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TERRICOLOUS SPIDERS (ARANEAE) OF INSECTICIDE-TREATED SPRUCE-FIR FORESTS IN WEST-CENTRAL MAINE

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ABSTRACT

Spiders of 12 families, 42 genera, and at least 62 species were captured in linear-pitfall traps placed in insecticide-treated[3] (Sevin-4-Oil®, Dipel 4L®, Thuricide 16B®) and untreated spruce-fir forests of west-central Maine. Species richness per family ranged from 1 (Theridiidae, Araneidae, Salticidae) to 19 (Erigonidae). Most trapped species were web-spinners (67.2%); most trapped individuals were hunters (75.2%). Lycosidae accounted for 66.1% of all (n = 887) captured spiders.

Total trapped spiders varied among insecticide treatments, sampling dates, and study sites. However, comparison of mean prespray and postspray trap catches indicated no significant reduction (ANOVA, ANCOVA, $P \leqq 0.05$) in terricolous spiders following insecticide treatments. Increases in spider abundance during postspray sampling periods may have masked detection of treatment effects.

Spiders are among the dominant predatory arthropods in many terrestrial communities (Gertsch 1979). Despite their ubiquitous occurrence and potential economic importance (Riechert 1974), few investigations have been made of the spiders associated with forest communities in North America. For northeastern forests, Loughton et al. (1963), Renault and Miller (1972), and Jennings and Collins (1987) provide lists of arboreal spiders associated with spruces (*Picea* spp.) and with balsam fir (*Abies balsamea*). Only one in-depth study has been made of the terricolous spider fauna of spruce-fir forests in Maine (Jennings et al. 1988).

Since the mid-1950's, numerous chemical and microbial insecticides have been aerially applied to suppress populations of the spruce budworm, *Choristoneura fumiferana* (Clemens), in Maine's spruce-fir forests. Carbaryl (Sevin-4-Oil®) and various formulations of the entomopathogenic bacterium *Bacillus thuringiensis* var. *kurstaki* Berliner (hereafter, *B. t.*) have been sprayed from fixed-wing aircraft and helicopters (Trial et al. 1979, Dimond et al. 1981, Dimond 1982, Maine Forest Service 1981). Because both pest and nontarget organisms may be affected, numerous studies have addressed the effects of these insecticides on pollinators, parasites, and predators. [For reviews of carbaryl and nontarget organisms, see Trask (1982); for *B. t.* and nontarget organisms, see Dulmage and Aizawa (1982), Krieg and Langenbruch (1981), Morris (1982).]

The effects of carbaryl on spiders in Maine's spruce-fir forests were investigated by Hydorn (1979); the effects of *B. t.* on spiders in Ontario's fir-spruce forests were studied by Buckner et al. (1974).

Because most spiders are obligate predators that feed chiefly on insects (Gertsch 1979,

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[3]Mention of a commercial or proprietary product does not constitute endorsement by the University of Maine or the U.S. Dept. of Agriculture, Forest Service.

Kaston 1981), the potential detrimental effects of insecticides directed at pest populations are of paramount importance. Spiders are only one trophic level above insect herbivores; drastic reductions in pest (prey) populations could adversely affect predator populations (Newsom 1967, Coppel and Mertins 1977).

In the spring of 1980, a comparison was made of the impacts of carbaryl (Sevin-4-Oil®) and two formulations of *B. t.* (Thuricide 16B® and Dipel 4L®) on nontarget terrestrial insects and spiders in spruce-fir forests of west-central Maine (Hilburn 1981). For that study, spiders were identified to family level. Here we report the species of spiders collected; compare total catches of spiders among treatments, sampling dates, and study sites; and determine possible treatment effects based on mean pitfall catches of spiders during prespray and postspray sampling periods.

METHODS

Study Sites. In 1980, 12 sampling sites were chosen for study in spruce-fir forests of west-central Maine near Moosehead Lake. All sites previously had been sprayed for spruce budworm control in 1978; none were sprayed in 1979. Three sites each were established in blocks sprayed with Sevin-4-Oil®, Dipel 4L®, and Thuricide 16B®; three sites were designated as untreated controls.

The Sevin-4-Oil® sites were within a series of spray blocks (4047 ha total) in T1 R13, Piscataquis County; the blocks were sprayed with fixed-wing aircraft at a rate of 2.9 l/ha (40 fl. oz./ac). The Dipel 4L® sites were three blocks (40.5 ha each), one each in Lily Bay, T1 R13, and Spencer Bay Townships, Piscataquis County; the blocks were sprayed with fixed-wing aircraft at a rate of 9.35 l/ha (1 gal/ac) (20 BIU/ha). Thuricide 16B® sites were within a spray block (2833 ha total) in Tomhegan Township, Somerset County; the block was sprayed with helicopters at a rate of 5.8 l/ha (80 fl. oz./ac) (20 BIU/ha). Control sites were three blocks (40.5 ha each), one each in Lily Bay, T1 R13, and Spencer Bay Townships, Piscataquis County; the blocks were left untreated. All spray treatments were applied between 1 and 5 June 1980.

Pitfall Traps. At each study site, a linear pitfall trap (Pausch et al. 1979) was placed in a forest opening large enough (10–50 m diam.) to allow aerially applied insecticide to reach the ground near the trap. Despite limitations, pitfall trapping remains the best available means for sampling cursorial spiders (Uetz 1975, Uetz and Unzicker 1976). Traps consisted of 1-m sections of galvanized rain gutter buried flush with the ground (Fig. 1); each had a wooden cover. Four short corner legs held the cover 2 cm above the top edge of the trap. A 1:1 mixture of ethylene glycol (automobile antifreeze) and water was added to each trap and maintained at a depth of ca. 2 cm. An aquarium net was used to scoop captured insects and spiders out of the traps. Trap catches were stored in 70% ethanol until specimens were sorted and identified.

Sampling Periods. There were six sampling periods, three before insecticide treatment (prespray) and three after insecticide treatment (postspray). Each sampling period lasted 48 h. Between sampling periods, trap covers were turned over to prevent entry of insects and spiders; covers were positioned in place during sampling periods. All samples were taken during sunny, warm weather; mean daily maxima were 23°, 22°, 20°, 23°, 25°, 24° C each sampling period, respectively (N.O.A.A. Climatological Data, Ripogenus Dam, 1980). Prespray sampling dates were 21–23 May, 23–25 May, and 29–31 May; postspray sampling dates were 6–8 June, 13–15 June, and 27–29 June, for possible detection of immediate, 1-week, and 2-week post treatment effects.

Spider Identifications. Most collected spiders were identified by the junior author; species determinations follow Kaston (1981) and other consulted sources including: Opell and Beatty (1976) for the Hahniidae; Leech (1972) for the Amaurobiidae; Chamberlin and Gertsch (1958) for the Dictynidae; Dondale and Redner (1982) for the Clubionidae; and Dondale and Redner (1978) for the Philodromidae and Thomisidae. Some Erigonidae were identified by C. D. Dondale and J. H. Redner, Biosystematics Research Centre, Ottawa; species determinations of the Erigonidae follow numerous consulted taxonomic

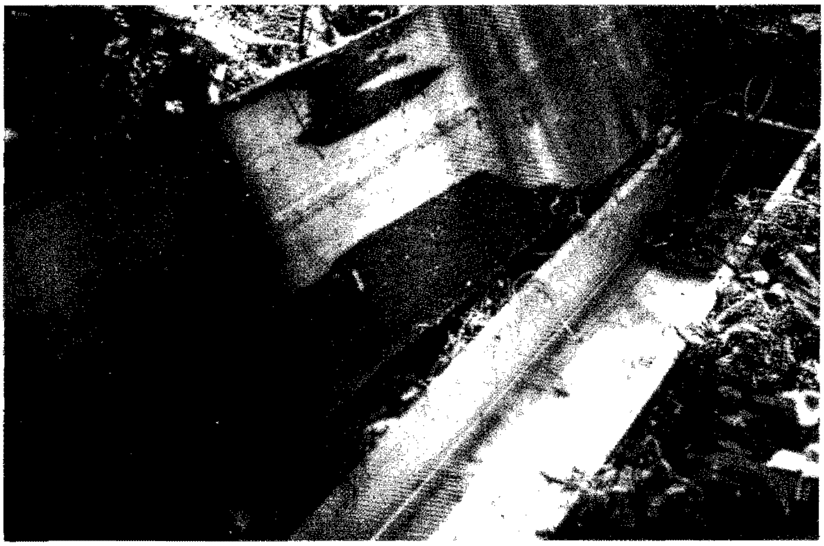

Fig. 1. Linear-pitfall trap for sampling terricolous spiders in spruce-fir forests of west-central Maine.

papers and comparisons with voucher specimens housed in the Canadian National Collections of Insects, Arachnids, and Nematodes, Ottawa.

Only sexually mature spiders were identified to species; juvenile and penultimate stages were identified to generic level. Species descriptions of spiders are based chiefly on the genitalia, which are not fully developed until maturity. Representative specimens of most spider species trapped during this study are deposited in the arachnid collections of the U. S. National Museum of Natural History, Washington, DC.

Data Analyses. Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) were used to compare mean catches of spiders during prespray and postspray sampling periods for insecticide treatments and control at $P = 0.05$. Hartley's Test for homogeneity of variance indicated transformations were not required.

RESULTS

Spider Taxa. Spiders of 12 families, 42 genera, and at least 62 species were captured in linear-pitfall traps placed in spruce-fir forests of west-central Maine (Table 1). Species richness per family ranged from 1 to 19; the Erigonidae had the richest representation (i.e., 31.2% of all species). Species of web-spinning spiders (67.2%) outnumbered species of hunting spiders (32.8%) about 2 to 1. More species of web spinners were captured during the postspray period (32 spp.) than during the prespray period (23 spp.); whereas, species of hunters were about equally represented during both periods.

Spider Numbers. Wolf spiders (Lycosidae) were numerically dominant, and accounted for 66.1% of all ($n = 887$) captured specimens. The next most abundantly represented families were the Erigonidae (8.0%), the Amaurobiidae (6.5%), and the Agelenidae (5.4%). Each of the remaining families accounted for < 5% of the total trapped spiders.

Grouping spider families by foraging strategy indicated that hunters outnumbered web

Table 1. Species and number of spiders collected in linear-pitfall traps, insecticide-treated spruce-fir forests, west-central Maine, 1980.

FAMILY	Number		
Genus species	♂♂	♀♀	juv
WEB SPINNERS			
AGELENIDAE			
Agelenopsis sp.			1
Cicurina brevis (Emerton)	3	4	
Cicurina pallida Keyserling	13	2	
Cicurina sp.			3
Cryphoeca montana Emerton	8		
Wadotes calcaratus (Keyserling)	10	3	
Wadotes sp.			1
HAHNIIDAE			
Antistea brunnea (Emerton)	1		
Hahnia cinerea Emerton	4		
Neoantistea agilis (Keyserling)	1	7	
Neoantistea magna (Keyserling)		13	
Neoantistea sp.			2
AMAUROBIIDAE			
Amaurobius borealis Emerton	7		
Amaurobius sp.			1
Callioplus tibialis (Emerton)	3		
Callobius bennetti (Blackwall)	14	13	
Callobius sp.			20
THERIDIIDAE			
Robertus riparius (Keyserling)	2		
Undet. sp.			1
LINYPHIIDAE			
Aphileta misera (O.P.-Cambridge)	1		
Bathyphantes pallidus (Banks)		2	
Bathyphantes sp.			1
Centromerus persolutus (O.P.-Cambridge)	2		
Lepthyphantes zebra (Emerton)		1	
Meioneta fabra (Keyserling)	1		
Oreonetides recurvatus (Emerton)	1		
Oreonetides retangulatus (Emerton)		1	
Oreonetides sp. 3	1		
ERIGONIDAE			
Baryphyma kulczynskii (Jeskov)		1	
Baryphyma longitarsum (Emerton)	1	1	
Ceraticelus bulbosus (Emerton)		1	
Ceraticelus laetabilis (O.P.-Cambridge)	1	1	
Ceraticelus minutus (Emerton)	1		
Ceratinella brunnea Emerton	1	2	
Gonatium crassipalpum Bryant (Blackwall)		1	
Grammonota gigas (Banks)	6	5	
Grammonota sp.			9
Halorates plumosus (Emerton)		2	
Oedothorax trilobatus (Banks)	2		
Pocadicnemis americana Millidge	2		
Scotinotylus pallidus (Emerton)	1		

