Performance of two arboreal pitfall trap designs in sampling cursorial spiders from tree trunks

Jaime Pinzón and **John Spence**:   Invertebrate Ecology Laboratory, Department of Renewable Resources, 442 Earth Sciences Building, University of Alberta, Edmonton, Canada, T6G 2E3. E-mail: jpinzon@ualberta.ca

Abstract.   Tree trunks link the forest floor and higher canopy layers, thus constituting an important habitat element for many arthropod species, including spiders living in the canopy. We sampled spiders moving on tree trunks in the boreal forest using two trap designs referred to as "bottle traps" (BT) and "cup traps" (CT) placed on both trembling aspen (*Populus tremuloides* Michaux) and white spruce (*Picea glauca* (Moench) Voss) trees of similar DBH (diameter at breast height). Over an average of 83.5 ± 6.3 days/trap (48 traps), we collected a total 333 spiders, representing 13 families and 33 species. *Clubiona canadensis* Emerton 1890 (Clubionidae), *Callobius bennetti* (Blackwall 1846) (Amaurobiidae), *Pocadicnemis americana* Millidge 1976 (Linyphiidae), and *Orodrassus canadensis* Platnick & Shadab 1975 (Gnaphosidae) were the most commonly collected species, representing more than 60% of the total catch. Twenty eight species and 285 individuals were collected by BTs compared to 18 species and 48 individuals by CTs. Catches in BTs included 15 unique species, whereas five species were unique in CT catches. BTs are easier to transport and deploy, they catch more spiders per trap, and appear to more efficiently sample spider diversity. Thus we recommend the use of BTs to effectively sample wandering spiders on tree trunks; however, the use of both designs could increase understanding about the role of tree trunks as structural features linking forest canopies to the ground layers below.

Keywords: Sampling, arboreal fauna, Araneae, boreal forest, mixedwood, Canada

Tree trunks are an important structural feature in forest ecosystems because they link the forest floor and the canopy (Moeed & Meads 1983). Structural characteristics of trees affect the composition, abundance, and distribution of tree-dwelling organisms (Palik & Engstorm 1999). Tree bark is a key component for maintaining biodiversity in managed and unmanaged forests (Hanula et al. 2000); for example, habitat structural diversity provided by bark influences spider assemblages (Horvath et al. 2005), suggesting that this complexity is correlated with abundance of predators (Langellotto & Denno 2004). Recent studies have shown that high species richness of lichens on spruce trees positively influenced spider species richness (Gunnarsson et al. 2004). In addition, tree bark provides shelter for overwintering arthropods (Pekar 1999), and provides resting places or habitat islands for arthropods that are dispersing across habitats (Proctor et al. 2002).

Sampling techniques developed to collect arthropods moving on and inhabiting tree trunks include stem-eclectors (Funke 1971), emergence traps (Glen 1976), arboreal photo-eclectors (Moeed & Meads 1983), vacuum samplers (Nicolai 1986), branch traps (Koponen et al. 1997; Koponen 2004), corrugated cardboard bands (Pekar 1999; Isaia et al. 2006), time stem-eclectors (Simon et al. 2001), intercept traps (Majer et al. 2003), sticky traps (Basset et al. 2003), polyethylene bubble wraps (Roberts & Roberts 1988; Isaia et al. 2006), artificial shelters (Hodge et al. 2007), among many others (Basset et al. 1997; Szinetar & Horvath 2005). Some of these techniques are especially well-suited for sampling certain arthropod groups in relation to their activity patterns or microhabitat associations; others are expensive and difficult to transport or operate under field conditions. Some of these traps are effective for collecting spiders in trees (e.g., branch traps, corrugated cardboard bands) but generally particular traps target only some groups (e.g., foliage-dwelling spiders, under bark-dwelling spiders). Overall, there is a lack of

agreement about which trap designs are most suitable and appropriate for collecting arthropods associated with tree bark. As a consequence, knowledge about the arthropod fauna inhabiting tree trunks remains preliminary (Roberts & Roberts 1988), although we are starting to understand species composition and habitat/microhabitat associations for spiders (Szinetar & Horvath 2005).

In this paper we present two new designs for traps that are easy to transport and to set and operate to collect spiders on tree boles in the field. Deployment of these traps is cost effective, allowing use of many traps so as to improve sampling effort and reliability of resulting data (Churchill & Arthur 1999). Additionally, we compared trap performance (in terms of spider abundance and richness) between these trap designs. Furthermore, we report a small experiment to estimate the variation in spider species composition between trunks of two common tree species in the mixedwood boreal forest.

