A baseline inventory of litter-dwelling arthropods and airborne insects including pollinators in two fir-spruce stands with dissimilar histories of insecticide treatment

by

I. W. Varty and N. E. Carter

Maritimes Forest Research Centre

Fredericton, New Brunswick

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ABSTRACT

Recurrent large-scale aerial spray operations with organophosphate insecticides for spruce budworm control in eastern Canada must influence the population dynamics of hundreds of vulnerable non-target arthropods in many ecosystems. Two faunal survey techniques, pitfall trapping and window trapping, were used in New Brunswick in May-July 1972 to compare species diversities and abundances of litter-dwelling arthropods (spiders, harvestmen, beetles) and flying insects (especially wild bees) in two fir-spruce stands with dissimilar spray histories, the one treated annually for 15 years, the other newly treated for the first time. The results support the hypothesis that repeated forest spraying tends to reduce species diversity, but population densities of most taxonomic groups were not strongly disparate between the two plots. The conclusion is that important functions such as predation in the litter and pollination in the forest are not drastically changed by long-term application of insecticides at conventional dosages.

RÉSUMÉ

Les arrosages aériens répétés et à grande échelle avec des insecticides organophosphates pour lutter contre la Tordeuse des bourgeons de l'Épinette dans l'est du Canada doivent influer sur la dynamique de population de milliers d'Arthropodes inoffensifs qui vivent dans plusieurs écosystèmes. Au Nouveau-Brunswick en 1972, les auteurs utilisèrent deux techniques de récolte de ces insectes, pour comparer les diversités et les abondances des Arthropodes vivant dans la litière (Araignées, Moissonneurs, Coléoptères) et des insectes volants (surtout les Guèpes) dans deux peuplements d'Épinettes et de Sapins arrosés différemment, l'un traité annuellement durant plusieurs années l'autre traité pour la première fois.

Les résultats confirment l'hypothèse que des arrosages répétés tendent à réduire la diversité des espèces, mais par contre les densités de population de la plupart des groupes taxonomiques n'étaient pas fortement disparates d'une parcelle à l'autre. On conclut que des fonctions importantes telles que la prédation dans la litière et la pollinisation en forêt ne sont pas drastiquement changées par l'application à long terme des insecticides à doses ordinaires.

INTRODUCTION

The ecological implications of large-scale insecticide usage in forest ecosystems have been slowly emerging for quarter of a century, mainly as a consequence of perennial control operations against spruce budworm in Eastern Canada. Monitoring of vertebrate and invertebrate faunae for lethal and sublethal toxicity and for population responses has become a recognized part of the biological assessment of the spray programme. However the technology of ecosystem monitoring is weakly developed, and the ecologist's overview of the side effects of insecticidal sprays in the mosaic of dynamic ecosystems in and peripheral to the spray blocks is imperfect.

A forest is a complex of resilient biological systems characterized by much faunal, floral and physical diversity. These interlocked systems have evolved for stability and photosynthetic efficiency over millennia. The intrinsic long-term homeostasis stemming from this diversity permits foresters to harvest fibre with a low intensity of management input. Insecticide usage runs counter to this homeostasis by diminishing diversity and perturbing the relationships between pests and plants. Management may now be embarking on a silvicultural phase when New Brunswick's fir and spruce growing stock can be maintained only by perennial suppression of the spruce budworm through very large-scale spray operations. In that event the forester must ponder how far the non-target components of ecosystems in spray blocks may continue to produce multiple resources in their customary abundance. The danger of ecological upset will become more probable.

The problem is how to recognize adverse changes taking place in slow motion; how to determine significant changes in insect distributions that are less favourable to resource maintenance. If the ecologist is to detect the abnormal, he must first define the mean and oscillation of the normal. He needs a baseline inventory of species populations in key communities in each economically productive ecosystem. Ideally, a decade or longer would be required for pretreatment calibration of normal equilibrium and interaction of faunal components. In practice, ecologists do not have the time to describe normal population abundance in a chemically-undisturbed environment, nor do they yet know how to draw up such inventories with economy of effort.

The Canadian Forestry Service has a limited start on the inventory of the invertebrate fauna of fir-spruce forests, (especially in the crown zone) in eastern Canada. However there are large gaps in our knowledge, especially in soil biology and pollinator biology. This report describes the results of two trapping techniques (pitfall and window traps) used to gather baseline information.

The maintenance of soil fertility should be a prime objective of forest management. The continuing presence of a full complement of arthropods in balanced abundance promotes the efficient functioning of soil processes and the nutrient cycle. This is especially true in the thin infertile forest soils of eastern Canada now subjected to the side effects of defoliation by budworm and insecticidal counter measures. The arthropod agents of litter breakdown and of root-fungus control are mainly mites and springtails. The higher trophic levels of the litter community include such predators as beetles, harvestmen, spiders and ants. These occupy an intermediate habitat between the soil per se and the foliage zone above. It is possible that these large arthropods may act as indicators of insecticidal stress at the litter surface and fore-warn us of malfunction in soil processes at large. Pitfall trapping in 1972 was practiced to survey the predaceous arthropods for a species list and index of abundance.

We also attempted to measure insect abundance above ground by window traps to intercept airborne invertebrates. This aerial fauna of a forest stand is not a community but an ephemeral mix of habitat-related species from several merging ecosystems. But since it can be sampled, the abundance of airborne insects may be related to the insecticide factor. Pollinator insects such as bees and syrphid flies are a component in which there is both ecological and economic interest. If insecticides discriminate against pollinators, then recurrent spraying may weaken the value of the forest as a reservoir of insects having a beneficial role in adjoining agricultural crops, such as blueberries and orchards. In long term within the forest, the competitive position of insect-pollinated trees, shrubs and herbs might be eroded to the detriment of nectar-demanding beneficial insects such as parasitoids.

To determine whether perennial spraying had already intervened in population density of litter-dwelling and airborne arthropods, it was decided to apply the two trapping techniques simultaneously in two sample plots, one with a long history of aerial spraying of DDT and fenitrothion, and the other with a spray history just beginning in 1972.

Research plots

The two plots, separated by 100 miles, are:- Priceville, Northumberland Co., New Brunswick, and Elmsville, Charlotte Co., New Brunswick. They were selected for gross stand similarity, excepting spray history.

	Priceville	Elmsville
Dominant trees	balsam fir[1]	balsam fir
Codominants	red spruce, red maple, trembling aspen	red spruce, red maple, trembling aspen
Height	30 - 40 ft	30 - 40 ft
Structure	even-aged, open	even-aged, open
Ground flora	goldthread, wintergreen, blueberry, bunchberry, blue violets, mayflower starflower, strawberry	similar common herbs but probably richer in species diversity
Geology	glacial till/gravel	glacial till/gravel
Drainage	free	free
Slope	flat	gentle slope to SW
Felling history	cut over mid 1940s	cut over mid 1940s
Spray history	DDT 1956-7, 1960-67 fenitrothion 1969-1972	nil fenitrothion 1972

[1] See Appendix for scientific names.

In the sampling period, May to July 1972, both areas experienced similar general weather conditions. Elmsville received 1.4 ins (3.6 cm) more rain than Priceville in June, but in May and July differences were minor. Phenological developments in the two plots were almost contemporaneous due to similar rates of heat accumulation, but flushing occurred a few days earlier at Elmsville.