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Table 1. (Continued)

FAMILY Genus species	Number ♂♂	 ♀♀	 juv
WEB SPINNERS (Continued)			
ERIGONIDAE (Continued)			
Tapinocyba minuta (Emerton)	1		
Tapinocyba simplex (Emerton)	1	3	
Walckenaeria atrotibialis O.P.-Cambridge	1		
Walckenaeria communis (Emerton)		3	
Walckenaeria directa (O.P.-Cambridge)	1		
Walckenaeria minuta Emerton	1		
Walckenaeria spiralis (Emerton)	2		
Undet. sp.			20
ARANEIDAE			
Araniella sp.			1
HUNTERS			
LYCOSIDAE*			
Alopecosa aculeata (Clerck)	4		
Lycosa frondicola Emerton	1		
Pardosa hyperborea (Thorell)		1	
Pardosa mackenziana (Keyserling)	46	16	
Pardosa moesta Banks	192	77	
Pardosa xerampelina (Keyserling)	33	11	
Pardosa sp.			68
Pirata insularis Emerton	10	6	
Pirata minutus Emerton	4		
Pirata sp.			5
Trochosa terricola Thorell	57	14	
Trochosa sp.			28
Undet. sp.			1
GNAPHOSIDAE			
Gnaphosa parvula Banks	9	4	
Gnaphosa sp.			4
Haplodrassus hiemalis (Emerton)		1	
Micaria aenea Thorell	1	1	
Micaria pulicaria (Sundevall)	1		
Zelotes fratris Chamberlin	4	5	
Zelotes puritanus Chamberlin	1		
Zelotes sp.			11
CLUBIONIDAE			
Agroeca ornata Banks	23	5	
Agroeca pratensis Emerton	1		
Agroeca sp.			1
Clubiona canadensis Emerton	1	2	
Clubiona sp.			1
THOMISIDAE			
Xysticus elegans Keyserling	1		
Xysticus emertoni Keyserling	1	1	
SALTICIDAE			
Neon nelli G. & E. Peckham	2		

*12 specimens lost after data recorded.

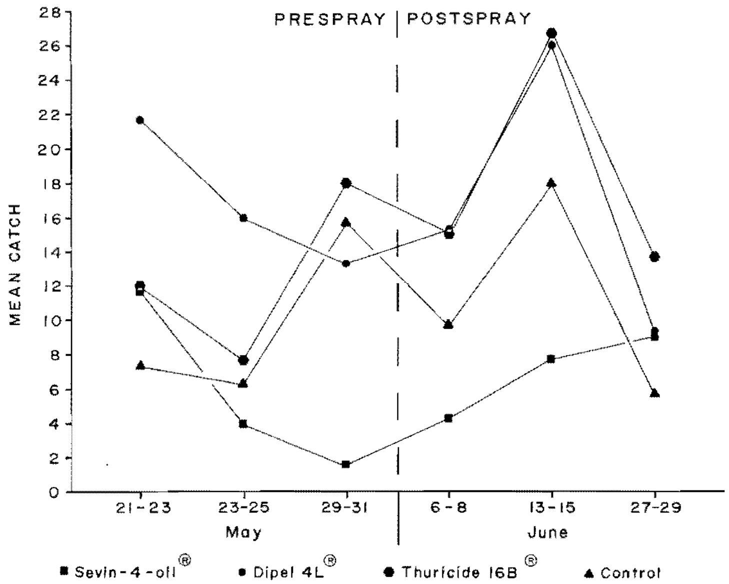

Fig. 2. Mean catches of terricolous spiders in linear-pitfall traps by insecticide treatments and sampling dates.

spinners 3 to 1. Most (87.9%) of the hunting spiders (n = 667) were Lycosidae. The web-spinning spiders (n = 220) primarily were represented by erigonids (32.3%), amaurobiids (26.4%), and agelenids (21.8%); followed by hahniids (12.7%) and linyphiids (5.0%).