METHODS

Study Site, Experimental Design and Sampling.—Traps were deployed during the summer of 2006 at the Ecosystem Management Emulating Natural Disturbance (EMEND) field site located in the Clear Hills Upland, Lower Foothills Ecoregion of northwestern Alberta, Canada (56°46′13″N, 118°22′28″W). This region is covered by a mosaic of different successional stages of boreal mixedwood forest dominated by aspen (*Populus tremuloides* Michaux), balsam poplar (*P. balsamifera* L.), white spruce (*Picea glauca* (Moench) Voss), and black spruce (*P. mariana* (Miller)). Two different traps designed to collect spiders moving on tree trunks (see below) were tested in three different stands of uncut mixedwood forest (minimum distance between stands ca. 3 km). In each stand, eight traps (four of each design) were placed on the boles of eight aspen and eight white spruce trees of similar DBH (diameter at breast height) selected haphazardly, for a
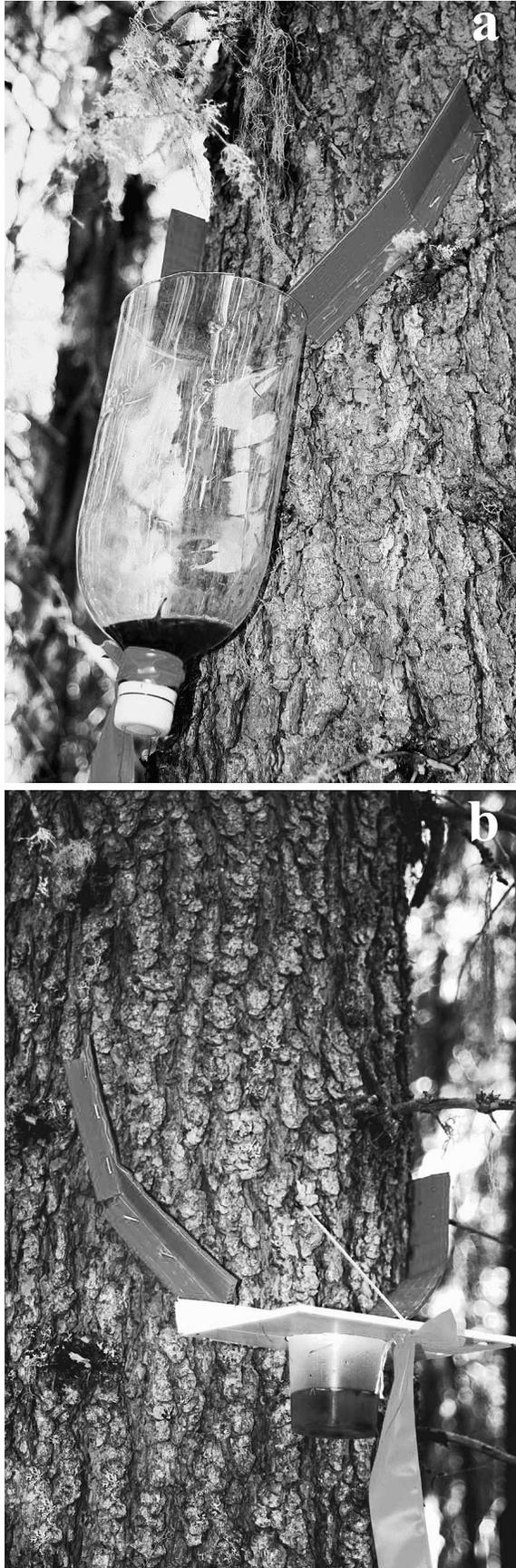
total of 16 traps per stand. Trees sampled were at least 10 m apart and traps were all placed 2 m from the ground.

Spiders were collected from the traps in four collection periods at 3-wk intervals from 28 May to 24 August 2006 and preserved in 70% ethanol. Specimens were sorted and adult individuals were identified to species using relevant literature (Dondale & Redner 1978, 1982, 1990; Platnick & Dondale 1992; Dondale et al. 2003; Paquin & Dupérré 2003; Ubick et al. 2005), nomenclature followed the World Spider Catalog V8.5 (Platnick 2008). Voucher specimens are presently held in the Spence laboratory collection (Department of Renewable Resources, University of Alberta).

Trap Design.—"Bottle Traps" (BTs) were inverted 2 liter pop bottles (11.1 cm diameter) with the bottoms removed (Fig. 1a). These were stapled to the surface of the trees to be sampled. "Cup Traps" (CTs) consisted of 20×20 cm heavy plastic board sheets stapled to the sample trees, each sheet fitted with a 4 oz plastic cup; a 4.1 cm diameter opening for the cup was cut in the center of each board and a string attached to the distal edge of the board was stapled to the tree to maintain the trap in a horizontal position (Fig. 1b). A 5×20 cm plastic strip was placed on each side of traps of both designs, acting as a fence to direct spiders into the devices. Silicate-free ethylene glycol was used as a preservative in both kinds of traps.

