
Medium (6–11 mm)	0.28	0.20
Large (≥12 mm)	−0.14	−0.39
Hard-bodied types		
Small (1–5 mm)	−0.25	−0.10
Medium (6–11 mm)	−0.08	0.56
Large (≥12 mm)	−0.64**	0.48
Total arthropod abundance	−0.65**	0.08

*** Significant at $P < 0.01$; ** $P < 0.05$.

(1), Neuroptera (1), Tricoptera (1), Lepidoptera (3), Hemiptera (2), and Homoptera (1), were found in the digestive tracts of four creepers. Coleoptera were found in the digestive contents of two creepers.

One Douglas-fir tree (112 cm dbh and 53 m tall) had 125 m^2 of bark surface area encompassing two-thirds of the height, a mature tree (67 cm dbh and 44 m tall) had 61.4 m^2, and a young tree (29 cm dbh and 30 m tall) had 18 m^2. We multiplied these areas by the average number of spiders found daily on trees in young, mature, and old-growth forests. We found that a creeper would have to fly to 13 young trees (29 cm dbh) or 3.3 mature trees (67 cm dbh), to obtain the same number of spiders available on one old-growth tree 112 cm dbh. Average daily spider estimates were 0.26/m^2 in old-growth, 0.17/m^2 in mature, and 0.14/m^2 in young stands.

DISCUSSION

Surveying even one substrate may require using more than one trapping technique because of the high temporal and spatial variability associated with arthropod abundance. The two traps we used were designed primarily to capture arthropods that use different types of locomotion. Both sampled an unknown amount of air space; the crawl traps also sampled an unknown area of forest floor surrounding the tree. Biomass of arthropods captured in the flight traps was more variable than those captured in the crawl traps. The flight traps often captured swarming arthropods (e.g., Diptera: Chironomidae) whose weights were slight relative to numbers. Both traps captured spiders; some of the spiders in the flight traps may have been young that "balloon" to colonize new substrates (R. Gara, pers. comm.). In general, the flight traps were ineffective for establishing relationships between creeper and arthropod abundances.

We did no observations of capture efficiency (i.e., the proportion of arthropods encountering a trap and subsequently caught) for either trap. Moeed and Meads (1983) found that for crawl traps only a few cockroaches (Blattodea) and ground beetles (Coleoptera) avoided capture by climbing over the netting girdle, and some Collembolla and mites (Acari) passed through the 1.5 mm mesh of the netting girdle. They observed spiders residing in down-traps (designed to capture arthropods crawling downward on tree trunks) on three occasions and on up-traps on one occasion but concluded that these were isolated instances and likely had no effect on capture rates for other insects.

We installed up-type (crawl) traps only and never observed spiders residing in them. Periodically checking and cleaning our traps between scheduled sampling periods was not feasible because our sites were not readily accessible.

Our study was an exploratory analysis of associations between Brown Creepers and certain habitat characteristics, including potential food resources. Whole prey items found in creeper digestive tracts were never larger than our medium-sized category, but arthropods with both hard and soft body conditions were present. Although not conclusive, bill morphology may not limit creepers' use of food items, as we had assumed.

We did not compare Brown Creeper use of prey items in comparison to the relative abundance of prey, but our results suggest that spiders may have been an important food item for creepers during the 1984 breeding season. The significant relationship between creeper abundance and very large trees may have been mediated to some extent by the deep bark furrows on such trees. Large trees or those with deeper furrows tend to have high densities of spiders (New Zealand—Moeed and Meads 1983; Europe—Nicolai 1986; USA—this study) and large, soft-bodied arthropods (this study). Spiders apparently comprise a major food source for creepers (e.g., Martin et al. 1951, this study), and Kuitunen and Tormala (1983) found that 90% of the food items (by number) brought to Treecreepers (*Cethia familiaris*) in Finland were spiders. Finally, spiders have a higher protein content than insects (Hurst and Poe 1985), perhaps making them a premium food item for small birds, and especially for creepers, which expend considerable energy climbing upward on tree boles (Norberg 1986).

Bark furrow depths, which are significantly correlated with tree size, increase available foraging substrate without substantially increasing the actual area over which the bird has to move to search for prey. Based on our calculations of bark surface area and the number of spiders (6–11 mm) potentially occurring on trees of various sizes, we hypothesize that creepers may be able to increase their energy intake by foraging on one large diameter Douglas-fir tree versus numerous small trees.

We conducted this study during a short time frame and our methods enabled us to conduct only descriptive types of analyses. Arthropod abundance and composition on tree trunks are affected by a combination of several factors including the microclimatic conditions produced by bark features (Nicolai 1986), the presence of fungi and epiphytes on bark, the proximity and composition of surrounding vegetation (Jackson 1979), and the tree species' relative abundance throughout recent geological history (Southwood 1961).

More comprehensive and intensive sampling efforts of arthropod populations are needed within and among seasons and on a long term basis. This information would be especially useful if collected in the context of examining the effects that habitat alterations have on food resource availability.

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