Priceville's budworm infestation began in the early 1950's, and moderate to severe defoliation has occurred annually to the present. Fenitrothion in emulsion formulation at 3 oz/ac (210 g/ha) was applied on June 5, 1972. In Elmsville, defoliation was first noticed in 1970, and was severe in the two following years. Fenitrothion was applied in oil formulation at 3 oz/ac on May 26, 1972, for the first time. It was not very effective against the target budworm.

Sampling techniques

Ten pitfall traps were laid out along a transect in each plot. They were located about 40 feet (12 m) apart in openings in the canopy. Each trap assemblage consisted of a plastic funnel 10 in (26 cm) high with a top diameter 8 in (20 cm) and a base opening of 1.5 in (4 cm) diameter. A Mason jar lid was heat-fused to the funnel spout to facilitate attachment of a pint jar containing 100 ml of 70% ethyl alcohol. The assemblage was placed in a metal sleeve set 20 in (50 cm) into the soil, so that the funnel lip was level with the litter surface. To prevent rain and debris from entering the funnel, galvanized metal sheets, one foot square (30 cm), were placed on wooden pegs 6 in (15 cm) above the funnels. The rain shields did not hinder movement of invertebrates.

Each sample was screened at the laboratory to remove debris, and stored in snap-cap vials with 70% alcohol until identification and tally.

Six window traps were employed in each plot. Each trap consisted of a pane of plexiglass (16 x 12 in: 41 x 30 cm), below which was wired an aluminum pan (12 x 5 x 3 in: 30 x 13 x 8 cm) containing 1500 ml ethylene glycol and water in 1:1 mix. The pane was suspended about 10 ft (3 m) above ground level by cords attached to trees, and guyed by other cords to stabilize the pan in high winds. The panes were placed in flight corridors between clumps of trees. Each plot was tended the same day every week from late May to late July (days 147-203 at Elmsville; days 152-209 at Priceville).

ARTHROPODS OF THE LITTER COLLECTED BY PITFALL TRAPS

The four major groups of arthropods collected by pitfall traps were spiders (Araneida), harvestmen (Phalangida), beetles (Coleoptera) and springtails (Collembola). The latter are not predaceous and were not tallied. Spiders were the most taxonomically diverse group, and individually the most numerous (Table 1). However the beetles had a larger biomass and presumably occupy the dominant role in predation of larger arthropods. Biomass considerations also upgrade the importance of harvestmen which were otherwise lowest in species diversity and numbers of individuals.

Spiders

Spiders are a conspicuous component of the northern forest litter community, exercising predatory control over centipedes, springtails and many other arthropods (Clark and Grant 1968). Pitfall trapping

Table 1. Arthropod diversity and abundance in pitfall traps, accumulative catches May-July 1972

	No. of Species			No. of Individuals		
	Elmsville	Priceville	Total	Elmsville	Priceville	Total
Spiders	45*	27*	45*	1776	1384	3160
Beetles	17	13	18	438	327	765
Harvestmen	4	5	5	145	68	213

* Species listing incomplete due to inability to identify immature erigonids and linyphiids.

is an efficient way to collect a broad spectrum of ground spiders. Our compilation (Table 2) includes almost all of those listed as characteristic of the fir-spruce litter habitat by Renault (Maritimes Forest Research Centre pers. comm.). It is also similar to the spider listing from a mature red spruce stand in the same region (Carter and Brown 1973), except that our fir stands were much richer in lycosids, both species and numbers. In fir-spruce litter the dominant families are Amaurobiidae, Clubionidae, Erigonidae, Gnaphosidae, Hahnidae and Lycosidae.

The various figures (1-10) show much variation in seasonal abundance of a species from May to July. This is an obvious sampling artifact related to spider behaviour (weather, prey movement, development stage) and not primarily to real change in spider abundance. The general pattern of spider density in spring is a slow decline, because reproduction does not usually begin until mid summer. No single sampling date can reliably provide a fix on such species populations, or a complex, across the year. An estimate of abundance best arises from a series of samplings presented as a seasonal chart or cumulative total (Renault and Miller 1972).

The raw totals in Table 1 show substantially lower species diversity and slightly lower total catches in the plot long treated with insecticide (Priceville) compared with the newly treated plot (Elmsville). If we assume that these similar sites should have essentially similar faunae in quality and quantity, then we would have to say that insecticidal history, which is the major cultural difference between the two plots, has not had a *drastic* compounding influence on populations or diversity of spiders.

There are some unexplained differences in species composition at the two plots, representing a mild pauperisation at Priceville. The Elmsville list included 18 species not encountered at Priceville, but only a few species were markedly more abundant at the former site compared with the latter, as follows:-

	Total Catches May-July	
	Elmsville	Priceville
Wadotes calcaratus	22	1
Phurotimpus borealis	21	1
Neoantistea riparia	77	8
Pardosa xerampelina	47	2
Xysticus luctuosus	16	1
Robertus riparius	23	0

Table 2. Species listing and catches of spiders in pitfall traps from two fir-spruce stands in New Brunswick, 1972

Species	Elmsville		Priceville	
AGELENIDAE				
Circurina brevis (Emert.)	8		11	
C. pallida Key	20		20	
C. robusta Simon	1		1	
Cicurina spp. (immature)	14		12	
Coras montanus (Emert.)	8		1	
C. juvenilis (Key)	1		0	
Cryphoeca montana Emert.	9		3	
Wadotes calcaratus (Key.)	22		1	
		83		49
AMAUROBIIDAE				
Amaurobius borealis Emert.	95		106	
Callobius bennetti (Black.)	39		75	
		134		181
CLUBIONIDAE				
Agroeca ornata Banks	99		46	
Clubiona canadensis Emert.	8		8	
Clubiona kastoni Gert.	3		1	
Micaria montana Emert.	8		0	
Phruronellus sp.	3		0	
Phrurotimpus borealis (Emert.)	21		1	
		142		56
DICTYNIDAE				
Dictyna volucripes Key.	2		0	
Lathys pallida (Marx)	1		0	
		3		0
ERIGONIDAE (many spp.)		501		486

Table 2 Continued

Species	Elmsville		Priceville	
GNAPHOSIDAE				
Drassyllus niger (Banks)	9		0	
Gnaphosa muscorum (L. Koch)	5		2	
Haplodrassus signifer (C.L. Koch)	5		7	
H. hiemalis (Emert.)	4		3	
Zelotes subterraneus (C.L. Koch)	77		37	
Z. inheritus Kaston	2		0	
Z. puritanus Chamb.	1		0	
		103		49
HAHNIIDAE				
Hahnia cinerea Emert.	42		71	
Neoantistea riparia (Key.)	77		8	
		119		79
LINYPHIIDAE (several spp.)		34		38
LYCOSIDAE				
Pardosa mackenziana (Key.)	235		282	
P. distincta (Black)	4		0	
P. xerampelina (Key)	47		2	
P. hyperborea (Thorell)	1		0	
P. moesta Banks	12		0	
Tarentula aculeata (Clerck)	154		65	
Pirata montanus Emert.	3		0	
Trochosa terricola Thorell	114		66	
		570		415
MICRYPHANTIDAE				
Maso sundevallii (West)	1		0	
		1		0
SALTICIDAE				
Neon nellii Peck	10		5	
Talavera minuta (Banks)	1		0	
		11		5

Table 2 Continued

Species	Elmsville		Priceville	
THERIDIIDAE				
Euryopis funebris (Hentz)	1		0	
Robertus riparius (Key.)	23		0	
Theridion sexpunctatum Emert.	2		0	
		26		0
THOMISIDAE				
Tibellus oblongus (Walck)	1		0	
Oxyptila americana Banks	9		17	
Xysticus elegans Key.	22		8	
X. canadensis Gert.	1		0	
X. luctuosus (Black.)	16		1	
		49		26
GRAND TOTALS		1776		1384

One hypothesis is that the long history of insecticide usage at Priceville has discriminated against species which are weakly competitive in fir-spruce habitats. However such faunal differences could also be accounted for by the ordinary variables such as climate, stand differences, floral differences and special habitat availability. The literature does not offer much guidance on the hypothesis of insecticidal reduction of spider species diversity and density. Barrett (1968), reporting on Sevin at heavy experimental dosages, found that grassland spiders were less acutely affected than grazing insects in the same habitat. On the other hand, Renault & Miller (1972) noted significantly lower densities of arboreal spiders at Priceville in 1968 (after 10 years of DDT usage) compared with chemically undisturbed areas in New Brunswick. Freitag and Poulter (1970) found persistently lower numbers of litter-dwelling lycosid spiders in plots treated once with fenitrothion at 6 oz/ac (420 g/ha) compared with untreated controls. Our survey tends to support their results since Elmsville produced 570 lycosids (8 spp) compared with Priceville's 415 (4 spp).

There is no information on the toxicological evaluation of fenitrothion on spiders, though it has been used against pest arachnids (cattle ticks, poultry mites). Our experience in forest spraying is that mortality of spiders is light, a small fraction of the resident population in tree crowns, compared with heavy mortality in insects. In practice the quantities of organophosphate insecticides reaching the forest floor in spray operations are very small compared with the emitted dosage, but faint residues persist for several weeks (Sundaram 1974).

Since arthropods vary widely in their susceptibility to insecticide deposits, the detection of population effects may be best accomplished by choosing indicator species which a) show an apparent susceptibility and b) are easy to sample. The following notes on spider families attempt to specify those spiders with potential indicator usefulness.

AGELENIDAE: Many species build sheet webs with a tunnel to which they retreat with their prey. The most notable indicator candidate is *Wadotes calcaratus*. Late summer and autumn are better sampling times than June-July (Carter and Brown 1973).

AMAUROBIIDAE: *Amaurobius borealis* and *Callobius bennetti* are large species which construct irregular webs under rocks, crevices and debris. Collections across the season showed parallel and similar abundance for *A. borealis* in the Elmsville series and the Priceville series (Fig. 1). The abundance *C. bennetti* was higher at Elmsville, but the trends do not suggest any within-season response to fenitrothion (Fig. 2).

CLUBIONIDAE: These hunting spiders prey nocturnally, and hide by day in tubular retreats in leaf rolls and crevices. *Agroea ornata* (Fig. 3) is a possible indicator because both plots showed a sharp post-spray decline, yet Elmsville had consistently higher density. *Phrurotimpus borealis*, common at Elmsville and scarce at Priceville, is another candidate.

ERIGONIDAE: Minute spiders weaving delicate sheet webs in litter and low growing herbage such as mosses. Our catches were similar in density and seasonal distribution in the two plots, and showed no apparent immediate response to spray application (Fig. 4).

GNAPHOSIDAE: Nocturnal hunting spiders building shelters in leaf rolls, moss and debris. *Zelotes subterraneus* was the principal species, and it was consistently more abundant at Elmsville (Fig. 5).

HAHNIIDAE: Most species prefer damp sites for their delicate sheet webs (Kaston 1948). *Hahnia cinerea* catches at Priceville and Elmsville were similar, parallel and apparently unresponsive to sprays (Fig. 6). However *Neoantistea riparia* was abundant at Elmsville (also in Carter's red spruce stand), but scarce at Priceville, so it has indicator potential (Fig. 7).

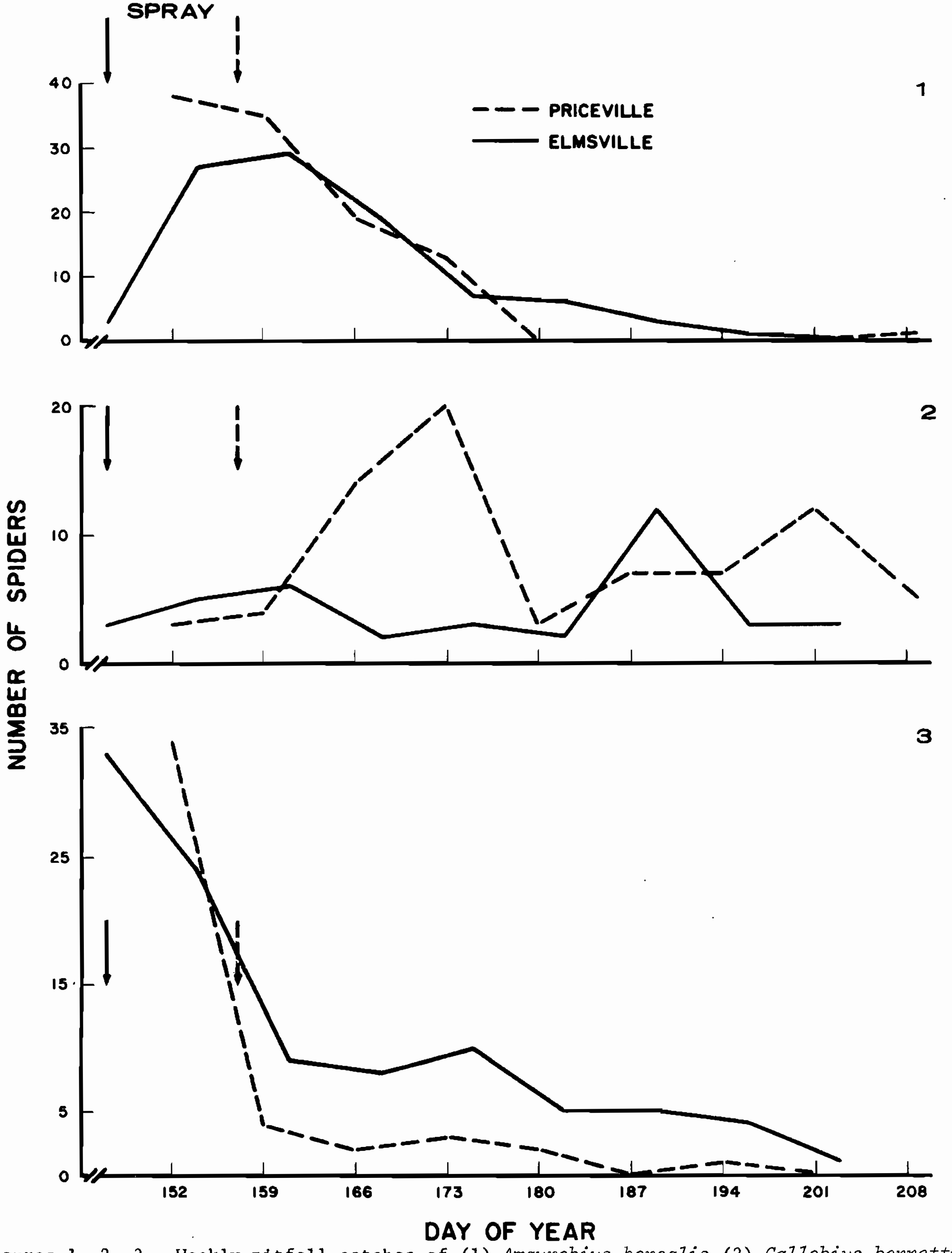
LINYPHIIDAE: Mostly arboreal, some litter-dwelling species; almost all build a snare webbing (Kaston 1948). Because of taxonomic difficulties in the identification of immature forms of species, they are not useful as indicators.