Data Analysis.—Captures from each trap were pooled over the entire sampling period, and abundance of each species was standardized to spiders/day to adjust for uneven sampling resulting from animal disturbance. It has been suggested that trap perimeter affects catch (Luff 1975; Work et al. 2002). Thus, to test if differences in spider catch can be simply explained by trap perimeter or reflect actual trap performance, both standardized abundance and richness values were adjusted for trap perimeter, dividing these parameters by the trap circumference (BT = 34.87 cm; CT = 12.88 cm). Both non-adjusted and adjusted standardized values were compared.

Trap performance was assessed comparing standardized abundance and richness using rarefaction estimates with non-standardized abundances (Magurran 1988). Differences between trap designs, tree species, forest stands, and the interaction of these variables were analyzed for both adjusted and non-adjusted standardized abundance and richness values using factorial analyses of variance (ANOVA, $\alpha = 0.05$) in R (R Development Core Team 2007), using the CAR package (Fox 2007). Rarefaction estimates were calculated in R (R Development Core Team 2007) using the VEGAN package (Oksanen et al. 2007). In addition a post hoc power analysis ($\alpha = 0.05$) (Cohen 1988) was carried out in R (R Development Core Team 2007) using the PWR package (Champley 2007) for each factor (stand, tree species, trap design) with adjusted and non-adjusted data to determine the probability of Type II error and thus, determine if sample size was sufficient to support conclusions.

$\leftarrow$

Figure 1.—Arboreal pitfall trap designs. a. Bottle Trap design (BT). b. Cup Trap design (CT). For details see text.

RESULTS

Over the four collections, 4.7% of the traps were disturbed by animals (six traps in the first collection and three in the second) and six traps (all CTs) collected no spiders throughout the sampling period. Thus, sampling effort averaged 83.5 ± 6.3 days/trap. In total, 13 families, 33 species and 333 individuals (Table 1) were captured. *Clubiona canadensis* Emerton 1890 (Clubionidae), *Callobius bennetti* (Blackwall 1846) (Amaurobiidae), *Pocadicnemis americana* Millidge 1976 (Linyphiidae), and *Orodrassus canadensis* Platnick & Shadab 1975 (Gnaphosidae) were the most abundantly collected species, collectively representing more than 60% of the total catch. Each of the remaining species in the catch was represented by fewer than 17 individuals.

Trap performance.—Both adjusted and non-adjusted standardized abundances and richness differed significantly between trap designs (Abundance: $df = 1, 42$ (for all comparisons of trap design), adjusted $F = 19.19$, $P < 0.0001$; non-adjusted $F = 61.80$, $P < 0.0001$. Richness: adjusted $F = 4.17$, $P = 0.049$; non-adjusted $F = 91.46$, $P < 0.0001$), suggesting higher abundance and richness in BTs. In addition, our analyses detected no significant differences in standardized abundance for either adjusted or non-adjusted data between tree species ($df = 1, 42$ (for all comparisons of tree species), adjusted $F = 1.20$, $P = 0.29$; non-adjusted $F = 0.47$, $P = 0.49$); however, richness adjusted values showed significant difference ($F = 4.31$, $P = 0.045$), indicating a slight higher adjusted richness in white spruce, however non-adjusted values showed no difference ($F = 1.32$, $P = 0.26$). Likewise, catch did not vary significantly among stands with respect to either abundance ($df = 2, 42$ [for all comparisons of stands], adjusted data $F = 1.77$, $P = 0.19$; non-adjusted $F = 1.08$, $P = 0.35$) or richness (adjusted $F = 3.0764$, $P = 0.058$; non-adjusted $F = 2.50$, $P = 0.10$). There was no significant interaction between trap design and tree species for abundance ($df = 1, 42$ [for all comparisons of interaction of tree species and trap design], adjusted $F = 0.2508$, $P = 0.62$; non-adjusted $F = 4.074e-06$, $P = 0.998$) and for the non-adjusted richness data ($F = 1.32$, $P = 0.26$). However, this "design × trap" interaction was significant for the adjusted richness values ($F = 4.31$, $P = 0.045$). Power analysis showed that the probability of Type II error in these comparisons is less than 0.01 for both adjusted and non-adjusted data.

BTs collected an average of 11.88 ± 1.18 spiders and 5.83 ± 0.42 species per trap in contrast to CTs that collected an average of 2.00 ± 0.35 spiders and 1.67 ± 0.25 species per trap. Thirteen species were collected in traps of both designs accounting for 39.4% of the total catch; BTs captured 15 unique species as compared to five unique species in CTs. An average of 7.54 ± 1.43 spiders and 4.00 ± 0.48 species were collected per trap on spruce trees, whereas in aspen an average of 6.33 ± 1.25 spiders and 3.30 ± 0.62 species were collected per trap. Eighteen species were observed on both spruce and aspen trees and these accounted for 54.6% of the total catch. Eight species were collected only on spruce and eight species only on aspen.

These results indicate that BT samples had both higher abundance and richness (Fig. 2) and this supports the use of this trap for assessing the spider fauna that is moving along tree trunks. However, rarefaction curves indicate that CTs collect a higher number of species based on the same number of individuals (Fig. 2).

Bark-dwelling spider assemblages in the boreal forest.—According to data about habitats in which the species in our traps were previously collected (Table 1), and to the habitat association classification proposed by Wunderlich (1982), 11 species can be characterized as accidental, three species as either accidental or facultative, eight as facultative, and two as either facultative or exclusive.

DISCUSSION

Trap performance.—In general, spider catch was low considering the number of traps placed in each forest stand. Spiders use tree bark only temporarily (Horvath et al. 2005) and our results suggest that spider activity is low on tree trunks. We remain convinced, however, that these trap designs provide reasonable samples of spider assemblages using the bole as habitat. The relatively high abundance of *C. canadensis*, which is generally associated with tree bark (Dondale & Redner 1982), and *C. bennetti*, which is a typical bark-dwelling spider, suggests that traps of both designs actually collect a representative fauna from this habitat.

Performance of BTs and CTs differed significantly, although the significance of the trap design effect is marginal for species richness adjusted for trap perimeter. This suggests that differences in abundance in fact reflect differences in trap efficiency but that differences in richness might be confounded by the low number of species observed in the tree bark habitat. Nonetheless, BTs collected six times more spiders and almost twice as many species as did CTs, in fact, six out of 24 CTs collected no spiders. Less than half of the species recorded were collected in both traps (13 spp.) and in general these were more abundant in BTs (Table 1). In addition, a large proportion of species were collected only in BTs but few species were unique to CTs. Abundances of species unique to one trap design were very low, mainly singletons and doubletons. *Cryphoeca montana* Emerton 1909 (Hahniidae) was the most abundant of these unique species (8 individuals, Table 1).

The better performance of BTs is probably due mainly to how they work. The opening of a BT is in direct contact with the tree bark (Fig. 1a) and, thus, there is higher probability that spiders will crawl into the device than first crawling out onto the horizontal platform (Fig. 1b) and then into a cup. At a low level of overall activity, differences in catch between CTs and BTs could be highly significant to the quality of faunal assessment achieved. Despite a clear difference in quantitative performance in favor of BTs, rarefaction curves suggest that under a similar sampling effort CTs collect more species. However, to collect a comparable number of species and individuals as in BTs, considerably more sampling effort must be expended using CTs.

Given the above results, we recommend use of BTs to effectively sample wandering spiders on tree trunks. In addition to performing well, BTs are easy to set and transport in the field. They are also cost effective; 2 liter plastic pop bottles can be purchased inexpensively in high quantities in any recycling center. The combination of species characteristics and microhabitat affinities inevitably biases any trap catch. Thus, we also recommend that other sampling

Table 1.—Total spider abundance by tree species and trap design and habitat association in a mixedwood forest in northwestern Alberta, Canada. Trap design: BT= Bottle Trap, CT= Cup Trap. Habitat Association: E=Exclusive, F=Facultative, A =Accidental.

Family	Species	Picea glauca BT	Picea glauca CT	Populus tremuloides BT	Populus tremuloides CT	Total	Habitat association	References for habitat association
Agelenidae	Agelenopsis utahana (Chamberlin & Ivie 1933)	3	2	2		7	A	(Lowrie 1948; Jennings et al. 1988; Buddle 2001)
Amaurobiidae	Amaurobius borealis Emerton 1909	1	1	2		4	A	(Jennings et al. 1988; Buddle 2001; Varady-Szabo & Buddle 2006)
	Callobius bennetti (Blackwall 1846)	48	2	17	1	68	A, F	(Szinetar & Horvath 2005; Varady-Szabo & Buddle 2006)
	Callobius nomeus (Chamberlin 1919)	1				1	A, F	(Aitchison-Benell & Dondale 1990)
Araneidae	Araneus sp1			1		1	—	—
	Araneus sp2		1			1	—	—
	Araniella displicata (Hentz 1847)	2				2	A	(Jennings & Collins 1986; Jennings & Dimond 1988; Jennings et al. 1990; Dondale et al. 2003)
	Cyclosa conica (Pallas 1772)	2	2	2		6	A	(Dondale et al. 2003)
Clubionidae	Clubiona canadensis Emerton 1890	24	2	44	6	76	F	(Dondale & Redner 1982; Jennings & Dimond 1988; Jennings et al. 1988; Buddle 2001)
	Clubiona moesta Banks 1896			1		1	F, E	(Dondale & Redner 1982; Buddle 2001)
Dictynidae	Dictyna brevitarsa Emerton 1915				1	1	F	(Jennings & Collins 1986; Jennings & Dimond 1988; Jennings et al. 1988; Jennings et al. 1990)
	Emblyna annulipes (Blackwall 1846)				1	1	A	(Hagley & Allen 1989)
Gnaphosidae	Orodrassus canadensis Platnick & Shadab 1975	14	2	9	1	26	A	(Jennings & Collins 1986; Jennings et al. 1988; Platnick & Dondale 1992)
Hahniidae	Cryphoeca montana Emerton 1909	5		3		8	A	(Koponen 1987; Jennings et al. 1988; Larrivee et al. 2005; Varady-Szabo & Buddle 2006)
Linyphiidae	Drapetisca alteranda Chamberlin 1909	1				1	F	(Buddle 2001)
	Estrandia grandaeva (Keyserling 1886)		1		1	2	F	(Pettersson 1996)
	Incestophantes calcaratus (Emerton 1909)	5	4	6	1	16	—	—
	Pityohyphantes costatus (Hentz 1850)	2	1	2		5	A	(Jennings & Collins 1986; Jennings & Dimond 1988)
	Pityohyphantes subarticus Chamberlin & Ivie 1943	2	3	1		6	—	—
	Pocadicnemis americana Millidge 1976	19	6	21	2	48	F	(Jennings & Dimond 1988; Jennings et al. 1988; Larrivee et al. 2005)
	Walckenaeria auranticeps (Emerton 1882)			2		2	—	—
Liocranidae	Agroeca ornata Banks 1892	3				3	A	(Dondale & Redner 1982; Koponen 1987; Buddle et al. 2000; Varady-Szabo & Buddle 2006)
Lycosidae	Pardosa mackenziana (Keyserling 1877)	1				1	A	(Dondale & Redner 1990; Buddle 2000; Buddle et al. 2000; Buddle 2001)
Philodromidae	Philodromus pernix Blackwall 1846	3		1		4	F, E	(Lowrie 1948; Dondale & Redner 1978; Jennings & Dimond 1988; Jennings et al. 1990)
	Philodromus placidus Banks 1892	3	1	2	1	7	F	(Dondale & Redner 1978; Jennings & Collins 1986; Jennings & Dimond 1988; Jennings et al. 1990)
	Philodromus rufus quartus Dondale & Redner 1968	1				1	F	(Dondale & Redner 1978; Jennings & Collins 1986; Jennings & Dimond 1988)
Salticidae	Pelegrina flaviceps (Kaston 1973)	1				1	—	—
	Pelegrina flavipes (Peckham & Peckham 1888)			1		1	—	—
	Sitticus finschi (L. Koch 1879)			1	1	2	—	—
Theridiidae	Enoplognatha intrepida (Sorensen 1898)	3				3	—	—
	Theridion montanum Emerton 1882	5	1	8	2	16	A, F	(Jennings & Collins 1986; Jennings & Dimond 1988; Jennings et al. 1988)
Thomisidae	Xysticus canadensis Gertsch 1934	1	1	7		9	A	(Dondale & Redner 1978; Jennings et al. 1988; Pearce et al. 2004; Larrivee et al. 2005)
	Xysticus obscurus Collett 1887	1		1		2	A	(Dondale & Redner 1978; Koponen 1987)
Total		151	30	134	18	333		

techniques should be employed while we are developing a more mature understanding of bark-dwelling spider species. Both trap designs introduced here can contribute to these efforts.

Bark-dwelling spider assemblages in the boreal forest.— Trunks of white spruce trees are structurally more complex than are those of trembling aspen. For example, spruce trees have more branches and these carry needles, even near to the ground, while aspen branches are restricted to higher layers of the canopy. In addition bark of spruce trees is of much rougher texture than is that of aspen. More microhabitats appear to be available on spruce tree boles and, thus, one might expect these to harbor a more diverse assemblage of bark-dwelling spiders. Even though most of our analyses demonstrated no significant effect of tree species on the spider catch, we did detect a significant but weak difference between tree species using richness values adjusted for trap perimeter. Nonetheless, the lack of apparent difference between catches on these two tree species with considerably different habitat quality suggests that most spiders captured on living tree trunks are using the boles mainly as movement corridors, rather than as habitat.

Bark-dwelling spiders have been classified according to how strongly connected they are to this habitat (Wunderlich 1982) as follows: 1) Exclusive bark-dwellers are species that live on or under the bark during all or most part of their life cycle; 2) Facultative bark-dwellers are species that typically, but not exclusively, use this habitat; and 3) Accidental species are typically from other habitats and use bark habitats by chance or as an alternative. According to Szinetar & Horvath (2005) of the 289 European species that have been recorded in tree trunks, 65% are accidental species, 27% are facultative species, and only 8% are exclusive bark-dwellers. In North America information on bark-dwelling species is scarce and scattered (e.g., Lowrie 1948; Bennett 2001; Buddle 2001; Holmberg & Buckle 2002); in particular, little is known about spider composition on tree trunks in the boreal forest, and thus habitat associations are difficult to determine.

