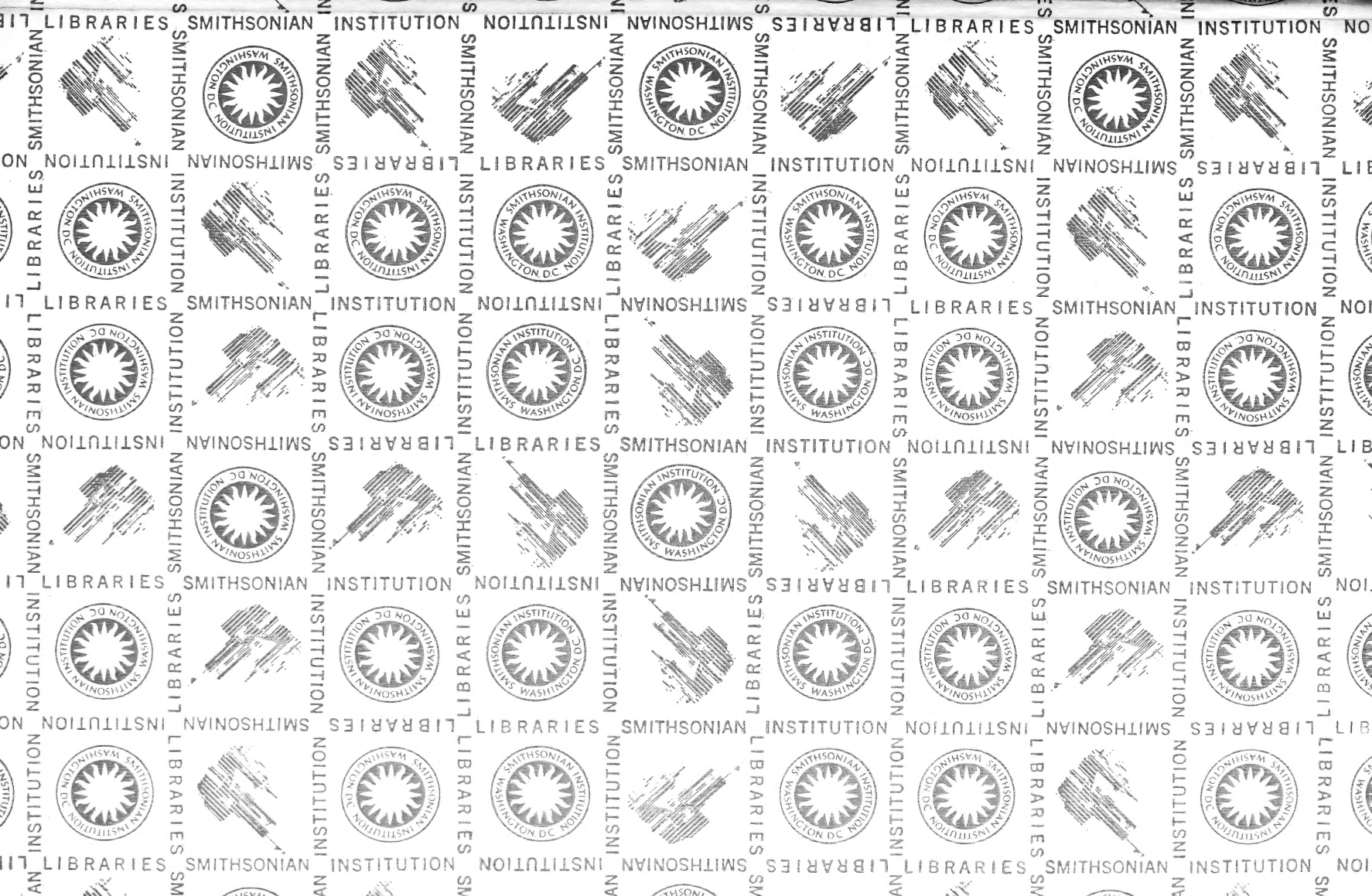
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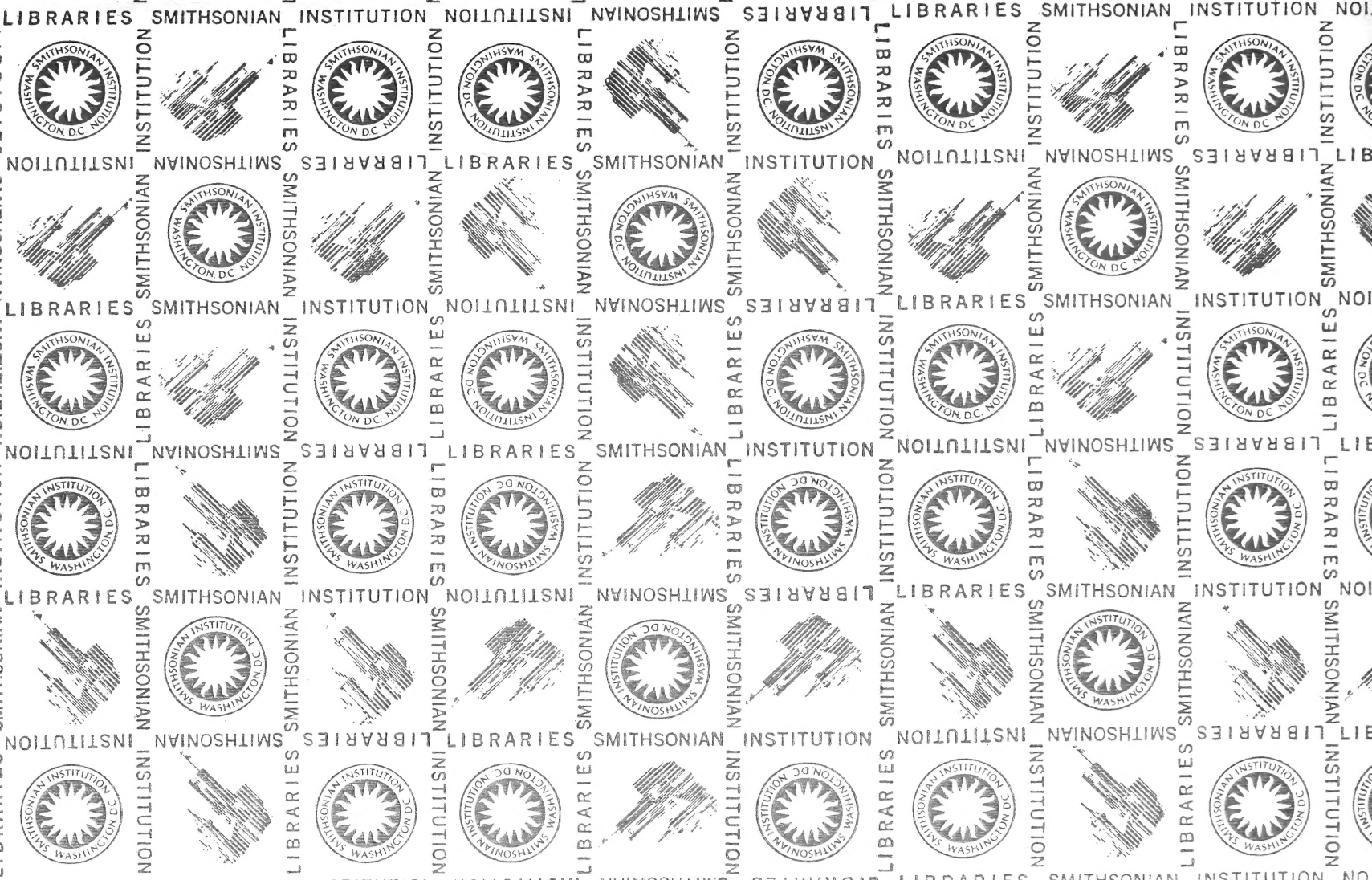
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PROCEEDINGS of the ENTOMOLOGICAL SOCIETY OF ONTARIO

Volume Ninety-Four

1963

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THE HONOURABLE WILLIAM A. STEWART, MINISTER OF AGRICULTURE FOR ONTARIO

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VOLUME 94

I. REVIEW

The European Pine Sawfly, *Neodiprion sertifer* (Geoff.) (Hymenoptera: Diprionidae).

A Review with Emphasis on Studies in Ontario[1]

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Introduction

The European pine sawfly, *Neodiprion sertifer* (Geoff.), has been present in North America for at least 40 years and in Ontario for about 25 years. Numerous investigations, both here and in Europe, on the biology, ecology, behaviour, natural control, and other features, have made it one of the best known members of the genus. The literature is now so extensive that a summary of our knowledge is essential for an intelligent approach to the economic problems this insect presents. The following review of published literature is supplemented by unpublished results of current investigations near Chatsworth in Ontario.

Taxonomy and Distribution

According to Ross (1951), *Neodiprion sertifer* was first named by Geoffroy in 1785 as *Tenthredo sertifera*. It has subsequently been included in the genera, *Pteronus, Lophyrus,* and *Diprion*. The latter is still used by some European writers, although the generic designation *Neodiprion* dates from 1918. *Lophyrus rufus* of various authors is a synonym. Keys for identification of adults were published by Enslin (1912-1917) and by Ross (1955), who on morphological evidence sketched the evolution of the genus. According to Ross's scheme, the original *Neodiprion* group, which spread across North America with its conifer host during the mid-Tertiary or early Miocene, was later split into eastern "lecontei" and western "sertifer" groups by the formation of the great plains; *N. sertifer,* or its ancestral form, later dispersed to the Eurasian continent via a Bering land bridge. Ross's family tree of the genus places *sertifer* closer to *nanulus* than to other western species, but a close affinity between these species was not confirmed by West et al. (1959), whose serological studies suggest that *sertifer* is more closely related to the eastern *rugifrons* Middleton *(virginianus)* than to *nanulus*.

The present uncertainty as to the affinities of *N. sertifer* in particular, and the taxonomy of the genus *Neodiprion* in general, may be clarified by current studies by D. R. Wallace (personal communication) employing spectrophotographic analysis of egg colours in addition to more conventional techniques. This approach has already permitted the identification of two types of *N. sertifer*: one that has so far been found only in Japan, and

[1]Contribution No. 1055, Forest Entomology and Pathology Branch, Department of Forestry, Ottawa, Canada, prepared at the invitation of the Publications Committee, Entomological Society of Ontario.

another occurring throughout Europe and eastern North America. The status of *N. sertifer* between Japan and the European part of the U.S.S.R. is uncertain.

Pest Distribution Map No. 98, issued June 1959 by the Commonwealth Institute of Entomology, shows *N. sertifer* as occurring in Europe, Japan, and Korea but not in the intervening region. However, according to Pschorn-Walcher (1963), *N. sertifer* is known as a pest of *Pinus* in Siberia, so there is probably one continuous Eurasian distribution. In Europe *N. sertifer* occurs from southern Italy to northern Finland. In Switzerland it has been found up to an elevation of 6,500 feet, feeding on prostrate forms of *Pinus mugho* and *P. cembra.*

The history of the introduction and establishment of *N. sertifer* in North America cannot be completely reconstructed. In 1925 and 1926 unknown sawfly larvae were collected in abundance on *Pinus montana* near Somerville, New Jersey, but were not identified as *N. sertifer* until 1936 (Schaffner, 1939). Shortly thereafter it was very well established in New Jersey and other localities as far west as Michigan (McDaniel, 1938; Girth and McCoy, 1946a). The Pest Distribution Map referred to above lists *N. sertifer* also from Pennsylvania, Indiana, Connecticut, Iowa, Missouri, New York, Illinois, and Wisconsin.

N. sertifer was first recorded in Canada at Windsor, Ontario, in 1939 and at Sarnia the following year. (Brown, 1940; Watson, 1949). Since then the distribution of this sawfly has been carefully followed by the Forest Insect Survey, whose efforts have resulted in a well-documented history of the advance of *N. sertifer* in Ontario. This is portrayed in Fig. 1, where the distribution boundaries are shown for every second or third year. Most of the extensions of distribution must be attributed to natural dispersal of adult sawflies, but in a few isolated cases the transfer of infested nursery stock has been implicated (Sippell, 1961). From 1939 to 1963 the average rate of natural spread has been about 10 miles per year, but this rate has not been evenly maintained. Little spread occurred during the first few years, and it was not until 1945 that larvae were recorded as far east as Strathroy (Watson and MacKay, 1946). The boundary is now being extended rather slowly, whereas in some years there have been apparent advances of as much as 30 miles. The present limits of distribution in Ontario seem to be approaching those of the European pine shoot moth as described by Pointing and Green (1962).

Clearly, *N. sertifer* is still extending its range in Ontario and has yet to reach the limits of its possible distribution. According to C. R. Sullivan (personal communication), the physical requirements of *N. sertifer* should permit it to exist considerably beyond its present distribution, particularly if the overwintering eggs are insulated by even a thin layer of snow. Also, even where such protection is not available, *N. sertifer* may become adapted to higher latitudes by selection of a race with lower freezing limits.

Hosts and Damage

N. sertifer attacks most species of two-needled pines. No oviposition has been seen in the field on soft pines in Europe or North America, but *N. sertifer* is known as a pest on *Pinus pumila* in the Japanese Alps (Pschorn-Walcher, 1963), and Rose (1952) observed oviposition on *P. strobus* under laboratory conditions. Foliage of the latter species may be consumed in the field. Occasional feeding on spruce has been recorded where these trees grow in close proximity to pines (Gabler, 1940; Forsslund, 1945, Crooke, 1957, Rivers and Crooke 1962).

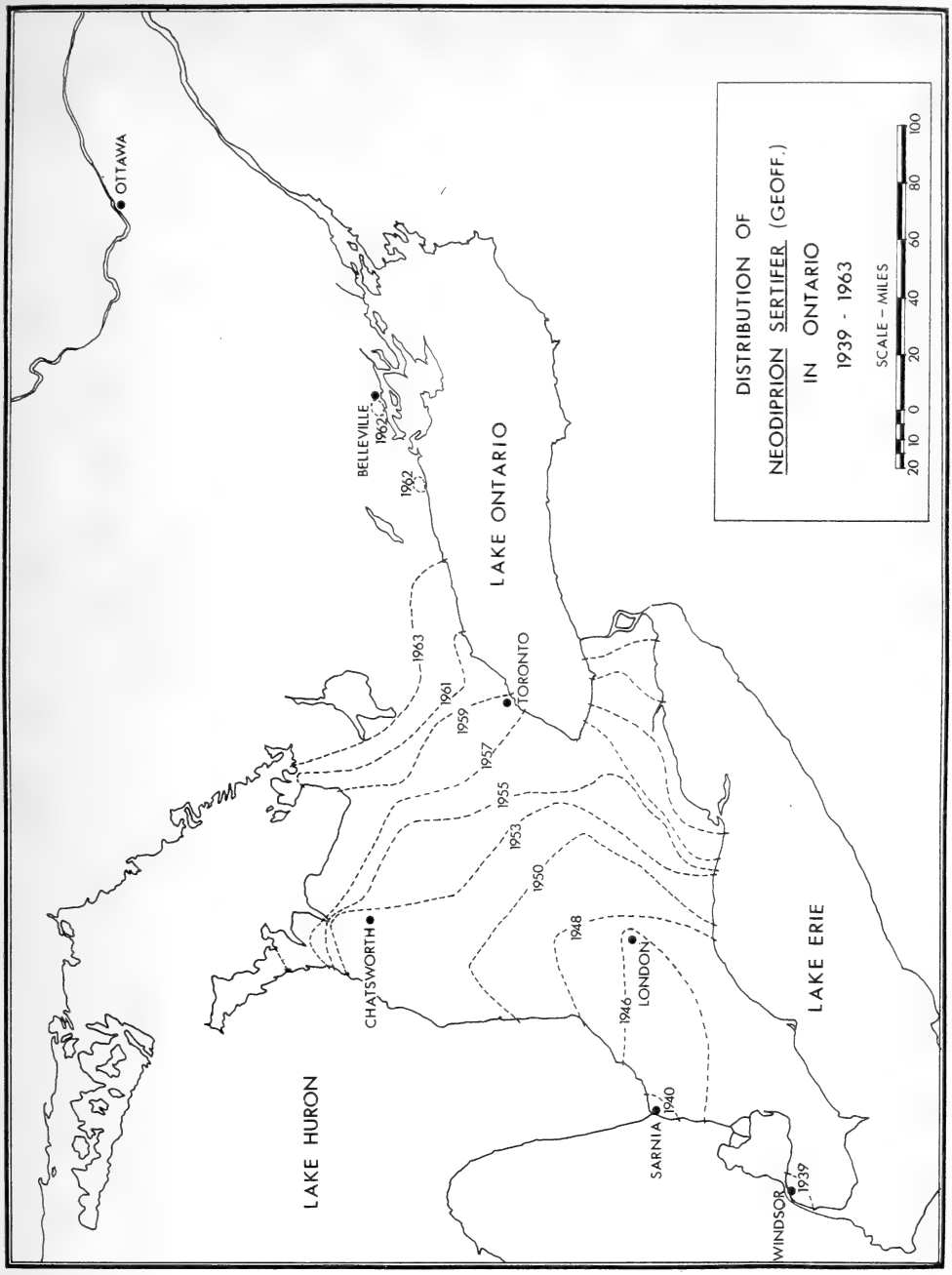

FIG. 1. Distribution of *Neodiprion sertifer* in Ontario, 1939-1963.

Evidence of host preference is conflicting, but the subject has received only casual study. Heavier defoliation of *P. sylvestris* than of other host species has often been observed (Brown, 1937; Schaffner, 1938;

Houser, 1939), suggesting that female sawflies prefer that host. However, Benson (1959) states that *N. sertifer* in some areas of Great Britain prefers *P. mugho* to *P. sylvestris*, and Rivers and Cooke (1962) state that attacks on *P. contorta* are usually more severe than those on *P. sylvestris*. In southwestern Ontario, *P. sylvestris* has been the most common host (Raizenne, 1957; Atwood, 1961), but this in itself does not indicate preference, since *P. sylvestris* is widely planted for Christmas trees in that area and is far more abundant than native pines. In Illinois, Benjamin, Larson and Drooz (1955) found that *N. sertifer* females laid larger clusters of eggs on *P. densiflora* than on other hosts (*P. sylvestris* not included); they found also that oviposition on *P. rigida* resulted in death of needles and hence of eggs. This would explain why Schaffner (1939) did not find *N. sertifer* on *P. rigida* in New Jersey. In that State, Soraci (1939) noted that eggs are rarely laid on *P. nigra*, but such rejection has not been observed elsewhere. In Ontario, *P. nigra* and the native *P. resinosa* and *P. banksiana* appear to be used for oviposition as frequently and as intensively as *P. sylvestris*.

Although no one host species is consistently preferred by ovipositing females, there is evidence that *P. sylvestris* is more suitable for the development and survival of *N. sertifer* than other hosts. Voûte (1956) pointed out that larvae in Europe develop more rapidly and with less mortality on *P. sylvestris* than on *P. nigra*. In Ontario, Griffiths (1959) observed lower mortality of eggs on *P. sylvestris* than on *P. resinosa* or *P. banksiana*, and recent observations at Chatsworth indicate that larvae develop more rapidly on *P. sylvestris* than on *P. resinosa*.

All age classes of host trees may be attacked, and there appears to be no consistent preference for trees of a particular age. Niklas and Franz (1957) in southern Germany, and Breny (1957) in Belgium, state that stands up to 20 to 25 years of age, i.e. stands not yet closed, are preferred, whereas a preference for older trees was noted by Schönwiese (1935) in Carinthia (Austria) and Rummukainen (1960) in Finland. In Ontario critical studies of host age preference are lacking, although the damage to young trees destined for the Christmas tree trade attracts more attention than that to established forest stands.

A number of writers have stated that *N. sertifer* prefers isolated or border trees (Hein, 1956; Kangas, 1941; Niklas and Franz, 1957; Breny, 1957). This appears to be due to the tendency of adult females to oviposit in well-illuminated zones of their habitat.

The effect of loss of increment on eventual timber production is uncertain. However, in a comparable situation in Virginia involving defoliation of *Pinus echinata* by *Neodiprion pratti pratti* (Dyar), a sawfly similar in habits to *N. sertifer*, Morris, Schroeder and Bobb (1963) found that an average defoliation of 55 per cent for two successive years resulted in a loss of 33 per cent of the anticipated growth of 4.68 cords per acre over a 4-year period. In addition to removing mature needles, *N. sertifer* larvae, particularly those in the last feeding instar, often chew into the bark of supporting shoots (Griswold, 1940; Lekander, 1962). According to Breny and Detroux (1950) this injury, which may result in the severing of new current-year shoots, is most serious when it affects young trees that have just been planted.

Stages in the defoliation and growth of a single tree during one season at Chatsworth, Ontario, are illustrated in Fig. 2. The conspicuous top-to-bottom trend is due partly to the concentration of oviposition on upper shoots, and partly to the upward movement of larvae searching for new

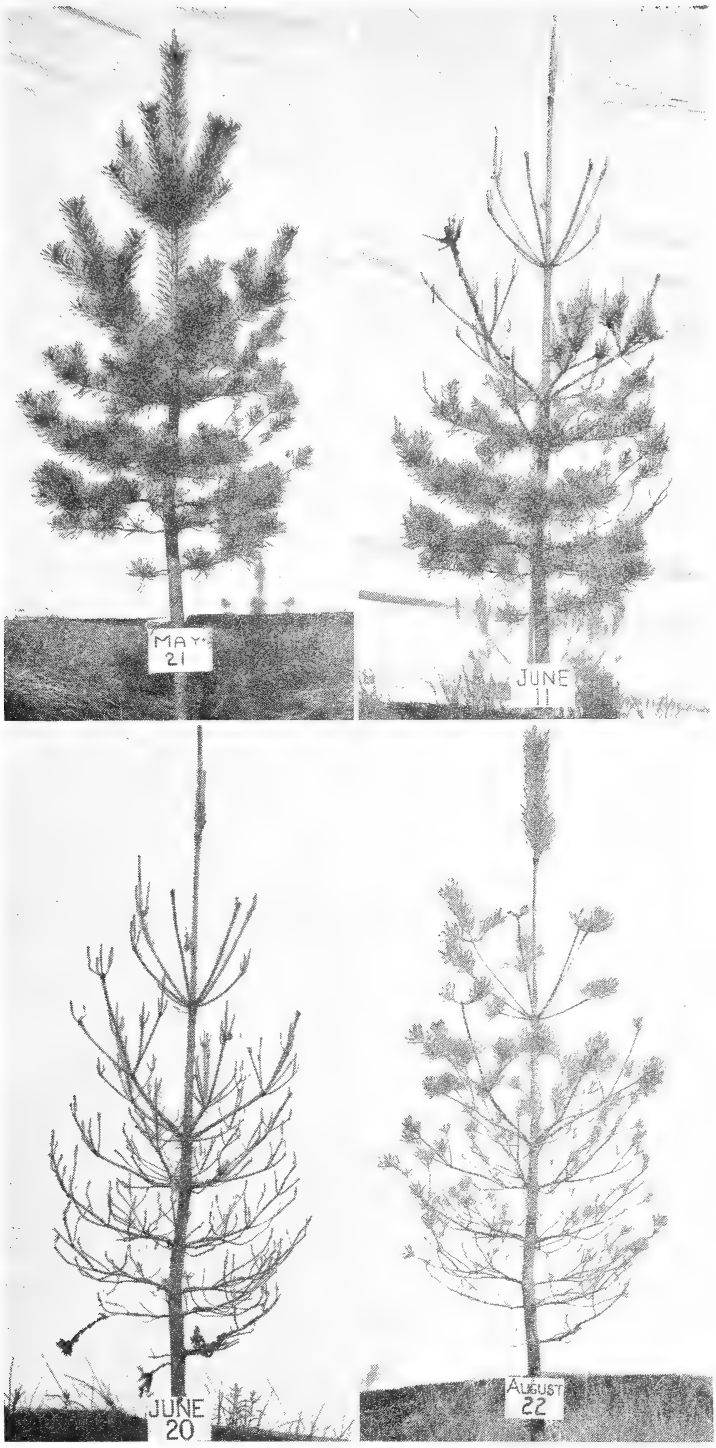

FIG. 2. Stages in the defoliation of one tree (*Pinus sylvestris*) by larvae of *Neodiprion sertifer*. Photos by J. Graham.

feeding sites. By June 20, when current needles were still immature, the larvae had consumed all the available foliage and were nearly ready to spin cocoons. By August 22, current growth had reached its full size, although some shoots appeared noticeably stunted. Height growth was less in the year of defoliation, and the terminal buds of several branches in the uppermost whorl were killed. Measurements on young red pines near Chatsworth show that the current foliage constitutes about 40 per cent of the tree's normal foliage complement. The development of the new foliage shortly after the insect finishes feeding in effect reduces or compensates for defoliation. On two small trees, for example, defoliation at the end of the feeding period, before new needles appeared, was 27.6 and 12.8 per cent, but when the new foliage had developed the trees were calculated to lack only 16.2 and 7.4 per cent, respectively, of their full foliage complement. In the tree shown in Fig. 2, development of current foliage reduced defoliation from an obvious 100 per cent to approximately 60 per cent in terms of shoot length.

In its damage to Christmas tree plantings, *N. sertifer is a* "direct pest" in the sense distinguished by Turnbull and Chant (1961). A moderate loss of foliage has no effect on subsequent growth of these trees, but makes them unsightly and thereby destroys their commercial value.

Life History and Natural Control

N. sertifer oviposits in the fall and overwinters in the egg stage. Larvae feed in the spring, and spin cocoons in June and July. Metamorphosis is completed within the cocoon in late summer and autumn.

Egg Stage

Biology

The intimate association between the egg of *N. sertifer* and the needle of the host is emphasized by Breny (1957), who points out that eggs are placed in sites where the influence of water will be maximal and most immediate, eggs are hermetically sealed within the needle and thus protected from ambient influences, and the embryo develops deep within the egg, close to a large conducting vessel of the needle. Brygider (1952) and Breny (1957) note that the germ band is positioned excentrically with reference to the sagittal axis of the egg, being located toward the centre of the needle and away from the outside surface.

Embryological development evidently begins early in the fall. By November the egg develops an exo- and an endochorion, a sheet of vascularized plasm within the chorion, a serosa, a periplasm, and an amnion surrounding a distinctly segmented embryo with differentiated embryonic layers and rudimentary coelomic cavities (Brygider, 1952). In most regions, embryonic development is suspended in late fall and not resumed until early spring, but according to Niklas and Franz (1957), development in southern Germany continues throughout the winter, retarded only by low temperatures. Breny's studies (1954, 1956b, 1957) in Belgium led to the conclusion that availability of water is the main factor regulating egg development. When water from the needle is freely available, the rate of egg development is determined by prevailing temperatures, but as the tree enters its own dormancy, its tissues dehydrate, osmotic pressure rises, and embryonic activity is inhibited.

Breny considers that *N. sertifer* at this stage does not undergo a true diapause, which by definition intervenes at well-defined stages of development without mitotic activity and cellular differentiation, but rather a pseudo-diapause for the following reasons: eggs will develop normally and

continually if placed in appropriate experimental conditions where moisture is freely available, and winter rest does not occur at an identical embryological stage in all eggs, but varies according to year and time of oviposition. During late winter, osmotic pressure in the tree declines, and the egg takes up water from the needle tissue, continuing differentiation at temperatures above 2°C. Breny (1957) also states that diapausing eggs, owing to the dehydrative action of the host tissues, have a considerable resistance to freezing. Recent studies in Ontario by C. R. Sullivan (personal communication) show that the mean freezing point of diapausing eggs is about —29°C, and that conditioning at low temperatures effects only a slight depression in the freezing point. Following hibernation, freezing points rise gradually, reaching —23°C after about 10 days.

Hibernation, where present, occurs approximately in the stage described by Brygider (1952). According to the growth ratio (mean width/mean length) devised by Breny (1957), the embryo at this time is about 8 times as long as broad, and occupies about three-quarters the length of the egg, being positioned on the ventral surface, facing ventrally. After hibernation, development proceeds rapidly. The egg swells greatly, thereby separating the lips of the cavity in the needle and exposing part of its surface. Some weeks before hatching the embryo becomes capable of independent muscular activity, enabling it to reverse its position in the egg. It is implicit in Breny's (1957) description that the cephalic pole of the egg is always directed toward the needle base, this orientation presumably resulting from the usual orientation of the ovipositing female toward the distal end of the needle, and that the final revolution within the egg brings the larva to a position such that it will always face the needle tip as it emerges. Observations by C. R. Sullivan (personal communication) indicate, however, that orientation in the needle is not constant, and that variations in orientation are in any case unimportant for development, survival, or hatching success.

Elens (1953b), as a result of a study of incubation under controlled conditions, believes that the relatively rapid rate of development of *N. sertifer* eggs compared to that of two other European diprionids, is directly correlated with adaptation to a colder environment. Time-temperature curves indicate that incubation is most rapid at about 25°C. Although pre-diapause development, which was not included in Elens' experiments, would increase the length of the total incubation period, other species (*Diprion pini* L. and *D. pallidum* Kl.) develop most rapidly at higher temperatures.

Natural Control

The survival of eggs is primarily dependent on the continued survival and functioning of the supporting pine needle, and if the needle should die for any reason, the egg will also perish. Benjamin et al. (1955) found that oviposition on *P. rigida* resulted in the death of the needle and thus of the eggs, but other hosts do not respond in this fashion. A small proportion of eggs (i.e. up to 2 per cent) die early in their development. According to Niklas and Franz (1957), these eggs are glassy yellow and without visible structure, the yolk is shrivelled, and the remainder of the egg pocket is filled with small drops of oil.

Mortality during diapause may vary from negligible to complete, depending on the occurrence of freezing temperatures. Most European writers have observed little mortality of this type, although Forsius (1920) notes that eggs can sometimes withstand temperatures of —30°C without damage. Studies in southern Ontario by Griffiths (1959) revealed egg

mortality in this period up to 10 per cent, depending on host species. However, recent studies, have shown average mortalities of 5 to 95 per cent. Mortality per individual egg cluster varies from nil to complete, apparently depending on local air drainage and the protection afforded by snow cover during the coldest time of the winter. Mortality is 6 to 8 per cent higher on *P. resinosa* than on *P. sylvestris,* for reasons that are still obscure.

Further mortality may occur in late embryogenesis, i.e. from the termination of dormancy to hatching. The total egg mortalities of 7 to 15 per cent recorded by Niklas and Franz (1957) seems to have occurred mostly late in development. Only 1.2 to 2.3 per cent of the eggs observed by Griffiths (1959) contained developed embryos that failed to hatch. Late egg mortality at Chatsworth has been slight compared to that during diapause. According to Breny (1955), failure of eggs to hatch tends to be greatest on the lateral branches of very young trees that have been very heavily used for oviposition. The eggs in question contain active larvae, which Breny believes are unable to emerge due to the dryness and stiffness of the needle tissues.