LYCOSIDAE: These robust hunting spiders forage diurnally in the litter and thus are well exposed to contact with insecticide deposits. The commonest species, *Pardoza mackenziana* showed little population difference between the two sites (Fig. 8); but *P. xerampelina*, much scarcer at Priceville, may be a good candidate. *Tarentula aculeata* (Fig. 9) and *Trochosa terricola* (Fig. 10) were also less abundant at Priceville.

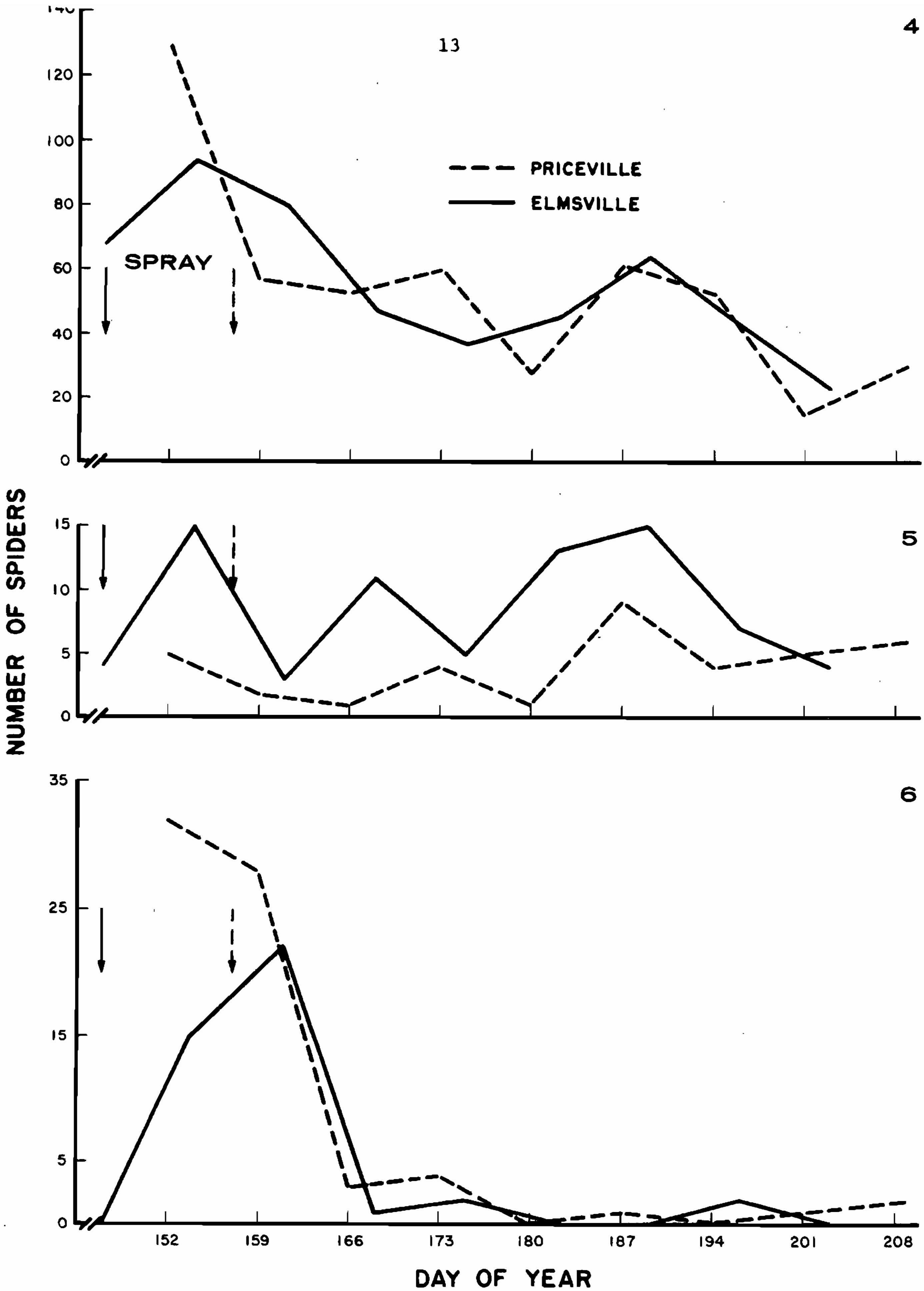
THERIDIIDAE: The litter-dwelling species are sedentary, and build an irregular web with viscid snare strands. *Robertus riparius* usually shelters under stones and woody debris, and thus its behaviour does not expose it to insecticide residues. Nevertheless its absence in the Priceville catches and abundance at Elmsville calls for an explanation.

THOMISIDAE: These sedentary hunters take their prey by ambush. The crab spider *Xysticus luctuosus* was scarce at Priceville compared with Elmsville, and therefore could be responsive to low levels of insecticide.

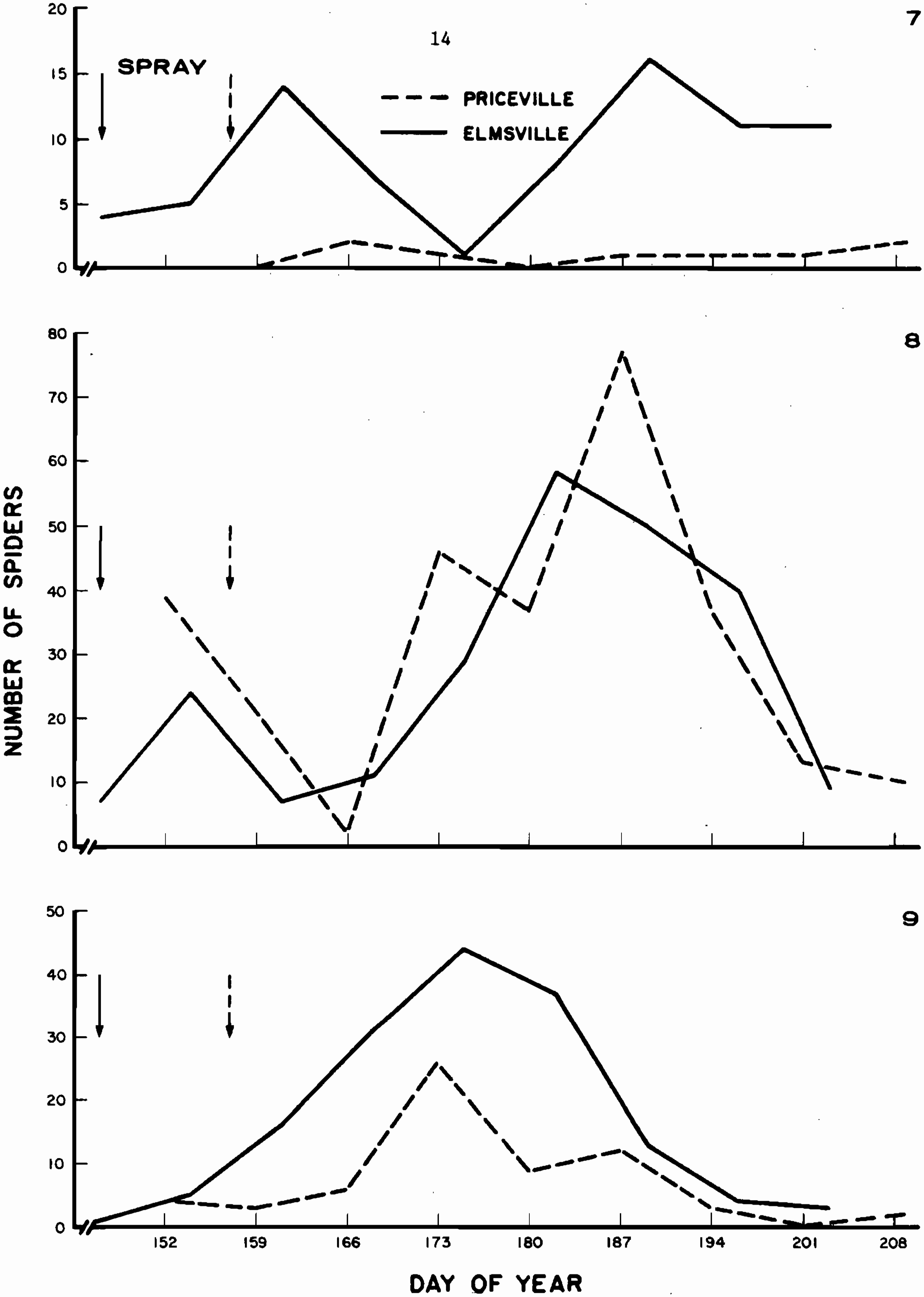
Conclusions: The lower species diversity at Priceville (27 identified spp) compared with Elmsville (45 identified spp) is prima facie evidence of insecticide-induced perturbation, but the indices of population



Figures 1, 2, 3. Weekly pitfall catches of (1) *Amaurobius borealis* (2) *Callobius bennetti* and (3) *Agroeca ornata* taken from two fir-spruce stands with dissimilar insecticide histories.



Figures 4, 5, 6. Weekly pitfall catches of (4) Erigonidae (5) *Zelotes subterraneus* and (6) *Hahnia cinerea* taken from two young fir-spruce stands with dissimilar insecticide histories.



Figures 7, 8, 9. Weekly pitfall catches of (7) *Neoantistea riparia* (Key.) (8) *Pardoza mackenziana* and (9) *Tarentula aculeata* (Clerck) taken from two young fir-spruce stands with dissimilar insecticide histories.

(Priceville 1384 specimens, Elmsville 1776) do not suggest severe damage to the function of predation. The species which are most likely to indicate insecticide impact are *Wadotes calcaratus*, *Agroea ornata*, *Phrurotimpus borealis*, *Neoantistea riparia*, *Pardoza xerampelina*, *Robertus riparia* and *Xysticus luctuosus*. Sampling techniques tailored to one or more of these species may be effective in detecting pesticidal disturbance of the environment.

Harvestmen

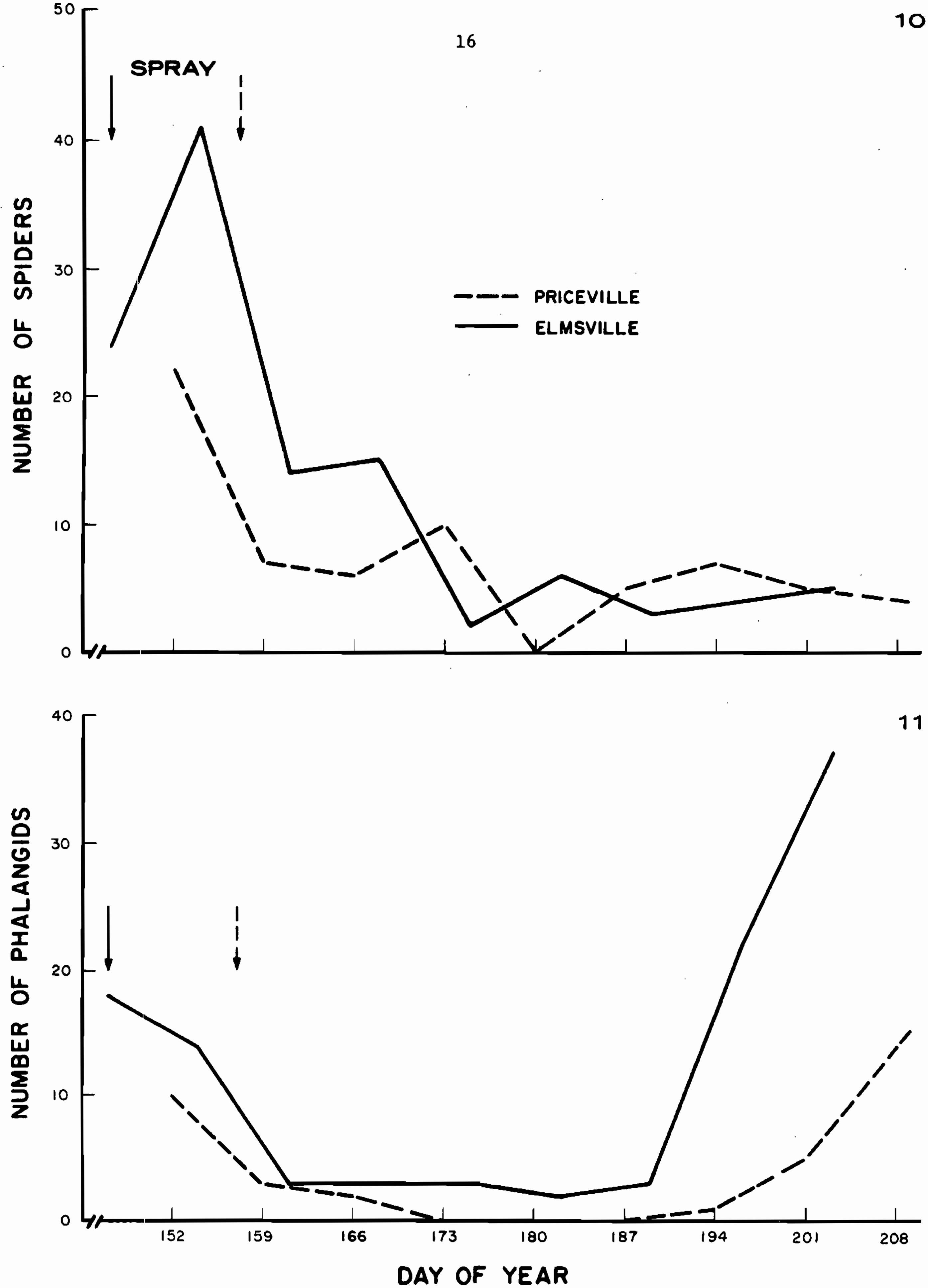
Harvestmen are predatory arachnids which range widely over the litter surface and will attack many kinds of smaller invertebrate prey, but their community influence is largely unknown. Our pitfall traps produced modest numbers of individuals and five species (Table 3), with a relative impoverishment at Priceville.

Leiobunum calcar was the dominant species in both plots, and seasonal distributions were parallel (Fig. 11). The down-turn just after spraying, persisting 40-50 days, is suggestive of immediate population reduction, but sampling was terminated too soon to determine severity or duration. Carter and Brown (1973) recorded a reduction in its abundance after spraying a red spruce stand with fenitrothion, and low catches persisted into the second year. Hoffmann *et al.* (1949) reported a severe reduction in a *Leiobunum* sp after heavy DDT applications.

Beetles

Beetles of many families were represented in the pitfall catches, but Carabidae and Staphylinidae were outstandingly the dominant predaceous groups. Carabids, both as adults and as larvae, prey upon a large variety of soil mesofauna especially the immature stages; in particular they feed heavily on such pests as cutworms, loopers and other lepidoptera that spend part of their life cycle in the litter. Having a large biomass in the litter fauna, carabids are important in the regulation of some foliage pests.

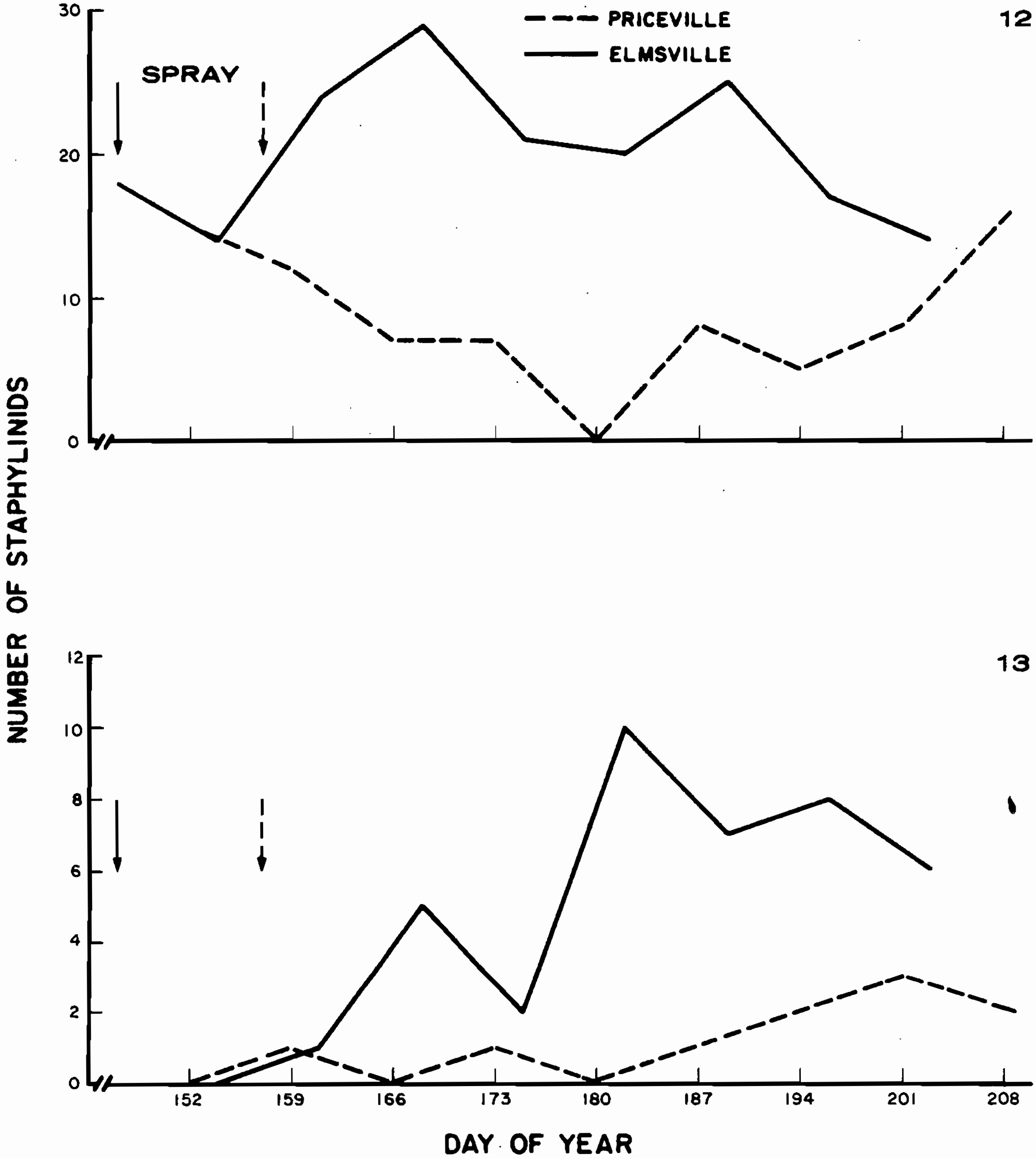
Carabid species diversity is responsive to soil type, ground cover, tree dominants, and less importantly to prey availability (Kulman 1974). A red pine stand in Ontario (Martin 1965) had the same two principal species, *Calathus gregarius* Dej and *Pterostichus pensylvanicus* Lec as our fir stands in New Brunswick. Table 4 shows that the diversity of species was lower and the numbers of individuals greater at Priceville, but there was no strong difference in the complexes found in the two plots. No species presents itself as a potential indicator



Figures 10, 11. Weekly pitfall catches of (10) *Trochosa terricola* and (11) *Leiobunum calcar* taken from two young fir-spruce stands with dissimilar insecticide histories.

Table 3. Species list and total catches of harvestmen in pitfall traps, May to June 1972, from fir-spruce stands

	No. of specimens Elmsville	Priceville
ISCHYROPSALIDAE		
Sabacon crassipalpe (L. Koch)	5	5
PHALANGIIDAE		
Caddo agilis Banks	3	1
Leiobunum calcar (Wood)	105	36
Leiobunum ventricosum (Wood)	32	1
Odiellus pictus (Woods)	—	25
TOTALS	145	68



Figures 12, 13. Weekly pitfall catches of (12) Aleocharinae and (13) *Bryoporus* taken from two young fir-spruce stands with dissimilar insecticide histories.

species. Freitag and Poulter (1970) recorded lower numbers of *Calathus ingratus* Dej and of *Pterostichus pensylvannicus* in Ontario spruce-fir woods one year after a heavy fenitrothion spray, than in control plots without a spray history; the authors considered this to be evidence of insecticidal reduction of carabids. Kulman (1974) quoted several other instances of apparent reduction of carabid populations following organic insecticide usage in orchard, field and forest. Our evidence in New Brunswick suggests that recurrent spraying for years may have little adverse influence on the effectiveness of the carabid group in predatory function.

Staphylinid or rove beetles are the second most important group. We assume that most species are predaceous, but it is known that staphylinids can be variously saprophagous and fungivorous according to species. The listing (Table 4) is somewhat suggestive of insecticidal reduction in diversity and abundance: 8 spp and 438 individuals at Elmsville, 6 spp and 327 individuals at Priceville; but that is entirely speculative. Regional and habitat differences independent of spray treatment could easily account for differences of this magnitude. The most likely indicator groups are the *Aleocharinae* spp, which are very small staphylinids hard to identify (Fig. 12), and *Bryoporus* sp. (Fig. 13).

Table 4. Pitfall catches of carabid and staphylinid beetles from fir-spruce stands, May-July 1972

Species	Number of Specimens	
	Elmsville	Priceville
CARABIDAE		
Apristus subsulcatus Dej.	26	4
Calathus gregarius Dej.	21	83
Notiophilus aeneus Hbst.	5	NIL
Platynus decens Say	10	NIL
Platynus ruficornis Lec.	6	8
Pterostichus adoxus (Say)	13	20
P. coracinus Newm.	15	8
P. corvinus Dej.	1	2
P. pensylvanicus Lec.	30	14
TOTALS	127 (9 spp)	139 (7 spp)
STAPHYLINIDAE		
Aleocharinae spp*	182	78
Boletobius cinctus Grav.	44	62
B. cingulatus Mann.	7	20
Bryoporus sp.	39	10
Lathrobium sp.	10	NIL
Mycetoporus sp.	16	NIL
Philonthus fusiformis Melsh.	8	12
Quedius sublimbatus Makl.	NIL	6
Tachinus repandus Horn	5	NIL
TOTALS	311 (8 spp)	188 (6 spp)
GRAND TOTALS	438 (17 spp)	327 (13 spp)

* No. of species uncertain, but small

FLYING INSECTS COLLECTED BY WINDOW TRAPS

Faunal diversity

Window trapping in the forest is a relatively indiscriminate technique which results in broad-spectrum insect collections beyond reasonable hope of complete identification to species. Identification to family is feasible, but such a taxonomic grouping does not well serve our purpose, i.e. to estimate insecticide-induced disturbance by reduction of insect diversity.

We investigated the taxonomic complexes of only the orders Diptera and Hymenoptera because these include so many species with important functions in pollination, parasitism, predation and the biting fly problem (Table 5). The great majority of the Diptera were cyclorraphal fly adults such as leaf miners, hump-backed flies and muscids; other well-represented groups were dance flies, gall midges, fungus gnats and various midges. Window-trapping appears to be ineffective for collection of mosquitoes, blackflies, deerflies, syrphid flies and tachinid flies.

We excluded from identification the following orders: Ephemeroptera (rare), Thysanoptera (very rare), Hemiptera (rare), Homoptera (occasional), Neuroptera (rare), Mecoptera (occasional), Coleoptera (abundant) and Lepidoptera (abundant).

The Hymenoptera were identified to family, and in the case of pollinating bees, to species. The largest family groups were the parasitoid wasps, ichneumonoids and chalcidoids. The "Chalcidoidea" was a catch-all taxon which actually includes cynipoids and proctotrupoids and minor families as well as chalcids. We paid special attention to the solitary and bumble bees because of their pollinating function, and importance in floral competition.

The comparison of insect tallies by family at Elmsville and Priceville offers little insight into the pesticide problem. It is worth noting, however, that in almost all major groups the traps were more productive at Priceville than at Elmsville:-

	Elmsville	Priceville
Lepidoptera	1,773	2,992
Diptera	1,927	11,398
Hymenoptera	544	927

This evidence disputes the contention of some environmental protagonists that forest spraying so decimates insect life that little remains for the life support of insectivorous vertebrates. The data also suggest the possibility that insecticide usage action may promote population density of leafminers, since the Priceville collection outnumbered the Elmsville collection by 6 to 1. Since many leafminer species overwinter in the litter, the lower predator populations at Priceville might permit a higher population level of leafminers.

The window trap method is useful as an index of abundance of wild bees. Table 6 lists five species of bumble bees, one plasterer bee sp, four leaf-cutter bee spp and fourteen spp of solitary bees. Boulanger *et al.* (1967) list several of these species as being characteristic of lowbush blueberry, *Vaccinium* spp, stands in New Brunswick. Since blueberries are a common component of the open forest vegetation in both plots, it is surprising that the two most common pollinators, *Andrena regularis* Malloch and *A. carlini* Cockerell were not collected by window trapping. In all probability their absence is derived from unsuitable edaphic and floral habitats at Elmsville and Priceville, but there is a possibility of hypersensitivity to fenitrothion.

In the conflict between spray agencies and blueberry growers in New Brunswick, it has been alleged that forest spray drift causes extensive death of wild bees, leading to poor fruitset and loss of crop. Our window-trap sampling of bees at Priceville shows that bees are certainly not extirpated since 14 spp and 142 specimens were collected there (cf. Elmsville 18 spp, 131 specimens). On the other hand there were substantially fewer bumble bees in the Priceville collections (2 spp, 18 specimens), compared with Elmsville (5 spp, 70 specimens). Since the individual bumble bee has larger biomass and visits more flowers than the individual solitary bee, the function of forest pollination might be more adequately performed at Elmsville than at Priceville. There is a possibility, totally unsupported by other evidence, that perennial usage of insecticide may lead to reduced densities of *Bombus perplexus*, *B. ternarius* and *B. terricola*.

CONCLUSIONS

This report is a step towards a baseline inventory of the arthropod fauna of fir-spruce forest. It is primarily a taxonomic listing, secondly a statement of abundance. This fauna is vulnerable to the insecticides broadcast for spruce budworm control, and it is speculated that this mortality factor, if sustained in successive years, may lead to new equilibrium levels for most arthropod species in the target forest. Some species may tend to higher densities, some to lower densities, dependent upon habitat vulnerability, toxicological susceptibility and trophic relationships within the community. We are now seeking ways

Table 5. Window-trap collections of Diptera and Hymenoptera in fir-spruce stands

Order/Family	Number of specimens		Ecological function
	Elmsville	Priceville	
DIPTERA			
Undetermined	1,927	11,398	Mostly leaf miners and other phytophages
Nematocera			
Tipulidae	12	3	aquatic/semiaquatic (crane flies)
Psychodidae	7	9	aquatic/saprophagous (sand flies)
Culicidae	-	1	aquatic (mosquitoes)
Ceratopogonidae	27	112	aquatic/semiquatic (biting midges)
Chironomidae	120	55	aquatic/saprophagous (midges)
Simuliidae	-	14	aquatic (blackflies)
Anisopodidae	1	2	saprophagous (wood gnats)
Bibionidae	12	17	saprophagous (march flies)
Mycetophilidae	75	273	phytophagous (fungus gnats)
Sciaridae	260	463	saprophagous (dark-winged fungus gnats)
Cecidomyiidae	127	618	saprophagous/phytophagous/predaceous (gall midges)
Brachycera			
Tabanidae	1	1	aquatic/predaceous (horse or deer flies)
Rhagionidae	78	69	saprophagous/predaceous (snipe flies)
Asilidae	-	3	predaceous (robber flies)
Empididae	205	138	predaceous (dance flies)
Cyclorrhapha			
Phoridae	732	2,446	saprophagous/predaceous (humpbacked flies)
Syrphidae	6	25	saprophagous/predaceous (syrphid flies)

Table 5 (continued)

Order/Family	Number of specimens		Ecological function
	Elmsville	Priceville	
Drosophilidae	1	1	saprophagous (pomace or fruit flies)
Heleomyzidae	-	11	saprophagous (heleomyzid flies)
Muscidae	156	333	saprophagous/parasitic (muscid flies)
Tachinidae	2	-	parasitic (tachinid flies)
Total	3,749	15,992	
HYMENOPTERA			
Xyelidae	1	-	phytophagous (xyelid sawflies)
Tenthredinidae	6	4	phytophagous (typical sawflies)
Xiphydriidae	-	2	phytophagous (wood wasps)
Braconidae	116	230	parasitic (braconid flies)
Ichneumonidae	99	44	parasitic (ichneumonid flies)
Chalcidoidea	154	449	parasitic (chalcid flies)
Chrysididae	3	-	parasitic (cuckoo wasps)
Vespidae	11	22	parasitic (wasps)
Pompilidae	-	9	parasitic (spider wasps)
Sphecidae	23	25	parasitic (sphecid wasps)
Colletidae	-	20	pollinator (plasterer or yellow-faced bees)
Andrenidae	19	9	pollinator (mining bees)
Halictidae	39	84	pollinator/parasitic (mining bees)
Megachilidae	3	11	pollinator/parasitic (leaf-cutting bees)
Apidae	70	18	pollinator (bees and bumble bees)
Total	544	927	

Table 6. Window trap collection of wild bees in fir-spruce forest

Species	No. of specimens	
	Elmsville	Priceville
APIDAE		
Bombus perplexus Cresson	7	-
B. ternarius Say	17	-
B. terricola Kirby	29	2
B. vagans Smith	15	16
Psithyrus citrinus (Sm.)	2	-
	70	18
COLLETIDAE		
Hylaeus verticalis Cress.	-	20
MEGACHILIDAE		
Osmia atriventris Cress.	2	-
Megachile sp.	1	-
Megachile melanophaea Mitch.	-	10
M. relativa Cress.	-	1
	3	11
ANDRENIDAE		
Andrena ceanothi Viereck	2	-
A. milwaukeensis Graen.	2	-
A. clarkella (Kby.)	1	-
A. thaspii Graen.	6	3
A. geranii Robt.	7	3
A. lata Vier.	1	-
A. carolina Vier.	-	2
A. wilkella (Kby.)	-	1
	19	9

Table 6. (continued)

Species	No. of specimens	
	Elmsville	Priceville
HALICTIDAE		
Halictus confusus Sm.	2	54
Dialictus viridatus Lov.	2	7
Lasioglossum coriaceum Sm.	16	2
L. foxii Robt.	1	-
L. quebecensis (Craw.)	18	20
Sphecodes stygius Robt.	-	1
	39	84
Totals (specimens)	131	142
(species)	18	14

to measure those trends and assess their impact on resource conservation and productivity. Our methods are: first, to compare arthropod inventories in stands with dissimilar spray histories, and secondly, to remeasure these inventories at intervals over the years.

The problem is to know what to measure in a system so complex as the fir-spruce forest. This study now suggests that adequate indices of population abundance can be measured by pitfall trapping of litter arthropods and window trapping of the aerial insect fauna.

Pitfall traps do indeed sample a broad spectrum of the litter fauna, but they have technical limitations. Catches are much affected by faunal responses to weather and food supply; they favour nocturnally active species and those instars which forage extensively (Southwood 1966). Since these traps do not sample species evenly, they cannot be used to compare species abundances within the fauna. They can best be used to compare plots and years when a single species is under study.

The technique has revealed that the repeatedly-sprayed stand (Priceville) tends to have lower species diversity and population densities of spiders, beetles and harvestmen than the once-treated stand (Elmsville). However the differences between the two plots are not so great that a conclusion of cause and effect would be tenable. The relative poverty of the Priceville fauna could easily be accounted for by variation in habitat (vegetation/climate). Some species, much more abundant at Elmsville than at Priceville, are selected as possible indicators of insecticidal disturbance.

Window trapping is a blunt technique with some merits and many defects. It is cheap to make and to operate, and can be located in special habitats to tap populations of a desired species or complex. It is most effective when it operates continuously over several weeks or months to produce a seasonal curve of catches, rather than used at intervals to obtain one or several population fixes. In continuous operation, it overwhelms the researcher with the abundance and variety of trapped specimens, and it draws on several adjacent and merging ecosystems which may be superfluous to the research objective. It does not sample the whole airborne fauna, but discriminates heavily in favour of certain groups with particular flight behaviour. The trap is not effective with other types of flight behaviour e.g. of mosquitoes and blackflies. Furthermore it virtually excludes all stages except winged forms.

The practice of window trapping has been rarely reported in forest insect research since Chapman and Kinghorn (1955) initiated their apparatus. Macdonald (Canadian Forestry Service, Person. Comm.) found window traps useful to provide a general picture of the insect complex in fir-spruce forests sprayed with DDT; he reported immediate reduction of flying insects, especially Hymenoptera, but no evidence of long-term effect. Merrill and Skelly (1968) found window trapping effective for beetle flight at tree-top level.

We found the method to be useful in two contexts: first in faunal survey to detect gross differences between stands, and secondly, to investigate the abundance and diversity of a particular group, the wild bees. We now have evidence that gross or drastic reduction in flying insect populations has not followed perennial spray operations, but we lack a general measure of change in diversity. Wild bee populations and species diversity in the two plots were so similar that no drastic change in the performance of the pollination function following recurrent spraying should be anticipated. The method could be useful as an index of wild bee abundance in blueberry fields.

So far we have only the results of pitfall trapping and window trapping in one season. The techniques could be employed again in other years, using the same plots and the same phenological period to determine whether the continued use of fenitrothion at Priceville, and the cessation of usage at Elmsville have sustained or accentuated the faunal differences.

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Appendix I. List of common and scientific names of flora

Balsam fir	*Abies balsamea* (L.) Mill.
Red spruce	*Picea rubens* Sarg.
Red maple	*Acer rubrum* L.
Trembling aspen	*Populus tremuloides* Michx.
Goldthread	*Coptis groenlandica* (Oeder) Fern.
Wintergreen	*Gaultheria procumbens* L.
Blueberry	*Vaccinium angustifolium* Ait.
	V. myrtilloides Michx.
Bunchberry	*Cornus canadensis* L.
Blue violet	*Viola cucullata* Ait.
Mayflower	*Epigaea repens* L.
Starflower	*Trientalis borealis* Raf.
Strawberry	*Fragaria vesca* L.