Given the information available about habitat associations for species collected during the present study, we identify a similar trend in the boreal forest to that above: we found a higher proportion of accidental species and a lower proportion of facultative or exclusive species (Table 1). One third of the total number of species can be characterized as accidental species on tree bark, whereas only a few species could be categorized as facultative and/or exclusive, supporting the idea that most of the species present in tree trunks are using this habitat temporarily and that only a few species are true bark-dwellers. Although these species represent a small part of the overall fauna (standing dead trees were not included in this study), those species that are facultative or exclusive in use of trunk habitats should be considered as significant biodiversity components, especially if there are species associated with standing dead trees.

Further research should be focused on the role of bark-dwelling spider assemblages in the boreal forest, especially those dependent on dead trees. Buddle (2001), for example, showed that spider assemblages collected directly from downed woody material (DWM) are highly similar to assemblages collected on the forest floor. Our work supports
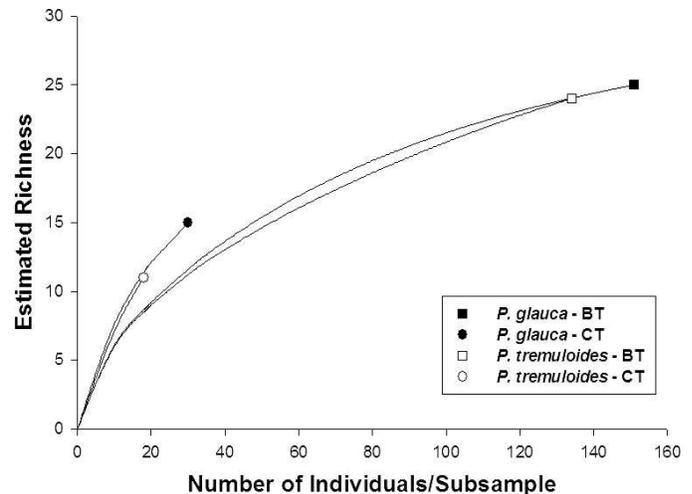

Figure 2.—Rarefaction curves for two arboreal pitfall trap designs in *P. glauca* and *P. tremuloides* trees in a mixedwood forest. BT: Bottle Trap design, CT: Cup Trap design.

a similar conclusion because many of the species collected in BTs and CTs are also common either on the foliage (J. Pinzon, unpublished data) or on the forest floor (Dondale & Redner 1978, 1982; Buddle 2001). However, little is known about the spider composition on dead standing trees in the boreal forest; as a consequence, at this point, it is difficult to determine if specialists inhabit this habitat or if the species composition in dead standing trees is comparable to that in living trees.

One set of species commonly found on tree trunks are not exclusively bark-dwellers because they are common in other habitats, such as forest litter and foliage (e.g., *Agelenopsis utahana* (Chamberlin & Ivie 1933) (Agelenidae), *Amaurobius borealis* Emerton 1909 (Amaurobiidae), *C. canadensis*, *O. canadensis*, *Pityohyphantes costatus* (Hentz 1850) (Linyphiidae)). Such species could use tree boles either as a connection between the forest floor and higher layers of the forest, as a suitable place for mating, foraging for food, or for hiding from predators. This study provides new trap designs for exploring the fauna of spiders using tree trunks. In addition some information regarding bark dwelling spiders in the boreal forest is presented, however these traps could be used in any kind of forest. Using BTs to thoroughly sample this type of habitat for spiders will increase understanding of the role of tree trunks and standing dead trees as habitats and structural features for spider assemblages as components of biodiversity in forested ecosystems.

LITERATURE CITED

Aitchison-Benell, C.W. & C.D. Dondale. 1990. A checklist of Manitoba spiders (Araneae) with notes on geographic relationships. Naturaliste Canadiene 117:215–237.

Basset, Y., H.P. Aberlenc, H. Barrios & G. Curletti. 2003. Arthropod diel activity and stratification. Pp. 304–314. *In* Arthropods of Tropical Forests. (Y. Basset, V. Novotny, S. Miller & R. Kitching, eds.). Cambridge University Press, Cambridge, UK.

Basset, Y., N.D. Springate, H.P. Aberlenc & G. Delvare. 1997. A review of methods for sampling arthropods in tree canopies. Pp. 27–51. *In* Canopy Arthropods. (N.E. Stork, J. Adis & R.K. Didham, eds.). Chapman & Hall, London.

Bennett, R.G. 2001. Spiders (Araneae) and araneology in British Columbia. Journal of the Entomological Society of British Columbia 98:85–92.

Buddle, C.M. 2000. Life history of *Pardosa moesta* and *Pardosa mackenziana* (Araneae, Lycosidae) in central Alberta, Canada. Journal of Arachnology 28:319–328.

Buddle, C.M. 2001. Spiders (Araneae) associated with downed woody material in a deciduous forest in central Alberta, Canada. Agricultural and Forest Entomology 3:241–251.

Buddle, C.M., J.R. Spence & D.W. Langor. 2000. Succession of boreal forest spider assemblages following wildfire and harvesting. Ecography 23:424–436.

Champley, S. 2007. PWR: Basic functions for power analysis, R package version 1.1. Online at http://rss.acs.unt.edu/Rdoc/library/pwr/html/00Index.html.

Churchill, T.B. & M. Arthur. 1999. Measuring spider richness: effects of different sampling methods and spatial and temporal scales. Journal of Insect Conservation 3:287–295.

Cohen, J. 1988. Statistical Power Analysis for the Behavioral Sciences, Second edition. Lawrence Erlbaum Associates, Hillsdale, New Jersey. 567 pp.

Dondale, C.D. & J.H. Redner. 1978. The insects and arachnids of Canada. Part 5. The Crab Spiders of Canada and Alaska (Araneae: Philodromidae and Thomisidae). Agriculture Canada Publication 1633. Ottawa. 255 pp.

Dondale, C.D. & J.H. Redner. 1982. The insects and arachnids of Canada. Part 9. The Sac Spiders of Canada and Alaska (Araneae: Clubionidae and Anyphaenidae). Agriculture Canada Publication 1724. Ottawa. 194 pp.

Dondale, C.D. & J.H. Redner. 1990. The insects and arachnids of Canada. Part 17. The Wolf Spiders, Nurseryweb Spiders, and Lynx Spiders of Canada and Alaska (Araneae: Lycosidae, Pisauridae, and Oxyopidae). Agriculture Canada Publication 1856. Ottawa. 383 pp.

Dondale, C.D., J.H. Redner, P. Paquin & H.W. Levi. 2003. The insects and arachnids of Canada. Part 23. The Orb-weaving Spiders of Canada and Alaska (Araneae: Uloboridae, Tetragnathidae, Araneidae, Theridiosomatidae). NRC Research Press, Ottawa. 371 pp.

Fox, J. 2007. CAR: Companion to applied regression, R Package version 1.2-7. Online at http://cran.r-project.org/web/packages/car/index.html.

Funke, W. 1971. Food and energy turnover of leaf-eating insects and their influence on primary production. Pp. 81–93. *In* Ecological Studies 2. (H. Ellenberg, ed.). Springer-Verlag, Berlin.

Glen, D.M. 1976. An emergence trap for bark-dwelling insects, its efficiency and effects on temperature. Ecological Entomology 1:91–94.

Gunnarsson, B., M. Hake & S. Hultengren. 2004. A functional relationship between species richness of spiders and lichens in spruce. Biodiversity and Conservation 13:685–693.

Hagley, E.A.C. & W.R. Allen. 1989. Prey of the cribellate spider, *Dictyna annulipes* (Araneae, Dictynidae), on apple tree foliage. Journal of Arachnology 17:366–367.

Hanula, J.L., K.E. Franzreb & W.D. Pepper. 2000. Longleaf pine characteristics associated with arthropods available for red-cockaded woodpeckers. Journal of Wildlife Management 64:60–70.

Hodge, S., C.J. Vink, J.C. Banks & M.H. Bowie. 2007. The use of tree-mounted artificial shelters to investigate arboreal spider communities in New Zealand nature reserves. Journal of Arachnology 35:129–136.

Holmberg, R.G. & D.J. Buckle. 2002. Prairie spiders of Alberta and Saskatchewan. Arthropods of Canadian Grasslands 8:11–15.

Horvath, R., S. Lengyel, C. Szinetar & L. Jakab. 2005. The effect of prey availability on spider assemblages on European black pine (*Pinus nigra*) bark: spatial patterns and guild structure. Canadian Journal of Zoology-Revue Canadienne De Zoologie 83:324–335.

Isaia, M., F. Bona & G. Badino. 2006. Comparison of polyethylene bubble wrap and corrugated cardboard traps for sampling tree-inhabiting spiders. Environmental Entomology 35:1654–1660.

Jennings, D.T. & J.A. Collins. 1986. Coniferous-habitat associations of spiders (Araneae) on red spruce foliage. Journal of Arachnology 14:315–326.

Jennings, D.T. & J.B. Dimond. 1988. Arboreal spiders (Araneae) on balsam fir and spruces in east-central Maine. Journal of Arachnology 16:223–235.

Jennings, D.T., J.B. Dimond & B.A. Watt. 1990. Population-densities of spiders (Araneae) and spruce budworms (Lepidoptera, Tortricidae) on foliage of balsam fir and red spruce in east-central Maine. Journal of Arachnology 18:181–193.

Jennings, D.T., M.W. Houseweart, C.D. Dondale & J.H. Redner. 1988. Spiders (Araneae) associated with strip-clearcut and dense spruce-fir forests of Maine. Journal of Arachnology 16:55–70.

Koponen, S. 1987. Communities of ground-living spiders in six habitats on a mountain in Quebec, Canada. Holarctic Ecology 10:278–285.

Koponen, S. 2004. Arthropods from high oak branches - comparison of two trap types, with a special reference to spiders. Latvijas Entomologs 41:71–75.