Three chalcid egg parasites *Dipriocampe diprioni* (Ferr.), *Achrysocharella ruforum* (Krause) and *Closterocerus ovulorum* (Ratz.) have been recorded on *N. sertifer* in Europe, but do not occur in North America (McGugan and Coppel, 1962). Egg parasitism by native species has not been recorded in North America.

N. sertifer eggs are preyed upon by a variety of other animals. Forsius (1920) mentions acarids and Hemiptera, and Forsslund (1945) recorded predation by *Chrysopa ventralis* Curt. Niklas and Franz (1957) observed one instance of egg predation by tits (*Parus* sp.); Galoux (1952) recorded 67 per cent predation, probably by the same species. At Chatsworth, up to 10 per cent of eggs have been destroyed during winter and spring by an unidentified predator that chews scallop-shaped sections out of egg-bearing needles. This predation (possibly by birds) occurs sporadically, and typically affects a large proportion of the eggs in a few clusters. Light mortality (up to 5 per cent) by pentatomids has also been observed occasionally. K. J. Griffiths (personal communication) collected *Euschistus tristigmatus* Say in the act of sucking out eggs, and *Podisus* spp. may be involved as well.

Feeding Larvae

Biology

Emergence of the *N. sertifer* larva from the egg is described by Breny (1955, 1956a). The embryonic larva, which is capable of extensive movement inside the egg, changes its position so as to bring the head and mandibles in contact with the exposed portion of the chorion, chews a hole in the chorion, and gradually works its way out of the egg. Breny (1956a) recorded hatching at temperatures as low as 5°C, and observed that larval emergence was greatest on warm days that had been preceded by warm nights; no association was found between the rate of hatch and relative humidity. However, studies by C. R. Sullivan (personal communication) show that no hatching occurs at 5°C, and that the threshold is close to 7.5°C. In Ontario, hatching occurs in early or mid-May, depending on the season and latitude. Hatching generally occurs in mid-April in Austrian and south German lowlands, and up to late May or early June in Finland. According to Pshorn-Walcher (1963), seasonal development in continental Europe is retarded 3 to 4 days per 100 metres of altitude and about 3 days per degree of north latitude.

At Chatsworth in 1961, the larvae emerging daily in five egg clusters were reared separately according to the date of hatching until they reached a stage where their sex could be determined. Results show clearly that females tend to hatch sooner than males, and despite differences in the hatching periods of different clusters, the proportion of females in each day's hatch declined from about 90 per cent on the first day to less than 20 per cent on the last day. A sexual difference in the length of the developmental period following hibernation is probably responsible.

Soon after emergence, larvae (Fig. 3) crawl to the tips of the needles and begin feeding in groups. Their feeding behavour is apparently the same as that described by Ghent (1960) for *N. pratti banksianae* Roh. Young larvae consume only the parenchymous tissue of the needles, leaving the central vascular bundle and the portion containing eggs. Later larvae (Fig. 4) consume the entire needle down to the basal sheath.

FIG. 3. Newly hatched larvae of *Neodiprion sertifer* on egg-bearing pine needles. Photo by D. C. Anderson.

FIG. 4. Advanced feeding larvae of *Neodiprion sertifer* on *Pinus sylvestris*. Photo by D. C. Anderson.

Typically, male larvae have four and female larvae five feeding instars before moulting to the final non-feeding prepupal or prespinner stage, which spins the cocoon (Griffiths, 1959; Niklas and Franz, 1957; Rose, 1952). This seems to hold for most larvae, although in rearing of solitary larvae, some of both sexes may pass through an extra feeding instar.

Male larvae complete their feeding period and leave the tree 4 to 9 days earlier, on the average, than female larvae. Collections of larvae made after the appearance of the first prespinners will thus necessarily lead to erroneous conclusions as to sex ratio; this may explain Will's (1960) report of a population consisting almost entirely of females. Descriptions of six larval stadia, including the final non-feeding one, have been given by Scheidter (1934), who does not mention the instar difference between

males and females. In instars I and II the single mid-dorsal stripe is due to the dorsal blood vessel which is visible through the integument. True dorsal and lateral markings appear in instar III and become gradually more distinct with subsequent moults. Freshly moulted feeding larvae have white heads which darken to a shining black within 1-1.5 hours. In the final non-feeding instar, the head is grey-brown above, and paler below the eyes, and the body has a dark broken double mid-dorsal stripe and dark quadrangular pleural markings on a dirty grey background. The colour of the prespinner is derived from the blood and fat body, and ranges from pale grey to mauve and bright green.

The duration of the larval feeding period is longer for females than for males, since the former complete an extra instar, but in each sex depends on both temperature and host species. Possibly some of the discrepancies among published reports of developmental rates (e.g. Elens (1953d)) are due to variations in sex ratios and type of food. Laboratory studies by C. R. Sullivan (personal communication) indicate a threshold for development of 6°C and an optimum (15 to 17 days) close to 25°C; feeding activity is inhibited at relative humidities above 70 per cent. Rose (1952) recorded mean developmental periods of 21 to 28 days at 24°C on four different hosts, females taking 3 to 5 days longer than males; larvae of both sexes developed more rapidly on *P. strobus* than on *P. sylvestris, P. resinosa* or *P. banksiana,* but no consistent differences appeared between larvae on *P. sylvestris* and *P. resinosa.* However, field observations at Chatsworth indicate clearly that development is more rapid on *P. sylvestris,* and the same difference has been found in laboratory rearing by C. R. Sullivan (personal communication) at carefully controlled temperatures.

Weight increment, oxygen consumption and excrement output of the last two feeding instars of *N. sertifer* have been described by Janda (1961). The insect gains weight fairly regularly, except for brief pauses during moulting, until the completion of instar V; within the next 4 days, during which cocoon spinning occurs, there is a reduction in weight of over 70 per cent. Maximal rates of oxygen consumption and excrement output per unit body weight are attained during the penultimate feeding instar. Janda suggests that whereas this instar is a typical one of growth, the final instar includes a period of preparation for processes connected with morphogenesis.

The larvae from one cluster usually remain together throughout the feeding period in a well integrated colony or aggregation. Rarely large colonies split into smaller groups, but nearby small colonies often coalesce to form larger ones. According to Prop (1960) the integrity of *N. sertifer* colonies is maintained primarily by the following behaviour patterns: "1. In moving to a new feeding place the larvae keep contact by using scent trails as a means of communication. 2. The forming of relatively large sub-groups is due to a positive attraction between the larvae complemented by an inhibition of feeding in larvae that have no place at the top of the needle. 3. Isolated larvae react independently of food conditions, to the absence of contact with other larvae, with searching behaviour that enables them to catch up with the colony."

The colonial pattern of behaviour has certain disadvantages such as preventing all larvae from feeding continuously, and promoting the spread of diseases, but these seem to be counterbalanced by greater benefits to the species. One such advantage is possibly that discussed by Ghent (1960) for *N. p. banksianae,* where collective effort by grouped larvae in the difficult task of initiating feeding sites increases the likelihood of success,

and thus promotes survival. It is uncertain whether Ghent's findings apply *in toto* to *N. sertifer*. During studies at Chatsworth, all isolated larvae observed in the field died before completing development, whereas in the laboratory most isolated larvae developed normally, and seemed to have no difficulty in initiating feeding sites.

Another advantage of aggregation is that the various alarm reactions or displays (e.g. Iltis, 1930) that occur when a colony is disturbed may prevent or reduce attack by parasites and predators. Prop (1960) distinguished three types of displays. In the first, the "U-bend", the larva raises its anterior and posterior segments from the needle surface for periods exceeding 10 minutes, and extrudes orally for a few seconds a drop of gummy whitish fluid. In the second type, "Jerking", the larva raises its head and thorax perpendicularly from the needle and immediately lowers them again. This action is repeated rhythmically and rapidly by all or most larvae and is closely synchronized; no oral exudate is produced. In the third display, "Stretching", the larva raises the anterior half of the body slightly, and stretches horizontally, orienting continuously toward the source of the stimulus, and exudes a drop of sticky fluid orally. Some types of display, e.g. jerking and stretching, are shown by Prop to protect the colony from attack by several predatory birds in a large proportion of cases. Some slow-moving insect parasites may be driven off by the displays and even damaged by the oral secretion, but other parasite species either attack so quickly that a display is evoked too late, or approach and attack so stealthily that no display is evoked.

Little has been published on the behavioural response of individual larvae to physical factors. Wellington (1953) observed that fourth instar larvae orient to polarized light and become photonegative when too hot. Recent studies by C. R. Sullivan (personal communication) show that the temperature at which larvae become photonegative declines gradually from 42°C in the first instar to 24°C in the non-feeding prespinner stage. The larva's reaction to light protects it from lethal high temperatures during the feeding period, and later induces it to leave the tree before spinning the cocoon.

Natural Control

As a general rule, larval mortality is considerably greater during the first two instars than during later development, although mortality may later increase if disease is present. Physical factors seem to exert their greatest influence during early development. According to Galoux (1952) some larvae may be crushed by the needle as they emerge from the egg, apparently due to extreme dryness. Schönwiese (1935) states that young larvae are susceptible to weather factors, but Forsslund (1945) observed that even snow storms during hatching had no effect. Niklas and Franz (1957) recorded mortalities during the first two instars of 20 to 55 per cent during a 4-year period; they believed freezing temperatures were responsible. In southern Ontario, Griffiths (1959) considered that the 23 per cent mortality that occurred up to the third instar reflected the difficulty of larvae establishing themselves on the pine needles.

In studies at Chatsworth, early larval mortality has been similar to that observed by Niklas and Franz (1957). Mortality per colony to about the third instar commonly varies from nil to complete, and is apparently not correlated with previous egg mortality or original colony size. In 1961, the larvae hatching daily in eight clusters were transferred to different shoots and observed daily thereafter. The few solitary larvae in this experiment lived no longer than 5 days, but otherwise no relation was evident

between mortality and the number of larvae per group. Of the larvae that did not complete development, 64 per cent died before they were 6 days old, but mortality varied considerably according to the date of hatching. Weather was doubtless primarily responsible for the mortality. Since females tend to eclose earlier than males, an interval of heavy mortality during the hatching period might affect one sex more than the other and thereby alter the original sex ratio of a population; the operation of such a mechanism has not been confirmed.

Predation by insects and spiders has been widely reported. Franz, Krieg and Langenbuch (1955) calculated that a bug, *Rhinocoris annulatus*, destroyed 0.58 mature larvae per day, but predation by all agents combined totalled less than 3 per cent. Niklas and Franz (1957) quote references to predation by *Picromerus bidens* L., *Rhaphidia* sp., and spiders. Benjamin et al. (1955), mention predation by *Podisus placidus* Uhler. Predation by ants would appear to be of very great importance in some areas of Europe. Schwerdtfeger (1936) considered them to be one of the most important mortality factors affecting larvae. Bruns and Schrader (1955) go so far as to claim that no cocoons with living *N. sertifer* can be found within 30 metres of nests of *Formica rufa* L.

K. J. Griffiths (personal communication) observed predation on larvae of *N. sertifer* at Chatsworth by coccinellids (*Coccinella transversoguttata* Fald., *Anatis mali* (Say), and *Mulsatina picta* Rand.); pentatomids (*Euschistus tristigmatus* Say, *Podisus serieventris* Uhl. and *P. modesta* Dall.); reduviids (*Zelus* sp.); nabids (*Nabus* sp.); and ants (*Formica fusca* L.). In laboratory studies, *N. sertifer* larvae were attacked by the following spiders: *Araniella displicata* (Hentz), *Paraphidippus marginatus* (Walek.), *Cyclosa conica* (Pallas), *Hypselistes florens* (O.P.- Cambridge), and *Xysticus emertoni* (Keyserling). The impact of predation is difficult to assess, since predators rarely leave evidence. However, in an experiment in which non-flying predators were excluded from some larval colonies by the use of "tanglefoot", K. J. Griffiths estimates that as much as two-thirds of the 30 per cent loss that occurred by the end of the first instar was due to predation; the most important predator during this period was probably *Zelus* sp.

Predation by a number of birds has been reported from both Europe and North America — even such unlikely predators as starlings, crows, and wild fowl are mentioned in the literature — but they rarely cause heavy larval mortality. Some of the reasons for this have been explored by Tinbergen (1960) and Prop (1960), who note that *N. sertifer* larvae are protected by their unpalatability to birds (mainly *Parus* spp.) and their colonial behaviour. The various displays mentioned earlier (e.g. jerking) cause an initial avoidance by birds; if larvae are very abundant this response wanes and attack may ensue, but the bird then rejects the larva because of its bad taste. Displays evoked by subsequent encounters serve to remind the bird of the distasteful properties of the larvae, and attack is avoided. Although the general level of predation does not increase beyond a rather low prey density, *N. sertifer* larvae may for short periods constitute up to 60 per cent of the diet of some bird pairs. Tinbergen explains that these birds, when searching for prey, concentrate on one or a few abundant species at one time by adopting a "specific searching image". However, the birds do not permit one prey species to form more than a certain proportion of their diet, and may adopt a new searching image in order to vary the diet. Presumably it is this mechanism that limits predation at high *N. sertifer* density.

Mortality from bacterial and fungal infections has been reported from many parts of Europe. For example, Kangas (1941) speaks of larvae dying from both types of organisms; those affected by bacteria became stuck to the needles and remained alive on the tree long after healthy larvae had spun cocoons. According to Shiperovich (1927) large numbers of larvae were destroyed by *Bacillus septicemiae lophyri*. Hein (1956) reported mortality due to bacteriosis. Niklas and Franz (1957) consider that many published reports of bacterial and fungal diseases of *N. sertifer* are fallacious, and that the observed mortalities were in fact due to polyhedral virus disease (*Borrelina* sp.), which has been known for many years (e.g. Escherich, 1913). This disease was artificially introduced into Ontario in 1949, and owing to intensive studies by Bird (1953, 1955, 1961), Bird and Whalen (1953), Krieg (1955), Franz (1956), Franz and Niklas (1954) and Franz et al. (1955), is now rather well understood. Larvae become infected either by ingesting polyhedral bodies with the food, or by transovarial transmission of the virus from the parent. Ingested polyhedral bodies invade and destroy the digestive cells of the mid-gut epithelium. Larvae, if infected at an early stage, die in 4 to 10 days, depending on temperature and the number of virus particles ingested. Dead larvae disintegrate on the tree, releasing virus particles, which may be distributed to healthy larvae by rain or birds and insects. Epizootics that start at an early larval stage may result in complete mortality before cocoon spinning. If started too late, some larvae may moult to the final non-feeding stage, in which the disease can no longer develop. Some of these infected survivors apparently die during the cocoon period, but others reach the adult stage. Some of the latter (less than 10 per cent) are able to transmit the disease to their offspring via the egg, in which case, all larvae of the affected colony die from polyhedrosis in the third and fourth instar. Persistence of the disease from year to year is more common in stands of trees over 8 feet in height than in stands of smaller trees.

Virus epizootics that do not result in complete larval mortality may drastically alter the sex ratio of the surviving population. Since females cease feeding and spin cocoons a week or more later than males, they are more exposed to infection. In virus-free populations, 70 to 80 per cent of the insects are females, but where virus has caused appreciable mortality, the proportion of females among the survivors may be far below 50 per cent (Niklas and Franz, 1957; Griffiths, 1959; Bird, 1961).

The effect of the physiological condition of the host tree on the survival of *N. sertifer* larvae has received little attention, but studies on other sawflies suggest it may be important. For example, in a study on *Diprion pini* L., Schwenke (1962) observed higher larval mortality and smaller cocoons in well-watered stands than in dry ones. Needles in the latter showed a higher concentration of sugar, which evidently promotes larval development and survival. Schwenke considers that sawfly survival could be reduced by the use of fertilizers, particularly those containing nitrogen. Applications of such fertilizers have been found by Merker (1961) to greatly increase the larval mortality of *Pristiphora abietina* Christ.; the effect is thought to be due to structural changes in the spruce needles.

Larvae of *N. sertifer* are attacked by a number of parasitic insects. Since none of these complete development until the cocoon stage of the host, they will be referred to later. Similarly, the effect of some environmental factors that larvae experience, such as photoperiod, is not expressed until later in development, so will be discussed in the proper place.

Cocoon Period

Biology

Cocoons may be formed above ground on the host tree and other vegetation, or in the soil. Niklas and Franz (1957) found cocoons only in the soil; this may be considered a normal condition. In contrast, Morris and Cameron (1935) state that in Yugoslavia almost all cocoons are formed on the trunks of host trees. The difference has not been explained, but has a great effect on survival. At Chatsworth up to 3 per cent of the *N. sertifer* cocoons are located on the host tree. Most larvae spin cocoons within 24 hours after their moult from the final feeding stage, but they may be delayed if a suitable spinning medium is not available. Spinning is completely inhibited in a saturated atmosphere. Although cocoon density is usually highest immediately beneath the infested tree, larvae commonly crawl 20 feet or more before spinning. Within closed stands, cocoon density is very weakly related to tree proximity, so opportunities for reducing variability in population density estimates, e.g. stratification, are limited. In distribution, cocoon populations are mildly aggregated, generally conforming to the negative binomial model. For reasons not yet understood, cocoons of males are more highly aggregated than those of females.

When first formed, cocoons are golden brown; they gradually darken and eventually become almost black. They probably remain intact in the soil for many years. There appears to be a complete absence of information in the literature regarding the chemical structure of cocoons of this and other sawflies, and the changes associated with aging, discoloration and disintegration. This lacuna has been an obstacle to the development of methods of dyeing or otherwise marking cocoons *in situ* in the soil. Such methods are needed for the assessment of population density and mortality factors in long-term studies of population dynamics.

The cocoon period extends from June or July to September or October, when adults emerge, and includes a number of distinct phases of development. The first of these is the eonymphal period, which includes a diapause. Then follows the pronymphal period of active morphogenesis, culminating in the pupal period. After the final moult, the adult remains within the cocoon for several days before emerging.

Larvae lose their ability to crawl soon after spinning the cocoon, but are able to move about inside, and to repair damage to the cocoon wall, at first by spinning fibres, later by an oral secretion. The rate of metabolism declines rapidly after the moult from the final feeding instar; measurements by Slama (1960) show that the rate of oxygen consumption, for example, drops within 10 days from almost 700 to less than 20 mm^3 gram hour. Water content and body weight also decrease (Marek, 1963; Wallace and Sullivan, 1963), and the specific gravity of the hemolymph increases (Baldwin and House, 1954). All physiological and morphological activity is not suspended, however, since an inverse relation has been found between the durations of the eonymphal and pronymphal periods (Wallace and Sullivan, 1963). The duration of the eonymphal period itself is extremely variable, e.g. averaging about 18 weeks in Czechoslovakia (Marek, 1963), but only 5 to 7 weeks in Ontario (Lyons and Griffiths, 1962). Some, but not all, of this variation can be explained on the basis of temperature. Laboratory studies by Wallace and Sullivan (1963) indicate that diapause requirements are fulfilled most rapidly (29 days) at about 8°C and that up to 60 days may be required at 26°C. However, at any one temperature, insects that spin cocoons early in the

season undergo a longer eonymphal diapause than those spining later (Lyons and Griffiths, 1962). Preliminary experiments suggest that photoperiods experienced by feeding larvae somehow regulate the period of diapause. The mechanism involved is not understood, but its effect is to closely synchronize all insects in their transition from eonymphs to pronymphs, and to remove the temporal disparity between males and females introduced by the earlier cocoon spinning of males.

Pronymphal development is characterized by an intensification of physiological activities, e.g. oxygen consumption (Slama, 1960; Wallace and Sullivan, 1963), and can be recognized externally by the appearance of pupal characteristics, particularly the pupal eye developing within the head. Usually the majority of larvae begin pronymphal development one to three months after spinning, but some remain in a prolonged eonymphal diapause one or more years longer. The factors inducing prolonged diapause, either in *N. sertifer* or in other sawflies, are not yet understood, but the fact that the incidence of prolonged diapause increases with both latitude and altitude in Europe suggests that temperature and possibly photoperiod are involved.

In Ontario, the pronymphal period, beginning in early August, lasts 2 to 3 weeks and is followed by the pupal period of about the same length (Lyons and Griffiths, 1962). In each period males take 2 to 3 days longer to develop than females. The optimal temperature for pronymphal and pupal development is 22°C (Wallace and Sullivan, 1963).

According to Elens (1953c), the cocoon period at the optimal temperature of 18°C lasts 99 days, and extends as long as 128 days at 30°C. Wallace and Sullivan (1963) calculated about the same optimum (i.e. 17°C); at this temperature the cocoon period averaged only 82 days, but was about 116 days at 26°C. Under insectary conditions, Lyons and Griffiths (1962) recorded average cocoon periods of 81 and 65 days in two successive years, but cocoon periods for the earliest spinning insects were about 50 per cent longer than for the latest spinning ones, due to the fact that the earlier an insect completes its feeding and spins its cocoon, the more prolonged its eonymphal diapause will be. The fact that *N. sertifer* larvae in Belgium spin cocoons several weeks earlier than those in Ontario is probably enough in itself to explain the relatively extended cocoon periods recorded by Elens (1953c).

Natural Control

Few reports are to be found of direct killing of cocooned *N. sertifer* by physical factors in the field. However, Elens (1953c) recorded no adult emergence from cocoons maintained at 35°C, and Schönwiese (1935) observed that cocooned larvae died in a few days at 33°C. Elens (1953a) reported that eonymphs are rather resistant to desiccation. Experiments by Baldwin and House (1954) demonstrate that eonymphs of *N. sertifer* can be acclimated to lethal high temperatures. Some mortality in cocoons is possibly incorrectly attributed to disease, e.g. fungus, particularly when the larvae have long been dead. At Chatsworth, for example, early sampling provided recently killed larvae that several weeks later would likely have been heavily coated with fungus mycelium. Examination of these specimens by pathologists at the Insect Pathology Research Institute, Sault Ste. Marie, failed to reveal disease organisms. It is not impossible that they had succumed to lethal high temperatures, since many cocoons in the sample areas were located at the soil surface. On the other hand, dead cocooned larvae of the same appearance are common in artificial rearings that have

not been subjected to high temperatures. In Elens' (1953c) cocoon rearings, mortality exceeded 40 per cent at temperatures near the optimum for development. An unidentified factor or agent would appear to be responsible. One possibility is a delayed effect of polyhedrosis.

Field sampling of cocoon populations generally produces dead larvae, which are usually said to have been killed by fungus or bacteria. Occasionally it is admitted that the cause of death is unknown. Some estimates of this type of mortality given in the literature are: 4.5 per cent in Belgium (Galoux, 1952), 3 to 11 per cent in southern Ontario (Griffiths, 1959), 7 to 18 per cent in Germany (Thalenhorst, 1952), 19 per cent in Finland (Kangas, 1941), 10 to 28 per cent in the Netherlands (Hein, 1956). The latter reports mortality up to 80 per cent in wet soil. In Austria, Schönwiese (1935) found that mortality was 0 to 7 per cent in cocoons from bare soil, but 20 to 25 per cent in cocoons in soil with heavy grass cover. In sample plots at Chatsworth, 10 to 28 per cent of current generation cocoons have contained dead larvae, some of which have been found by D. M. MacLeod (Insect Pathology Research Institute, Sault Ste. Marie, Ontario) to be infected by pathogenic fungi of the genus *Beauveria*.

Larvae of Elateridae are often cited as predators of cocoons of *N. sertifer* and other sawflies. Niklas and Franz (1957) consider that mortality by these insects was low, but admit that the damage is difficult to diagnose. Thalenhorst (1952) detected 3 per cent mortality by elaterids, and believed mortality was low because cocoons were not located deep in the soil. Galoux (1952) estimated that 20 per cent of cocoons were destroyed by elaterids; this seems unusually high. In soil samples at Chatsworth, mortality attributable to insect predation has been estimated at 10 to 15 per cent, but it is often impossible to decide whether there has been true predation on healthy sawflies or scavenging on dead ones. That scavenging does occur is indicated by the fact that through successive samples of the same population, a decline in the proportion of cocoons containing dead sawflies is accompanied by a rise in the proportion showing damage by insects.

The role of ants as predators of cocooned *N. sertifer* is still largely unknown. Niklas and Franz (1957) found it to be negligible in their area. However, Ayre (1963) observed predation on cocoons of *N. lecontei* by *Crematogaster lineolata* (Say) in the laboratory. Morris et al. (1963) cite *Aphaenogaster rudis* Em., *Tapinoma sessile* (Say) and *C. lineolata* as predators on cocoons of *N. p. pratti* in Virginia, although even at an artificial density of 600 cocoons per square yard, predation averaged only 13 per cent. In the Chatsworth area, there is evidence of predation by a very small ant, *Solenopsis molesta* Say. Small areas of the cocoon wall are gradually eaten away and penetrated. In some cocoons with this damage, all that remains of the *N. sertifer* larva is the head and the long, convoluted salivary glands. *Lasius alienus* (Foerster) has been observed damaging cocoons rarely. In laboratory studies, K. J. Griffiths observed predation by millipedes, elaterid larvae, and adults of the European earwig, *Forficula auricularia* L. The author observed light predation in the laboratory by adults of *Harpalus affinis Schrk.* (Carabidae) and a large field cricket; the latter destroyed about 40 cocoons during a 30-day period.

Cocoons of *N. sertifer* are subject to damage by birds. Niklas and Franz (1957) state that predation did not exceed 5 per cent in their area; they quote Kolubajiv's (1938) observation of predation by chaffinches in the Ukraine. Galoux (1952) estimated predation by birds (presumably *Parus* spp.) as 26.7 and 15.6 per cent in successive years; feeding was

TABLE 1. North American Records of Parasites of *Neodiprion sertifer* (Geoff.).

	Gahan 1938	Cushman 1940	Girth and McCoy 1946a	Girth and McCoy 1946b	Raizenne 1957	Finlayson and Finlayson 1958	Griffiths 1959	Finlayson 1960	Rose and Sippell 1964	Forest Insect Survey	Chatsworth Field Establishment 1960-63
Diptera											
Bombyliidae											
Hemipenthes sinuosa (Wd.) (c)						x	x		x	x	x
Muscidae											
Muscina stabulans (Fall.)							x				
Phoridae											
Megaselia sp.							x		x		
Tachinidae											
Diplostichus hamatus (A.&W.) (l)					x	x				x	x
**Drino bohemica* Mesn. (l)											x
Neophorocera edwardsii (Will.) (l)					x						
Neophorocera sp. (l)					x						
Spathimeigenia spinigera Tns. (l)					x	x					
Hymenoptera											
Eulophidae											
**Dahlbominus fuscipennis* (Zett. (c)			x			x	x		x	x	x
Tetrastichus sp.							x				
Pteromalidae											
Amblymerus verditer (Nort.) (c)											x
Dibrachys cavus (Wlkr.) (h)					x						
Habrocytus sp. (c)									x		x
Tritneptis diprionis Gahan	x								x		
Tritneptis klugii (Ratz.)							x				
Eupelmidae											
Eupelmella vesicularis (Retz.) (c)						x			x		x
Torymidae											
**Monodontomerus dentipes* (Dalm. (c)								x			x
Braconidae											
Aspilota sp.							x				
Ichneumonidae											
Agrothereutes lophyri (Nort.) (c)				x							
Agrothereutes sp. (c)						x					
Delomerista diprionis Cush. (c)						x	x		x		x
Endasys subclavatus (Say) (c)				x		x	x		x	x	x
Euceros frigidus Cress. (l:h)						x	x			x	x
Euceros neodiprioni (Walley) (l:h)				x							
**Extenterus abruptorius* (Thunb.) (l)						x					
**Exenterus amictorius* (Panz.) (l)					x					x	x
Extenterus canadensis Prov. (l)		x		x		x	x			x	x
Extenterus walleyi Cush. (l)								x			
Gelis tenellus (Say) (c)									x		
Lamachus sp. (l)								x			
Mastrus argeae (Vier.) (c)				x		x	x		x	x	x
**Pleolophus basizonus* (Grav.) (c)						x			x		x
Pleolophus indistinctus (Prov. (c)						x	x		x		x
unidentified Cryptinae								x			

* Introduced l = attacking host larva, c = attacking host cocoon, h = hyerparasitic.

concentrated on cocoons on and above the soil surface. Hein (1956) notes that predation by birds is variable, but that in light infestations almost all cocoons may be destroyed. There are no records of predation by birds on *N. sertifer* cocoons in Ontario.

Small mammals may have a very great impact on populations of *N. sertifer*, particularly when cocoons are very abundant. Some records of mortality include the following: 12 to 17 per cent by *Peromyscus maniculatus bairdii* Hoy and Kennicott in Ontario (Griffiths, 1959); 12.6 and 35 per cent by *Apodemus sylvaticus sylvaticus* L., *Evotomys glareolus* Schreber, and *Microtus arvalis* Pallas in Belgium (Galoux, 1952), 79 per cent by mice in Germany (Thalenhorst, 1952), and 50, 80, 84, and 88 per cent in successive years by unidentified species (Niklas and Franz, 1957). The actual mortality inflicted on a population may be difficult to assess because predation may affect cocoons that already contain dead or parasitized larvae. Holling (1955) demonstrated that highly insectivorous mammals, such as the cinereus shrew (*Sorex cinereus cinereus* Kerr) and the short-tailed shrew (*Blarina brevicauda talpoides* Gapper), very strongly select cocoons containing healthy sawfly larvae in preference to those containing dead, diseased larvae, and to a lesser degree, parasitized larvae. However, the white-footed mouse, *Peromyscus maniculatus bairdii*, an omnivorous species, discriminates against cocoons containing dead larvae but not against those containing parasites. The mammals detect the presence of cocoons in the soil by an olfactory stimulus. All species discover a higher proportion of female than male cocoons, owing to the larger size and hence stronger odour of the former, but the smaller species open and consume the contents of a higher proportion of male than female cocoons (Holling, 1958b). All small mammal species studies by Holling (1959) show a sigmoid functional response to cocoon density. *Sorex* and *Peromyscus*, but not *Blarina*, also respond numerically to increased prey density. Owing to plateaux in functional and numerical responses, the rate of predation, when plotted against cocoon density, rises to a peak and then declines. The position of this peak varies from one species to another, but combined predation by all species shows a high broad peak covering a wide range of cocoon density. On the basis of these analyses, Holling (1959) constructs a reasonable theoretical scheme modelling the regulation of a prey species by predators.

All parasites that attack *N. sertifer* larvae before cocoon spinning and those that attack during the cocoon period develop in and emerge from the host cocoon, so it is convenient to discuss them together in this section. On the basis of a recent compilation of European records, Pschorn-Walcher (1963) lists 34 parasitic species, exclusive of egg parasties, known from *N. sertifer*. The list included 14 larval parasites, 11 cocoon parasites, and 9 hyperparasites. In decreasing order of abundance and constancy, the main ones are *Exenterus abruptorius* (Thunb.), *Pleolophus basizonus* (Grav.), *Lamachus eques* (Htg.), *Lophyroplectus luteator* (Thunb.), *Dahlbominus fuscipennis* (Zett.), *Exenterus amictorius* (Panz.) *Drino bohemica* Mesnil, *Agrothereutes adustus* (F.), *Zemiophorus scutulatus* and *Lamachus frutetorum*. Table I summarizes records of recoveries of foreign and native parasites from *N. sertifer* in North America. Information on the habits of some species is included.

In Europe, mortality of *N. sertifer* due to parasitism varies greatly by year and locality. According to Thalenhorst (1952) the low parasitism he observed was due mainly to *Dahlbominus fuscipennis, Pleolophus basizonus* and *Exenterus abruptorius*. Niklas and Franz (1957) recorded

mortalities of about 15, 5, 14, and 7 per cent in successive years, due mainly to *P. basizonus, E. abruptorius* and *E. amictorius.* Hein (1956) observed parasitism of 18 per cent by *P. basizonus* and 17 per cent by *E. abruptorius.* Schönwiese (1935) recorded mortalities of 49 and 89 per cent in successive years, mainly by *E. abruptorius.* According to Kangas (1941) parasitism in three areas of Finland totalled 54, 32 and 57 per cent, and was mainly by *P. basizonus* and *E. abruptorius.* Cocoon sampling conducted by Finlayson and Finlayson (1958) in extreme southwestern Ontario yielded mortality rates of 9.3 per cent in 1941, 6.2 per cent in 1943, 19.3 per cent in 1946, 20.6 per cent in 1947, and 47.0 per cent in 1949. Only *D. fuscipennis, H. sinuosa, E. canadensis,* and *E. subclavatus* parasitized more than 4 per cent of the *N. sertifer* in any sample. In later studies near Strathroy by Griffiths (1959), parasitism varied from 8 to 29 per cent, and was mainly due to *H. sinuosa, E. canadensis,* and *E. subclavatus.* Recent sampling near Chatsworth shows parasitism to be 40 to 60 per cent. In one plot the main parasites are *P. basizonus, E. amictorius, E. canadensis,* and *M. argeae,* whereas in another plot only a few miles away, parasitism of 65 per cent has been exclusively by *E. canadensis.*

Literature on the behaviour, ecology, and taxonomy of *N. sertifer* parasites is too extensive to be reviewed here. However, it may be mentioneed that *Exenterus, Lamachus, Lophyroplectus,* (Ichneumonidae), *Drino, Diplostichus, Neophorocera* and *Spathimeigenia* (Tachinidae) are larval parasites, the remainder are cocoon parasites or of unknown status. *Pleolophus, Mastrus, Endasys* and *Dahlbominus* are multivoltine; most of the other species are univoltine, although some adults may emerge from host cocoons during the same season e.g. *Exenterus amictorius, E. canadensis,* and *D. bohemica. Lamachus, Lophyroplectus, Drino, Diplostichus* and *Spathimeigenia* are endoparasitic, whereas larvae of *Dahlbominus, Exenterus, Pleolophus, Endasys,* and *Mastrus* feed externally on cocooned host larvae. Some cocoon parasites, e.g. *Dahlbominus, Monodontomerus,* and *Eupelmella,* are of limited effectiveness because their attack is virtually confined to cocoons that are formed above ground and in surface litter. This characteristic, however, makes them effective parasites of the introduced pine sawfly, *Diprion similis* (Htg.), which habitually spins its cocoons on the host tree. Most species have been recorded from other sawfly hosts.

Holling (1958a) describes an X-ray technique by which certain parasites inside cocoons may be identified. Parasites may also be identified by examination of the contents of cocoons from which adults have emerged (Finlayson, 1960). The timing of collections is critical for proper evaluation of parasitism. For example, *Exenterus* attack is concentrated on prespinning larvae, so the rate of parasitism is correctly determined only by examination of host cocoons at the conclusion of the cocoon spinning period. Since some cocoon parasites are multivoltine, evaluation of their effect must be based on those cocoons from which parasites have already emerged as well as ones containing immature parasites. Accurate evaluation is hindered by damage to cocoons by predators and scavengers, and the interference between parasites.

Adult Stage

Biology

In most parts of Europe and in North America, the emergence of *N. sertifer* adults is restricted to a period beginning in late August or early September and extending to October or November. Insects that have

undergone prolonged diapause also emerge at this time (Griffiths, 1959), but scattered reports of emergence at other times are worth mentioning. According to Seitner (1933), high-alpine populations of *N. sertifer* include, in addition to the usual form that overwinters in the egg stage, another form whose larvae finish feeding in the fall, overwinter in the cocoon, and reach the adult stage in spring and early summer. Sitowski (1925) states that in Poland some adults, mostly males, emerge in the spring. In the Ukraine, according to Shiperovich (1925), some adults emerge from May to July. They oviposit at once, and the eggs hatch in two weeks. This form is said to differ morphologically from the common one emerging in the fall, and although the two forms are seldom together in the same locality, they may even occur in the same egg cluster. Kangas' (1941) studies in Finland show that while insects that complete eonymphal diapause at the normal time emerge in September, those that undergo prolonged diapause emerge as adults beginning in mid-June of the following summer. Finally, Styles (1959) in Scotland states that during the usual flight period in September, some larvae are still feeding on the trees; the latter he interprets as a partial second generation, implying that the parents had also been larvae in the same season, although they may have emerged from overwintering cocoons. The weight that should be given to some of these observations is questionable, considering the possibility of confusion with other sawfly species, and the fact that atypical emergence patterns can be produced unwittingly by artificial rearing conditions.

Males and females emerge contemporaneously during the entire emergence period, but generally the average emergence date of females is several days earlier than that of males (Lyons and Griffiths, 1962). This depends, however, on temperature during development in the cocoon, and may be reversed on exposed sites (Wallace and Sullivan, 1963). In any case the temporal difference between males and females at the beginning of the cocoon period is effectively removed by the time adults appear. Although the environmental control of the duration of eonymphal diapause tends to synchronize development of early with late individuals under one set of conditions (Lyons and Griffiths, 1962), the variability among cocoon sites in the field is enough to stretch the emergence beyond 6 weeks. Studies by Sturm (1942) suggest that adults may remain in the cocoon as long as 14 days before emerging. In Ontario, most adults emerge in late morning and early afternoon, the males appearing somewhat earlier. Kangas (1941) found in Finland that about 65 per cent of the adults emerged before 9:00 a.m. and a further 28 per cent between then and noon. Most of the emergence observed by Sturm (1942) occurred between noon and 2:00 p.m. Recent studies by C. R. Sullivan (personal communication) indicate that the optimal temperature for emergence of males is 21°C, and for females 23°C, and that emergence is stimulated primarily by rising temperatures and secondarily by declining atmospheric pressure.

In *N. sertifer*, as in other *Neodiprion* sawflies, it is generally conceded that males are haploid and produced from unfertilized eggs, whereas females are diploid and produced from fertilized eggs (Smith, 1960). The haploid chromosome number is 7 (Maxwell, 1958). Will's (1960) inference that *N. sertifer* can produce daughters parthenogenetically is erroneous. Only male offspring are produced by virgin females. Gynandromorphs have been observed and described (Watson, 1955). Barring heavy differential mortality there are generally two to three times as many females as males, presumably reflecting the sex ratio at the time of oviposition. Published records, given as per cent females, are: 60 and 54 (Griffiths, 1959), 77 (Kolubajiv, 1938), 62.5 (Niklas and Franz, 1957), 76 (Sturm, 1942),

70 and 74 (Galoux, 1952), 70 (Raizenne, 1957), and 45 to 92 (Thalenhorst, 1952). During epizootics of the polyhedral virus, however, more females than males are destroyed, and the proportion of females may decline to 17 to 35 per cent (Bird, 1961, Griffiths, 1959, Niklas and Franz, 1957). Predation on cocoons by small mammals may be selective for one sex or the other, depending on the predator species; shrews tend to select males, whereas mice tend to select females (Holling, 1958b). Parasitism by certain species may also be greater on females than on males.

At Chatsworth, 67 to 76 per cent of the *N. sertifer* recovered from soil samples have been females. Selective predation for male cocoons seems to have been balanced by selective parasitism of females, so there have been no consistent shifts in the sex ratio during the cocoon period. In colonies in which mortality was minimal, the percentage of females averaged 75, but varied from 8 to 86. The factors controlling the primary sex ratio have not been explained, and there is yet no basis for anticipating that the ratio can or should change with time or place.

Both males and females are ready to mate as soon as they emerge from the cocoon, and often do so in rearing containers. Males are attracted to females olfactorily, judging by their often sudden and abundant appearance near caged females in the field. Copulatory behaviour has been described by Ghent (1959). Some adults of both sexes apparently do not mate, even when they have the opportunity. In small cages, for example, some males make no attempt to mate, whereas at the other extreme a male may mate with 12 or more females within a few hours. Also, there are some females that consistently refuse to mate, even when given a choice of males, whereas others mate two or three times. The fact that all colonies in the field contain some females indicates that all adult females mate before ovipositing.

Ovaries of *N. sertifer* females are of the polytrophic type, the oocytes alternating with masses of nutritive cells in the ovarioles. Ovaries are visible as early as the pronymphal larval period, before pupation. The number of ovarioles per ovary varies from 14 to 22, averaging 17.5 (N=52). In newly moulted female adults, which are still within the cocoon, two types of oocytes can be distinguished: very minute ones located high in the ovarioles, and larger cream-coloured ones near the oviduct. Development proceeds rapidly, and after 4 days at 25°C about 53 per cent of all oocytes have attained their final size (approximately 1.5 to 1.9 mm long), shape, and mauve colour. About 65 per cent are mature after 6 days and about 71 per cent after 10 days. Thereafter there seems to be little further development, and some minute white oocytes always remain. Most writers consider that egg development reaches a maximum by the time the female emerges from the cocoon, but there is no firm evidence on this point.

The number of mature eggs per female at emergence is variable: 63 to 91 (Benjamin et al., 1955), 23 to 96 (Kolubajiv, 1938), 20 to 110, with means between 83 and 90 (Rose, 1952), 63 to 122 (Thalenhorst, 1952, 1953); a mean of 57.8 (Sturm, 1942), and means of 65.2 and 67.6 (Niklas and Franz, 1957). These estimates are low compared to those determined recently in Ontario, where a few insects have been found that contain no eggs, and others contain up to 140 eggs. In one study plot near Chatsworth, mean fecundity in three successive years was 103.8, 95.9, and 81.4; in another plot mean fecundity in two years was 87.8 and 89.9; in a third plot, in Norfolk County, fecundity averaged 96.1. The lowest mean fecundity recorded in a natural population is 57, the highest 115. Partial starvation of larvae produces females whose size and egg content are sub-

normal, but does not account for all the observed variability. Recent investigations by Campbell and Sullivan (1963) have shown that fecundity may be profoundly influenced by temperature during the cocoon period; females reared at 20°C completely utilized their fat body in the production of full-sized eggs, whereas those reared at 10°C used only 80 to 85 per cent of their fat body and contained fewer eggs. Insects transferred from 30°C to lower temperatures utilized still less of their fat body and produced relatively few eggs, which were reduced in size. These findings are of great importance, since they indicate that temporal and spatial variations in fecundity cannot be understood without consideration of the temperature conditions experienced by the insects during their development. The effects of these conditions have to be distinguished before the effect of more subtle factors can be determined.

It is generally considered that a female lays her eggs on the needles of only one shoot (Breny, 1954; Griffiths, 1959; Kangas, 1941), but some females likely oviposit at several sites. The eggs are laid in rows of 2 to 12 or more, most often on the lower edge of the needles, usually near the distal end of a current shoot. General descriptions of oviposition and the spacing of eggs are given by Scheidter (1926), Hein (1956), and others, but Ghent (1959) shows convincingly that the uniformity in egg spacing on the needles of one shoot is due to the stereotyped set of leg movements executed by the female in moving between successive oviposition sites. On the basis of field data, Ghent (1959) demonstrates the existence of a predicted inverse relationship between spacing and needle width. Curiously, the variation among clusters in egg spacing is least for the widest needles; this is explained by the fact that females of all sizes can oviposit on narrow needles, but only the largest females are able to utilize the widest ones (e.g. over 1.5 mm). Ghent's interpretation would account for the variations in egg spacing on different hosts observed by Rose (1952).

Other aspects of the behaviour of ovipositing females are also discussed by Ghent (1959), including orientation on the needle, cleaning of debris from the ovipositor, selection of sites by antennal palping, and the response to gravity.

The proportion of the egg supply that a female deposits is extremely variable. Thalenhorst (1952) observed that females deposited all but a small residue of their eggs. Niklas and Franz (1957) note that females generally oviposit completely or not at all; in cage tests, the two categories, complete and none, were 59 and 21 per cent in one year, but in the next generations were 15 and 69 per cent, respectively. No explanation is offred for the difference, but Niklas and Franz believe oviposition may be hampered if the flow of sap in the tree is disturbed, such as by heavy feeding. Hein (1956) argues that the moisture content of needles severely limits the number of eggs deposited per shoot; although the moisture content of different shoots varied from 57 to 67 per cent, eggs were found only on shoots with moisture contents from 58.5 to 64.5 per cent, and full-sized clusters (i.e. 40 to 80 eggs) occurred only on shoots within a narrow range of moisture content centering on 63 per cent. Whether this effect is directly due to water content, or to some correlated mechanical change in the needle tissue, has not been elucidated, but Hein (1956) and Voûte (1957) consider that a strong increase in water content following heavy defoliation could terminate an outbreak abruptly by preventing oviposition.

Studies by C. R. Sullivan (personal communication) indicate that the optimal temperature for initiation of oviposition is about 21°C, but that females will continue to oviposit until the temperature drops to about 9°C.

Females emerging in early September lay about twice as many eggs as ones emerging later in the season, when temperatures are less favourable.

Adults confined in glass tubes, where activity is restricted, remain alive for 3 weeks or more, depending on temperature; mean longevities for males and females were 20.2 and 16.7 days at 18°C, and 25.1 and 22.4 days at 15°C (Lyons and Griffiths, 1962). Longevity is probably considerably less in the field, particularly for females, which die soon after depositing their eggs.

Natural Control

Adult mortality before oviposition would seem to occur only rarely. Kangas (1941) mentions predation by birds, and the author has seen one instance of predation on an adult male by a hemipteran, *Sinea diadema* (F.), but most workers have nothing to say on the subject. Niklas and Franz (1957) point to the absence of published observations on adult mortality as evidence of its unimportance; their view is perhaps justified regarding the direct killing of adults, but this is only one possible type of loss. As far as a particular sawfly population is concerned, an adult sawfly is effectively dead if it does not contribute reproductively to the succeeding generation. Thus the natural control of adults is properly expressed as the difference between the egg potential of emergent adult females and the number of eggs they actually deposit. The loss is due partly to direct killing by predators and weather factors, partly to females that disperse from the stand, and partly to females that remain in the population but do not oviposit at all or do not deposit their full egg complement, owing to unsuitability of the host or unfavourable experiences earlier in development. Assessment of the loss must be based on a comparison of egg densities before and after oviposition. Unless such a comparison is obtained by actual counts, all but the most spectacular losses, such as that observed by Hein (1956), can be overlooked. In recent studies near Chatsworth, reproductive potential has been assessed by direct estimation of the surviving sawfly population and the fecundity of emergent females; the subsequent egg population is later estimated on the same scale of density. The measurements, although subject to considerable experimental error, show that in a red pine stand in which sawfly density has been declining, the loss of egg potential for 3 consecutive years was 61.1, 76.8, and 17.0 per cent. The importance of losses in two of the three years is illustrated by the fact that had they not occurred, sawfly density would have increased rather than decreased, since total mortality to the adult stage had already reached 97 per cent. The cause of the loss is not known, but it is probably safe to ignore direct mortality of females before oviposition. Dispersal out of the stand probably played some part, but the fact that the mean number of eggs per cluster declined during the same period suggests that conditions for oviposition were unsuitable, or that females lacked the vigour to oviposit fully.

Population Dynamics

Outbreaks, or gradations, of *N. sertifer* have occurred periodically in Europe for many years. They generally rise to a peak in 1 to 3 years and collapse abruptly. Niklas and Franz (1957), who surveyed the European literature, list 56 outbreaks beginning in 1873. These were concentrated in central Europe, but extended from Spain and Yugoslavia north to Finland. According to Trägårdh (1918) most outbreaks in Sweden occur south of the line where the mean temperature is 5°C, although there have been outbreaks in both Sweden (Lekander, 1962) and Finland (Kangas, 1963) north of latitude 67°, well inside the Arctic Circle. Outbreaks tend

to be contemporaneous over large areas. According to Niklas and Franz (1957) the main outbreak periods were 1873-95, 1907-13, 1918-22, 1932-35, 1938-40, 1948-50, and 1950-56. Kangas (1963) states that mild outbreaks appear locally in Finland at 5- or 6-year intervals, with heavy outbreaks at approximately 30-year intervals. In Sweden, *N. sertifer* is usually present in outbreak form somewhere every year (Forsslund, 1945).

There seems little doubt that the inception of outbreaks is regulated climatically, and that dry weather is the critical factor. Elens (1953a) notes a correspondence in Belgium between the occurrence of forest fires and outbreaks. According to Schwenke (1962), outbreaks of sawflies and other defoliators have long been known to coincide with the occurrence of "wine years", i.e. years when wine of exceptional quality is produced, owing to sustained periods of warm, dry weather that favour the ripening of grapes. Schimitschek (1962) emphasizes that outbreaks of *N. sertifer* in Austria and other parts of Europe are most frequent on sites with poor soil and very low water tables (65 feet or deeper). Dryness would seem to act indirectly rather than directly, promoting insect survival by decreasing host resistance, but the critical period of the year and the sensitive stage of the life cycle are not certain. Schönwiese (1935) asserts, on the basis of climatographic studies, that good weather in May and June for several consecutive years can lead to an outbreak, presumably by permitting above-average larval survival. This has support from the work of Schwenke (1963), who found that *Diprion pini* larvae feeding on trees on dry sites were larger and suffered less mortality than ones on trees on moist sites. On the other hand, Hein's (1956) observations on the relation between needle moisture and egg cluster size suggest that the condition of the host tree in the fall, during the oviposition period, is important. Possibly both the larval and adult periods are concerned. Unfortunately, little or no information is available on the extent of mortality in the interval between outbreaks, and even studies during periods of abundance make little attempt to account for all mortality, which it is necessary to do before critical periods in the life cycle can be identified. Thalenhorst (1953) considers that the quantitative study of individual sawfly species cannot solve the problem of sawfly outbreaks, and that studies of comparative population behaviour are needed. He points out, for example, that the most serious diprionid pests, such as *N. sertifer* and *D. pini,* are ones that deposit eggs in clusters, thereby overcoming resistance of the host tree and promoting their own survival. Although this approach may yield insight into some aspects of the problem of outbreaks, there remains the need for assessment of mortality in all life history stages so that the factors regulating density can be determined.

In most European outbreaks, density declines abruptly after a few years. Absolute population densities are not often recorded. Galoux (1952) estimated cocoon density per year from 1947 to 1950 as approximately 0.5, 2.4, 6.0 and 0.5 per square foot, respectively. Counts by Rummukainen (1960) at three locations in Finland at the height of an outbreak averaged about 7 cocoons per square foot. In the majority of cases epizootics of the indigenous polyhedral virus disease are clearly responsible for population decline (e.g. Breny, 1951; Schimitschek, 1962), but other explanations have also been advanced. Polyhedrosis was present in a part of the infestation in Belgium observed by Galoux (1952), but did not spread and caused little mortality; Galoux attributed the termination of the outbreak to predation by birds on eggs and cocoons and by mammals on cocoons. Hein (1956) attributed the breakdown of one outbreak in the Netherlands

to "bacteriosis", but in another area to unsuitability of the needles for oviposition. