

THE INSECT ECOLOGY OF RED PINE PLANTATIONS IN CENTRAL ONTARIO

V. THE COCCINELLIDAE (COLEOPTERA)

W. C. GAGNÉ¹ and J. L. MARTIN²

Forest Research Laboratory, Department of Forestry and Rural Development,
Sault Ste. Marie, Ontario

Abstract

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Thirteen species of Coccinellidae were found to occur in adjacent red pine plantations of five different ages near Thessalon, Ont. These populations fell into two major ecological groups corresponding to the two plantation age classes. One group (the old-field species) inhabited young plantations up to 16 years old, and the other (the old-stand species) inhabited older stands. Each group was characterized by different dominant species, *Coccinella transversoguttata* Falderman and *Scymnus lacustris* Lec. in the younger stands, and *Mulsantina picta* (Rand.) and *Anatis mali* Auct. in the older stands. Species diversity decreased as the stands aged.

As the red pines increased in size, they became less favourable for coccinellids in general because prey density decreased. As a consequence, the predator's search area per unit prey capture increased necessitating an increased searching capacity and mobility. Coccinellid population fluctuations were synchronized with those of the woolly pine needle aphid, *Schizolachnus pimiradiatae* (Davidson), the major food source, due to compensative movements to and from the plantations of the adult coccinellids and the dependence of the larvae on the aphid. Starvation and cannibalism during the larval stages appeared to be the major mortality factors. Inclement weather and predation were of minor direct importance to coccinellid populations and parasitism was rare.

All species, with the possible exception of *S. lacustris*, were univoltine.

Introduction

Martin (1966) showed that coccinellids comprise a significant portion of the insect predator complex in foliar crowns of red pine plantations in central Ontario. He also noted that the species composition of adult coccinellids changes markedly as the stands age. Adult and larval coccinellids are known to be active aphid predators, their chief prey on red pine being the woolly pine needle aphid, *Schizolachnus pimiradiatae* (Davidson) (Grobler 1962).

The study reported herein was designed to determine the factors involved in the changes in species composition of coccinellid populations in red pine plantations as the stands develop and to elucidate the importance of *S. pimiradiatae* as a primary food source. As such, it is a more intensive study of this arthropod group on red pine than has hitherto been reported.

Methods

The records of species composition and distribution were obtained in five adjacent red pine plantations in the Kirkwood Management Unit, about 5 miles north of Thessalon, Ont. The establishment of these plantations in 1965, 1960, 1950, 1939, and 1929 on a level sand plain (Martin 1965a) assured uniformity of site and local climate. Martin (1965a, b) has described the developmental stages of a red pine community, based on the effect of crown closure on ground cover in four of the five plantations used in this study. He called these the establishment stage (up to 6 years old), the transition stage (6 to 16 years old), the

¹Present address: Division of Entomology, University of California, Berkeley, Calif.

²Present address: Director, Nova Scotia Museum, Spring Garden Road, Halifax, N.S.

monoculture stage (16 to 26 years old), and the young-forest stage (over 26 years old). To these is added the newly planted stage which distinguishes the stand planted in the spring of 1965.

Sampling began in 1960 and continued to 1965, the method used varying with the age of the plantation. The three oldest stages were sampled each year at 3-week intervals from early May to late September, using the pyrethrin spray method outlined by Martin (1966). In these three stages, square cotton sheets were used to collect the falling arthropods. In the transition and monoculture stages, the sheets were 8 ft square and were attached by their corners to four tree trunks below the lowermost branches. A pint Mason jar, which was partially filled with water, was used as a collecting jar, and was fastened to the centre of each sheet: the weight of the jar was sufficient to pull the sheet down into a shallow funnel. In the transition and monoculture stages, a funnel arranged in the above manner sampled one-quarter of the crown of each of four trees. A complete sample consisted of four funnels in each of these two stands so that a quarter of each of 16 trees was sampled. In the young-forest stage, the funnels used were 16 ft square and were attached to six trees (three trees on each of two sides). In this case, a funnel-sampled four quarters and two half-crowns, and two funnels were used to provide the same relative sample as that taken in the two younger stages. Samples collected in the foregoing manner were extracted and counted in the laboratory.

The newly planted and establishment stages were sampled twice during the summer, once in mid-June and once in mid-July. During the establishment stage, the sample consisted of every tenth tree in eight plots, each of which contained an average of 210 trees in 1965. Sample trees were visually examined in the field. In the newly planted stage, each of the seedlings in four randomly selected plots was examined visually. Each of these plots was 25×25 ft and contained approximately 25 seedlings.

In conjunction with field observations, life histories of coccinellids were obtained by rearing them at a constant temperature of 21°C and under 12 hours of fluorescent lighting per day. Adults were placed in individual 8.5×6.5×3.5 cm plastic boxes, and were removed as soon as they deposited eggs, to avoid cannibalism. As larvae hatched, they were placed in individual 3.0×5.0 cm plastic vials. Periodic checks on parasitism were obtained by rearing all stages of field collected material. The coccinellids were fed *S. piniradiatae* daily.

Composition and Distribution of Species Within Stages

Newly-planted Stage

In this stage, the seedlings did not form an influential part of the community and conditions were essentially those of an old field (cf. Martin 1965a). No coccinellids were present by the mid-July check although *S. piniradiatae*, which apparently was introduced on the nursery stock, had infested 7.5% of the seedlings. No barriers, other than a behavioural one, prevented the entry of coccinellids from other stands.

Establishment Stage

Martin (1966) has shown that the arrival of predators coincides with the appearance and spread of aphids into this stage of the pine community. By 1965, *S. piniradiatae* had occupied all of the trees. The percentage of trees on which coccinellid adults and larvae and *S. piniradiatae* occurred in years following planting is summarized as follows:

TABLE I
Percentage composition of Coccinellidae in the establishment stage stand in 1964 and 1965

Species	1964		1965	
	Adults	Adults	Larvae	Total
<i>C. transversoguttata</i>	38.1	42.2	7.7	49.9
<i>S. lacustris</i>	14.3	15.3	19.2	34.5
<i>M. picta</i>	4.7	7.0	0.0	7.0
<i>A. mali</i>	0.0	3.8	0.0	3.8
<i>C. trifasciata</i>	9.5	0.0	3.8	3.8
<i>C. novemnotata</i>	19.1	0.5	0.5	1.0
<i>H. parenthesis</i>	14.3	0.0	0.0	0.0

Percent occupied	YEARS AFTER PLANTING				
	1	2	3	4	5
by Coccinellidae	0	3.8	4.4	10.5	23.7
by <i>S. pimiradiatae</i>	0	2.7	16.8	35.9	100.0

Coccinella transversoguttata Falderman and *Scymnus lacustris* Lec. were the dominant species in the establishment stage accounting for over 80% of the coccinellid population (Table I). *Mulsantina picta* (Rand.) and *Anatis mali* Auct., both present as adults in 1965, failed to reproduce and must be classed as adventives. Populations of *Hippodamia parenthesis* Say and *Coccinella novemnotata* Herbst., both present as adults in 1964 dropped drastically in 1965, the former disappearing. *Coccinella trifasciata* Linn. appeared to be decreasing in numbers between 1964 and 1965. No adults of this species were collected in 1965 although the appearance of its larval stages confirmed its presence.

Transition Stage

In this stage, 100% of the trees were occupied by Coccinellidae. *S. lacustris* maintained a dominant position and was joined by *M. picta* and *A. mali*, these three species comprising over 90% of the breeding coccinellid population (Table II). The appearance of the latter two species in relatively large numbers in this stage of the red pine community began a trend in which old-stand species replaced old-field species. Populations of *C. trifasciata* remained low. *Cycloneda munda* (Say) appeared as an adventive and *C. transversoguttata*, a species of dominance

TABLE II
Annual percentage composition of Coccinellidae in transition, monoculture, and young-forest stage stands in 1964 and 1965

Species	Transition		Monoculture		Young forest	
	1964*	1965†	1964*	1965†	1964*	1965†
<i>M. picta</i>	40.7	24.7	96.6	50.8	96.1	42.6
<i>A. mali</i>	9.8	34.3	3.4	39.6	3.1	52.4
<i>S. lacustris</i>	47.2	31.3	—	4.2	0.8	1.9
<i>C. trifasciata</i>	2.3	3.0	—	4.2	—	1.9
<i>C. munda</i>	—‡	2.2	—	2.2	—	1.2
<i>C. transversoguttata</i>	—	4.5	—	0.0	—	0.0

*Only adults counted.

†Adults and larvae counted.

‡Species ignored in 1964 counts.

in the establishment stage, appeared near the edge of the stand only. For some unknown reason, possibly behavioural, this species did not colonize the transition stage as *S. lacustris* did.

Monoculture Stage

S. lacustris, the last of the major old-field species in the younger stages was not present here as a breeding population and appeared as an adventive only (Table II). *M. picta* and *A. mali* were the dominant species comprising over 90% of the breeding population. A small breeding population of *C. munda* was present and *C. trifasciata* appeared as an adventive.

Young-forest Stage

There was no change from the overall species composition in the monoculture stage. Although the order of abundance of *M. picta* and *A. mali* was reversed (Table II), together they represented over 97% of the breeding population. The population of *C. munda* decreased in abundance, as did the adventives, *C. trifasciata* and *S. lacustris*.

All Stages

Figure 1 shows that *A. mali* and *M. picta* were relatively more abundant in the older stands and were the dominant species in the two oldest stages. *C. transversoguttata* and *S. lacustris* were more abundant under old-field conditions, these two species being the dominant ones in the establishment stage. Both old-field and old-stand species reproduced in the transition stage, but a general decrease in relative abundance of old-field species and an increase of old-stand species were indicated as the stands developed. *C. trifasciata* formed a comparatively insignificant proportion of the population in the 6- and 16-year-old stands, as did *C. munda* in the 26- and 36-year-old stands. Low breeding populations of these two species and of *C. novemnotata* in the establishment stage might indicate poor synchrony with *S. piniradiatae* populations, a low preference for this aphid as food (cf. Hagen 1962), or a marked specificity for a habitat other than red pine (cf. Thompson 1951). The latter possibility seems the most plausible here.

Table III shows the occurrence in all stands of the eight species previously mentioned, and in addition, the sporadic occurrence of other coccinellid species during the 5 years of sampling. *H. parenthesis* disappeared from the establishment stage in 1965, possibly due to heavy mortality from parasitism. Although Grobler (1962) mentions *Chilocorus stigma* (Say) as being a predator of *S. piniradiatae*, this coccinellid was not found on red pine in 1965. Breeding populations of this species were associated with scrub willow, *Salix* sp., near the plantations, which may indicate that it accepts *S. piniradiatae* in years when prey on willow is scarce. Adults of *Anisocalvia duodecimmaculata* Gebl., *Hippodamia convergens* Guer., *Anisosticta bitriangularis* (Say), and *Hyperaspis* sp. were caged with *S. piniradiatae* to determine if these species would prey on the aphid. The two former species accepted the aphid as food, while the latter two species refused it and starved when no food source other than *S. piniradiatae* was available. These findings might indicate that *A. duodecimmaculata* and *H. convergens* are potential colonizers of red pine and the fact that a small breeding population of *H. convergens* became established in the transition stage in 1965 is evidence in support of this possibility. Since *A. bitriangularis* and *Hyperaspis* sp. refuse the aphid, these two species probably are insignificant predators of aphids on red pine in central Ontario.

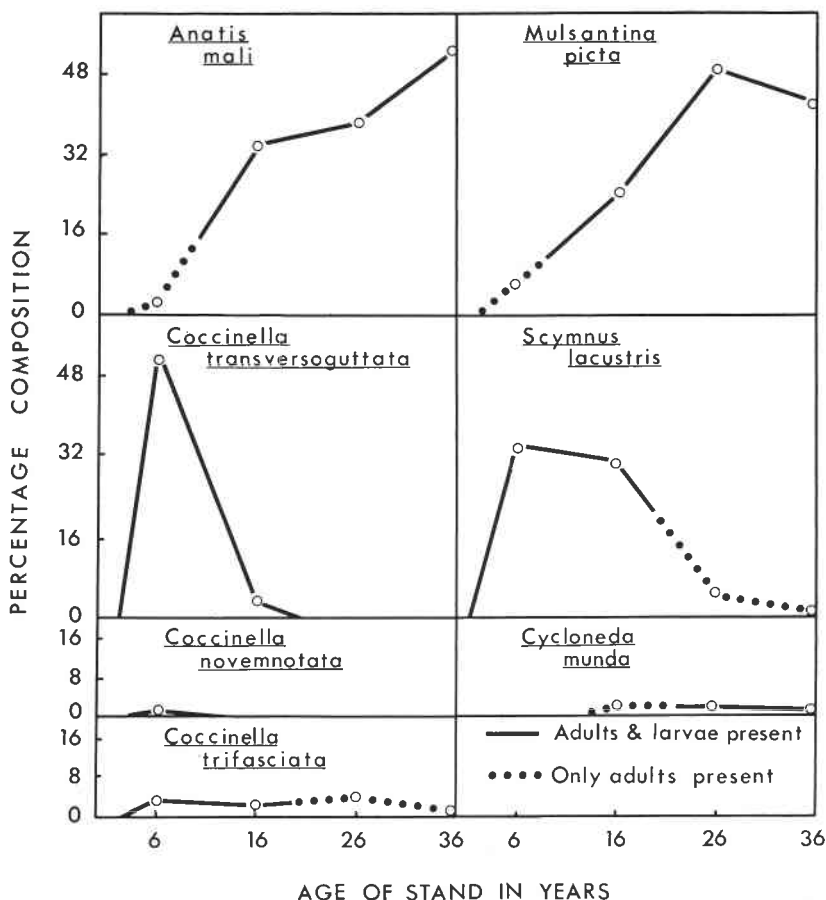


FIG. 1. Relative abundance of Coccinellidae in red pine plantations in Kirkwood Township, Ont., in 1965.

Factors Affecting Distribution

As the trees grew older they became less favourable for coccinellids in general. Prey density declines as crown volume increases (Martin 1966) and this, of necessity, leads to increased areas of search per unit prey capture. This, in turn, leads to increased exposure of the predator to various mortality factors. The greater searching capacity and mobility of the larvae of old-stand species would appear to be requisite for survival in areas where prey density is low. The larvae of *A. mali* and *M. picta* were frequently observed rapidly searching needle clusters for prey. Of interest in this respect are two recent articles by Ewert and Chiang (1966a, b) which reported that the adults of some species of coccinellids exhibited a vertical stratification in their distribution on field crops and that the higher flying species were the more mobile. In marked contrast, the larvae of *S. lacustris* are slow moving and practically sedentary; however, in this case, the adult of this species apparently provides for larval survival since some *Scymnus* species are known to lay their eggs singly, sometimes concealing them (Hagen 1962). C. J. Sanders (personal communication) has found that *Scymnus*

TABLE III

Occurrence of Coccinellidae in all stand stages showing those present and breeding in the stands, +; those present but not breeding in the stands, (+); and those not present in the stands, —

Species	Newly planted (1965)*	Establishment (1960)	Transition (1950)	Monoculture (1939)	Young forest (1929)
<i>Chilocorus stigma</i>	—	(+)	(+)	—	—
<i>Hippodamia parenthesis</i>	—	+	—	—	—
<i>Coccinella novemnotata</i>	—	+	(+)	—	—
<i>C. transversoguttata</i>	—	+	+	—	—
<i>C. trifasciata</i>	—	+	+	(+)	(+)
<i>Scymnus lacustris</i>	—	+	+	(+)	(+)
<i>Anatis mali</i>	—	(+)	+	+	+
<i>Mulsantina picta</i>	—	(+)	+	+	+
<i>Cycloneda munda</i>	—	—	(+)	+	+
<i>Hippodamia convergens</i>	—	—	+	—	—
<i>Anisocalvia</i>					
<i>duodecimmaculata</i>	—	—	(+)	—	—
<i>Hyperaspis</i> sp.	—	—	—	(+)	—
<i>Anisosticta bitriangularis</i>	—	—	—	—	(+)

*Year planted.

predators of the aphid *Pterocomma populifoliae* (Fitch), on poplar, lay eggs singly, placing them in or near the aphid colony.

Interspecific competition cannot be dismissed as a factor affecting distribution. This was evident particularly in the establishment stage stand in early summer. Here, there was a comparatively high prey and predator density. The competition arising among coccinellids in the establishment stage was apparently density dependent. When aphid populations in the older stands were still low in early summer, adults of old-stand species ((+) in Table III) foraged for prey here, contributing to the competition, as did growing populations of the dominant old-field species, *C. transversoguttata* and *S. lacustris*. Other old-field species, particularly *C. novemnotata* and *H. parenthesis*, not able to withstand the competition, were being gradually expelled (Table I).

The movements of adults to and from the plantations in search of prey effect their distribution. When aphid populations are high, there is a corresponding increase in the coccinellid population with comparatively large numbers of adult progeny being produced. The adults are not much affected by competition for prey in older stands at the time they emerge since aphid populations are still rising and since they hibernate soon after. However, when high aphid populations fail to materialize the following year, large numbers of adults which have returned to the trees in the spring, find prey insufficient and are forced to move out of the plantations in search of food. This migration contributes to a sudden drop in coccinellid populations in a year following low aphid populations. In 1962 (Fig. 2) aphid populations were comparatively high in all stands. The coccinellid population responded and reached its peak in 1963. High aphid populations failed to develop in 1963 and continued to drop in all stages in 1964. The large number of adults that had returned to the stands in 1963 were forced to seek food elsewhere and the coccinellid population dropped in the young-forest and monoculture stages in 1964 quite proportionally to the aphid population drop the previous year. Thus, the fluctuations of prey and predator were largely compensative.

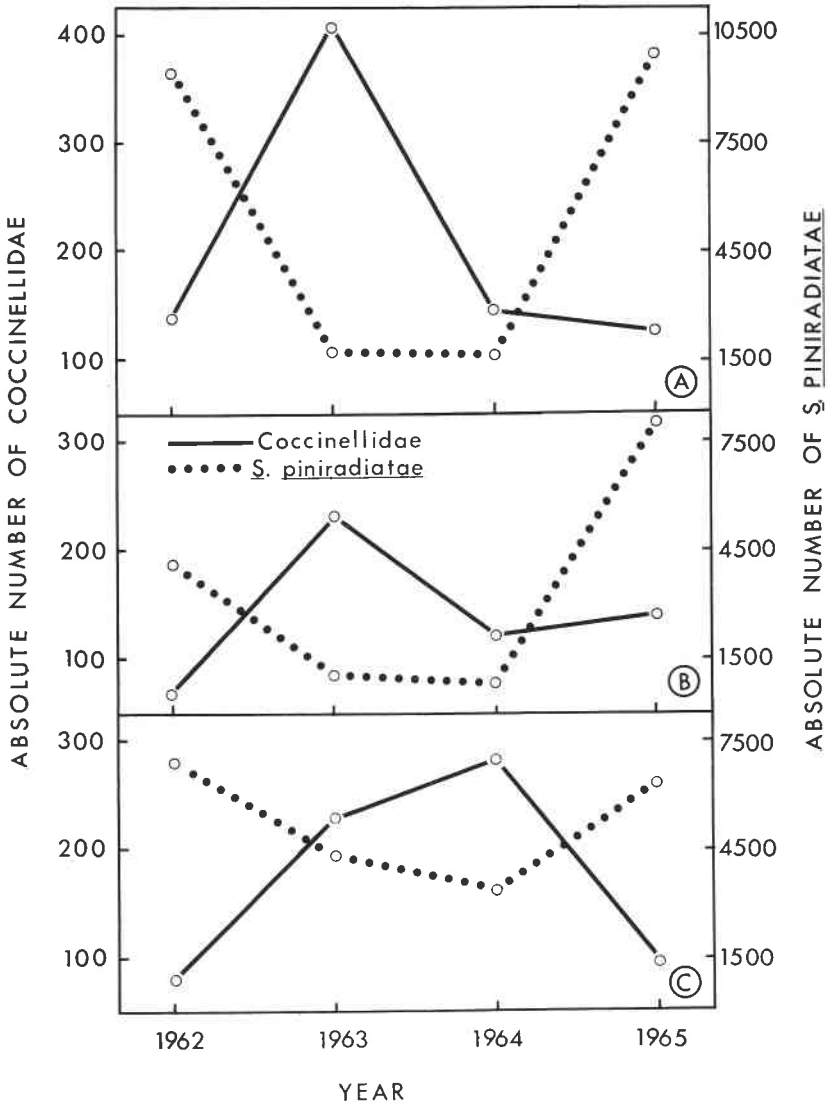


FIG. 2. Absolute numbers per year of Coccinellidae and *S. piniradiatae* in young-forest (A), monoculture (B), and transition (C) red pine stages, 1962 to 1965.

The numbers of Coccinellidae and *S. piniradiatae* in 1965 and in 1964 for four corresponding sampling periods in the three oldest stages (plotted on a logarithmic scale in Fig. 3) indicates a close synchrony between prey and predator in any one year, although in terms of absolute populations (Fig. 2), either the prey or predator population may be rising or falling. When prey is more or less sedentary, as is the case with *S. piniradiatae* (Grobler 1962), coccinellids attacking them usually show close synchrony with their prey, as Hagen (1962) finds with predacious Coccinellidae in general.

Grobler (1962) has shown that *S. piniradiatae* colonies are not distributed at random, definite areas of high population density being present in the stand.

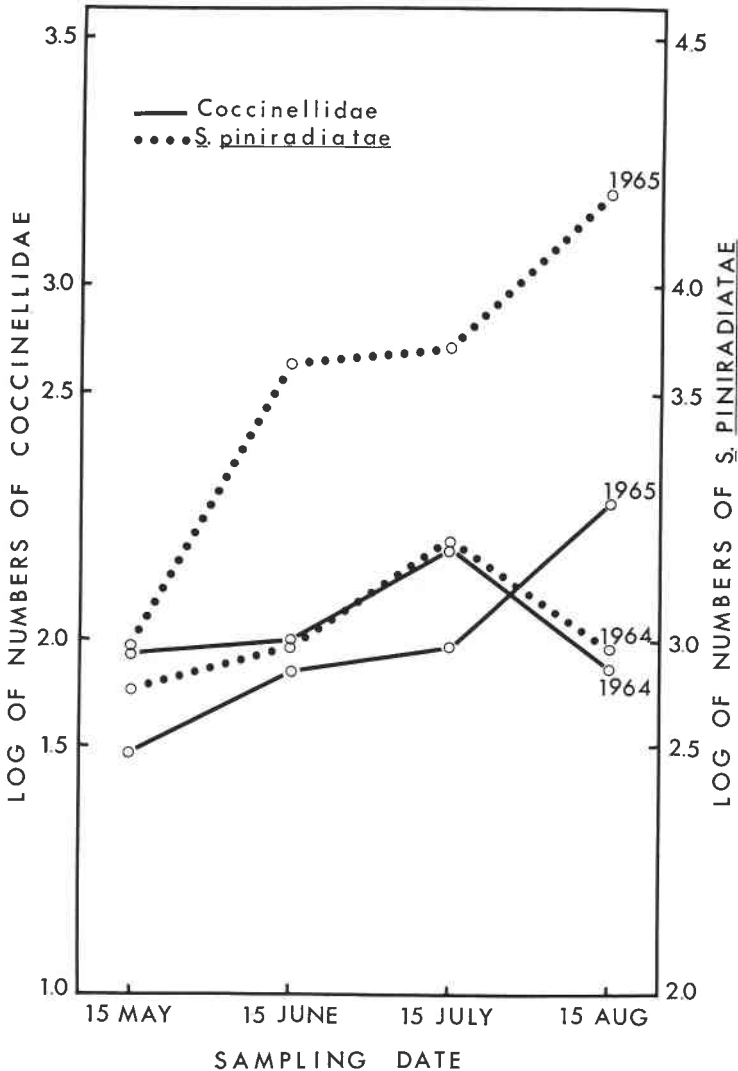


FIG. 3. Log_{10} of the lumped numbers of Coccinellidae and *S. piniradiatae* in the transition, monoculture, and young-forest stages of red pine community development on each of four corresponding sampling dates in 1964 and 1965.

Although not investigated, there remains the possibility that coccinellids were distributed according to the prey density. Banks (1956) has shown this to be the case with adult coccinellids feeding on *Aphis fabae* Scop. on beans in England. In late summer this possible concentration of coccinellids would probably not occur because there is almost 100% mortality of *S. piniradiatae* due to an entomophagous fungus, where there are high population densities of the aphid (Grobler 1962).

Coccinellid species diversity was influenced by the presence of mixed plant stands. Presumably, a number of old field species, which played undetermined roles in the community, were associated with predator-prey complexes on plants

other than red pine in and about the plantations. *C. stigma* was found primarily on scrub willow, *Salix* sp., in young plantations, whereas *H. parenthesis* has been associated with grass and *Carex* sp. (Palmer 1914). *C. transversoguttata* and *C. novemnotata* accept (*loc. cit.*) a variety of aphid species. In laboratory studies, Smith (1965a) showed that some foods and diets, not adequate for reproduction, served only to prolong the life span of *A. mali*. He indicated (1965b) that this species is restricted to certain prey in the field, pointing out that it is "able to survive low prey densities"; this also suggests that old-stand species have narrower food preferences than old-field species.

Mortality Factors

Larval starvation resulting from declining aphid populations was probably the key factor in periodically reducing coccinellid population levels between 1960 and 1965 (Fig. 2). The general decline in aphid populations began prior to 1960 (Grobler 1962) and continued in 1964, probably due to the combined effect of drought, disease, and natural enemies. Larval starvation evidently occurred as follows: when adults returned to the trees in the spring following hibernation, a low prey population was encountered. These adults fed, further depleting the prey, and then laid eggs, evidently not needing the stimulus of the presence of aphids for egg laying (cf. Banks 1956). Emerging larvae found the food supply insufficient for survival but could not migrate out of the trees in search of prey. The restricted diet of the old-stand species would likely prevent the adults from migrating to other habitats in search of prey and so they would be competing with the larvae for the prey available in the red pine stands. Consequently, in years when prey populations were abnormally low, the larvae starved.

Cannibalism was an important mortality factor in 1965, eggs being eaten most frequently. In any egg batch, slower-hatching eggs were invariably eaten by first-instar larvae. Adult females occasionally ate some or all of their newly-laid eggs. Before newly-hatched larvae had dispersed, many individuals fell prey to their more aggressive brothers, and this mortality continued as larvae encountered one another on the tree but gradually decreased among later-instar larvae. In September when the aphid population was decreasing, adults of *A. mali* were observed feeding on pupae and on teneral adults.

The direct effects of weather have not been fully investigated and although our observations indicate that weather *per se* was not an important mortality factor, some drowning of first- and second-instar larvae has been observed. In addition, wind dislodgement of young larvae, particularly in the monoculture and young forest stages, and early frosts could have been important mortality factors in certain years.

Spider predation on young larvae was observed, but the aggressiveness and protective mechanisms, particularly of later instars, provided some immunity from attack. Larvae of *C. trifasciata* and *C. novemnotata* were seen feigning death and dropping from the foliage at the approach of a potential predator. The waxy flocculence of *S. lacustris* larvae was undoubtedly protective. The larvae of *M. picta*, at least, were able to extrude repellent fluids ("reflex bleeding") from pores on the dorsolateral areas of the abdominal terga; the nature of the latter has been described (Gage 1920; Boving 1917; McIndoo 1931). Fragile setae on the body of the larva are thought to be specialized for defensive purposes (Boving 1917; McIndoo 1931). Adults of all species were observed expelling fluids from the femorotibial articulations and from between some of the lateral abdominal

TABLE IV

Mean duration in days of developmental stages of coccinellids reared at 21°C and under 12 hr of fluorescent lighting per day. The range (if any) in each stage is shown in parentheses beneath the mean

Species	Egg	Larva	Pupa	Egg to adult	Female after egg laying
<i>A. mali</i>	4.5 (4-5)	32.6 (15-58)	4.7 (4-7)	41.8 (34-66)	9.0 (5-15)
<i>C. novemnotata</i>	5.0	31.0	NR	NR	19.0
<i>C. transversoguttata</i>	5.0	29.0 (25-33)	5.3 (5-6)	39.6 (36-43)	35.2 (10-60)
<i>C. trifasciata</i>	4.3 (4-5)	17.3 (15-20)	5.0	26.6 (25-29)	> 54.0* (7-> 90)
<i>C. munda</i>	4.0	19.0	NR	NR	> 61.0* (22-> 100)
<i>M. picta</i>	4.3 (4-5)	19.2 (16-22)	3.8 (3-6)	26.7 (24-30)	> 90.0*
<i>S. lacustris</i>	NR	10.6 (7-15)	8.0	Near 23	NR
MEAN	4.3 (4-5)	21.3 (7-58)	5.3 (3-8)	—	—

NR, no record available.

*Rearing terminated.

articulations. It is presumed that these fluids are repellent to predators of adult coccinellids. Hagen (1962) mentions the reddish color displayed by adults of the larger species as being "apparently aposematic in function, acting as a warning coloration".

Parasitism was rare generally but might have been important in the population drop of *H. parenthesis* since two of three adults of this species collected as larvae in the plantations were parasitized by *Perilitus coccinellae* (Schrank), a braconid. Only one adult of *M. picta*, of hundreds observed in the field, and of scores reared, had this parasite. Adult parasitism is easily observed since the dead or dying adult host remains on the emerged parasite's cocoon. Of hundreds of healthy pupae of *A. mali*, four from one red pine were found mummified, and from each of these, two or three of the pteromalids, *Pachyneuron* sp., emerged.

Notes on Life Histories

Life histories of most species encountered were essentially similar. *C. transversoguttata*, *C. trifasciata*, *A. mali*, and *M. picta* were univoltine. Palmer (1914) indicated that *C. novemnotata* is bivoltine in Colorado although this species appeared to be univoltine in central Ontario. *H. parenthesis* and *H. convergens* also appeared to be univoltine in central Ontario although Hagen (1962) indicated that these two species have variable voltinisms in temperate regions. The voltinism type of *S. lacustris* was not determined although the short duration of the last three larval instars (Table IV) and the known voltinism type of other *Scymnus* species (cf. Hagen 1962) would suggest that the species is multivoltine. The remainder of the species mentioned in Table III were encountered infrequently and no attempt was made to determine their voltinism type.

The adults became active on the trees in early May and egg laying began about a month later and continued to mid-July. Except for the eggs of *S. lacustris* which were probably concealed individually and which were not observed, eggs of the other species were laid randomly in clusters on the needles

of the crowns. The duration of the egg stage (Table IV) was markedly similar, varying from 4 days for the smaller species to 5 days for the larger.

As soon as they hatched, the larvae consumed their egg shells and usually other unhatched eggs in the batch, then they dispersed and searched for food. The duration of the larval stages (Table IV) increased proportionally to the adult size of the species, being shortest with *S. lacustris*, the smallest species, and longest with *A. mali*, the largest species. All larval instars of the various genera were distinct except the *Coccinella* spp. which were practically inseparable in early instars. Moulting took place on the needles in the crown.

Pupation also occurred in tree crowns. The pupation site of *A. mali* in the transition stage was characteristic of this species, in the needles of the lowest foliated branches. Except for *S. lacustris*, which had a longer pupal period than most, the duration of the pupal stage was quite uniform between species. Pupation and adult emergence were virtually complete by late August and mid-September respectively.

Data on the survival of the female after egg laying are included in Table IV to indicate the segment of the adult population in late summer that might be represented by adults from the previous year. The data indicate that "old" adults of *A. mali*, *C. novemnotata*, and *C. munda* did not persist, while those of the other species did. Males of all species usually died within a month of mating. The duration of egg to adult stages also indicates some dependency on the size of the adult of the species and was shortest with *S. lacustris*, the smallest species, and longest with *A. mali*, the largest species.

Discussion

Martin (1965a, b) found that soil surface fauna among the Gryllidae, Carabidae, Formicidae, and certain of the spiders could be used as indicators of stand changes within red pine plantations. Old-field and old-stand species appeared in the soil surface fauna. The present work has shown that the Coccinellidae on the foliage can also be broken down into old-field species (*C. transversoguttata* and *S. lacustris*) and old-stand species (*A. mali* and *M. picta*) and provide reliable indicators of stand change. No species of the Coccinellidae were present in about equal numbers throughout the five stages; coccinellid species were either restricted to certain stands or reached their highest densities at a particular period of red pine community development. The establishment stage species were largely replaced by a different species-complex through the monoculture and young forest stages.

Although the numbers of coccinellids fluctuated quite closely with the aphid population in any one year (Fig. 3) and the predator-prey ratio would appear to be quite stable as Martin (1966) noted, a net increase or decrease of the coccinellid population was evident in the year following a net increase or decrease of the prey (Fig. 2).

The movements of adult coccinellids in search of prey and hibernation sites and their specificity for food or habitat are some of the important factors requiring further investigation. Old-stand and old-field species forage for food on the younger and older plantations respectively but do not reproduce there. As fall approaches the adults begin disappearing from the stands and it is not known where they hibernate, or if they form aggregations when they hibernate. It is interesting to note that of the species occurring in the plantations, only *H. parenthesis* and *H. convergens* are known to hibernate in aggregations.

Although we have tried to elucidate the mechanisms affecting coccinellids as a whole in these plantations, it must be remembered, as Hagen (1962) points out, that "each species can be sensitive to entirely different sets of ecological triggers . . . the facts responsible for these differences are just beginning to unfold". When each species is investigated individually, perhaps its effectiveness as a controlling agent, and coccinellids in general as controlling agents of aphids in red pine plantations, will become evident.

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