Koponen, S., V. Rinne & T. Clayhills. 1997. Arthropods on oak branches in SW Finland, collected by a new trap type. Entomologica Fennica 8:177–183.

Langellotto, G.A. & R.F. Denno. 2004. Responses of invertebrate natural enemies to complex-structured habitats: a meta-analytical synthesis. Oecologia 139:1–10.

Larrivee, M., L. Fahrig & P. Drapeau. 2005. Effects of a recent wildfire and clearcuts on ground-dwelling boreal forest spider assemblages. Canadian Journal of Forest Research-Revue Canadienne De Recherché Forestière 35:2575–2588.

Lowrie, D.C. 1948. The ecological succession of spiders of the Chicago area dunes. Ecology 29:334–351.

Luff, M.L. 1975. Some features influencing efficiency of pitfall traps. Oecologia 19:345–357.

Magurran, A. 1988. Ecological Diversity and Its Measurement. Princeton University Press, Princeton, New Jersey. 192 pp.

Majer, J.D., H.F. Recher, R. Graham & R. Gupta. 2003. Trunk invertebrate faunas of Western Australian forests and woodlands: influence of tree species and season. Austral Ecology 28:629–641.

Moeed, A. & M.J. Meads. 1983. Invertebrate fauna of 4 tree species in Orongorongo valley, New-Zealand, as revealed by trunk traps. New Zealand Journal of Ecology 6:39–53.

Nicolai, V. 1986. The bark of trees: thermal properties, microclimate and fauna. Oecologia 69:148–160.

Oksanen, J., R. Kindt, P. Legendre, B. O'Hara & M.H.H. Stevens. 2007. VEGAN: Community ecology package, R Package version 1.8-8. Online at: http://r-forge.r-project.org/projects/vegan/.

Palik, B. & R.T. Engstorm. 1999. The macro approach, managing forest landscapes: species composition. Pp. 65–94. *In* Maintaining Biodiversity in Forest Ecosystems. (M.L. Hunter, ed.). Cambridge University Press, Cambridge, UK.

Paquin, P. & N. Dupérré. 2003. Guide d'indentification des araignées (Araneae) du Québec. Fabreries, Supplément 11, 251.

Pearce, J.L., L.A. Venier, G. Eccles, J. Pedlar & D. McKenney. 2004. Influence of habitat and microhabitat on epigeal spider (Araneae) assemblages in four stand types. Biodiversity and Conservation 13:1305–1334.

Pekar, S. 1999. Some observations on overwintering of spiders (Araneae) in two contrasting orchards in the Czech Republic. Agriculture Ecosystems & Environment 73:205–210.

Pettersson, R.B. 1996. Effect of forestry on the abundance and diversity of arboreal spiders in the boreal spruce forest. Ecography 19:221–228.

Platnick, N.I. 2008. The World Spider Catalog, Version 8.5. American Museum of Natural History, New York. Online at http://research.amnh.org/entomology/spiders/catalog/INTRO1.html.

Platnick, N.I. & C.D. Dondale. 1992. The insects and arachnids of Canada. Part19. The Ground Spiders of Canada and Alaska (Araneae: Gnaphosidae). Agriculture Canada Publication 1875. Ottawa, 297 pp.

Proctor, H.C., K.M. Montgomery, K.E. Rosen & R.L. Kitching. 2002. Are tree trunks habitats or highways? A comparison of oribatid mite assemblages from hoop-pine bark and litter. Australian Journal of Entomology 41:294–299.

R Development Core Team. 2007. R: A language and environment for statistical computing, version 2.5-1. Viena. Online at: http://www.r-project.org/.

Roberts, D.J. & M.J. Roberts. 1988. Don't forget those trees. Newsletter of the British Arachnological Society 52:8.

Simon, U., J. Pfutze & D. Thomen. 2001. A time-sorting stem-eclector. Ecological Entomology 26:325–329.

Szinetar, C. & R. Horvath. 2005. A review of spiders in tree trunks in Europe (Araneae). Acta Zoologica Bulgarica Supp. No. 1, 221–257.

Ubick, D., P. Paquin, P.E. Cushing, & V. Roth (eds.). 2005. Spiders of North America: an Identification Manual. American Arachnological Society. 377 pp.

Varady-Szabo, H. & C.M. Buddle. 2006. On the relationships between ground-dwelling spider (Araneae) assemblages and dead wood in a northern sugar maple forest. Biodiversity and Conservation 15:4119–4141.

Work, T.T., C.M. Buddle, L.M. Korinus & J.R. Spence. 2002. Pitfall trap size and capture of three taxa of litter-dwelling arthropods: implications for biodiversity studies. Environmental Entomology 31:438–448.

Wunderlich, J. 1982. Mitteleuropäische spinnen (Araneae) der baumrinde. Zeitschrift für angewandte Entomologie 94:9–21.