Most of the trapped spiders were males (55.5%); females accounted for 24.0%, and juveniles 20.5% (12 specimens of Lycosidae lost; n = 875). Percentage life-stage representation in trap catches differed by foraging strategy; for web spinners (n = 220)—males (42.7%), females (30.0%), juveniles (27.3%); for hunters (n = 655)—males (59.8%), females (22.0%), juveniles (18.2%).

Total numbers (n = 887) and percentages of spiders captured in linear-pitfall traps varied among treatments, sampling dates, and study sites (Fig. 2). The abundance or scarcity of Lycosidae accounted for most of the unequal distribution of spiders among study sites. For example, the Lycosidae accounted for more than 70% of all spiders captured during the 13–15 June sampling.

Treatment Effects. We detected no significant reduction in mean catches of terricolous spiders following any of the insecticide treatments (Table 2). In fact, postspray trap-catch means were greater than prespray trap-catch means for the Sevin-4-Oil®, Thuricide 16B®, and control treatments, but not significantly greater ($P > 0.05$). The interactions between treatments and sampling dates were nonsignificant. An analysis of covariance also

Table 2. Comparison of mean pitfall-trap catches of terricolous spiders before and after insecticide treatments for spruce budworm suppression, west-central Maine, 1980.

	Prespray*		Postspray†			
Treatment	$\overline{X}$	(±S.E.)	$\overline{X}$	(±S.E.)	F value	F prob.‡
Sevin-4-Oil®	5.78	2.16	7.00	1.28	0.24	0.63
Dipel 4L®	17.00	5.17	16.89	6.32	0.00	0.99
Thuricide 16B®	12.56	4.01	18.44	5.11	0.82	0.38
Control	9.78	1.95	11.11	2.69	0.16	0.69

*Prespray means based on 48-h pitfall-trap catches for 3 sampling periods (21–23 May, 23–25 May, and 29–31 May) with 3 replications/treatment.
†Postspray means based on 48-h pitfall-trap catches for 3 sampling periods (6–8 June, 13–15 June, and 27–29 June) with 3 replications/treatment.
‡Mean prespray and postspray trap catches are not significantly different, ANOVA, $P \leqq 0.05$.

indicated that none of the postspray mean catches were significantly reduced by any treatment (Table 3).

Although we observed no dramatic reduction in mean pitfall catches of spiders following insecticide treatments, mean catches declined slightly for Thuricide 16B® and control sites (Fig. 2) immediately after spray. However, mean catches increased for all treatments by the 2nd-postspray collection period. By the 3rd-postspray collection period, all but the Sevin-4-Oil® treatment showed declining trends in mean catches of spiders.

Between prespray and postspray periods, mean catches over *all* treatments were not significantly different (i.e., prespray $\overline{X} = 11.28 \pm 1.85$; postspray $\overline{X} = 13.36 \pm 2.21$).

DISCUSSION

The terricolous spider fauna of Maine's spruce-fir forests has received scant attention from investigators. Procter (1946) listed spiders of 15 families, 94 genera, and 179 species from various habitats on Mount Desert Island, Hancock County; many were from spruce-fir habitat. Jennings et al. (1988) pitfall-trapped spiders of 15 families, 76 genera, and at least 125 species in strip-clearcut and dense (uncut) spruce-fir forests of Piscataquis County. The terricolous spiders we trapped in Somerset and Piscataquis Counties of west-central Maine provide new locality records for most species.

The species of spiders collected during this study generally are typical for spruce-fir habitat; all but 2 genera and 14 species (mostly Erigonidae and Linyphiidae) have been collected from spruce-fir forests of northern Maine (Jennings et al. 1988). Most of the pitfall-trapped species are epigeal or terricolous; hence, the fauna on or near the ground in spruce-fir forests differs markedly from the arboreal fauna found on spruce and fir trees (Loughton et al. 1963, Renault and Miller 1972, Jennings and Collins 1987).

The preponderance of hunting spiders captured over web spinners was not unexpected because pitfall traps are selectively biased toward capture of wandering cursorial spiders (Uetz and Unzicker 1976). Pitfall trapping samples a quantity that is the product of activity and density (Breymeyer 1966, Uetz 1975). Because male spiders generally are more mobile and may move considerable distances in search of females, the sexes are seldom equally represented in pitfall-trap catches (Hallander 1967, Muma 1975). We observed greater percentages of male captures for both web spinner and hunting-spider categories; however, most of the males were hunters.

The preponderance of wolf spiders (Lycosidae) in our pitfall-trap collections was no doubt influenced by microhabitat. To allow for maximum insecticide-treatment exposure, the traps were placed in small forest openings devoid of canopy closure. Because many

Table 3. Analysis of covariance (ANCOVA), postspray spider populations,* west-central Maine, 1980.†

Treatment	Sevin-4-Oil®	Dipel 4L®	Thuricide 16B®	Control
Sevin-4-Oil®	—	0.59	0.19	0.76
Dipel 4L®	0.59	—	0.44	0.80
Thuricide 16B®	0.19	0.44	—	0.30
Control	0.76	0.80	0.30	—

*None of the adjusted postspray means are significant, ANCOVA, $P \leqq 0.05$.
†Prespray means were used as the covariate.

lycosid species are cursorial and sun-loving (Gertsch 1979), traps placed in such openings away from dense shade are more likely to capture wolf spiders, particularly species of *Pardosa*. In northern Maine, Jennings et al. (1988) found wolf spiders more abundant in open, sunny areas of clearcut strips than in closed shaded areas of uncut residual strips or dense stands. Bultman et al. (1982) found a scarcity of wolf spiders in a beech-maple climax forest of western Michigan; Wolff (1981) noted *Pardosa* spiders were abundant in fields and more open habitats of Michigan.

In west-central Maine, we found no evidence that terricolous spider populations were adversely affected by any of the three insecticide treatments. The results for Sevin-4-Oil® are in general agreement with those reported by Hydorn (1979, p. 44), i.e., "Severe effect of spraying on total terricolous spiders was not indicated . . . , although immediate post-spray rate of decline was relatively steep in plots sprayed with carbaryl." Barrett (1968) concluded that phytophagous insects were more severely affected by carbaryl than predaceous insects and spiders.

We also detected no significant effects of two *B. t.* formulations on terricolous spiders in west-central Maine. These results are in general agreement with earlier studies; Buckner et al. (1974) concluded that pitfall-trapped spiders were relatively unaffected by *B. t.* treatments applied to fir-spruce forests in Ontario. Other *B. t.*-arachnid studies concern mites (Krieg and Langenbruch 1981) and the scorpion *Buthus occitanus* Amoreux (Morel 1974). Because spiders ingest liquefied-prey remains (Gertsch 1979), we suspect that spiders would make ideal subjects for bioassays of *B. t.*-induced secondary effects (e.g., *B. t.*-infected larvae fed to spiders before larval death).

Detection of treatment effects in west-central Maine may have been masked by apparent increases in spider abundance during the postspray sampling periods (Fig. 2). Initially, we hypothesized that spider abundance following treatment was influenced by egg hatch and appearance of young spiderlings. However, few young spiderlings were captured; most juveniles (especially of *Pardosa* species) were penultimate males and immature females. We also are unable to explain fully the apparent decreases in spider abundance for most treatments during the last sampling period (i.e., 27–29 June). A delayed secondary treatment effect is possible but unlikely because populations also declined on control sites. Spiders feed chiefly on live insects. Insects weakened or dying from any of the insecticide treatments may also have been susceptible to spider predation. However, dead insects probably did not constitute major portions of spider diets, although a few species of spiders are known to scavenge on dead insects (Knost and Rovner 1975, Ross 1981). Availability of potential prey may have been a factor because peaks and troughs in spider abundance generally coincided with similar peaks and troughs in insect abundance, especially during the postspray sampling periods (Hilburn 1981).

We conclude that future field studies based on pitfall trapping should use more traps to help stabilize variances in trap catches of spiders, both before and after insecticide treatments. Although species per trapping effort (62 species/12-trap days) was unexpectedly great during this study, continuous operation of traps over longer periods of time (i.e., > 48 h) may be desirable.

Finally, aerially applied insecticides may have more drastic effects on arboreal spiders (Hydorn 1979) than on terricolous spiders; the faunas associated with both strata need much more investigation in Maine's spruce-fir forests.

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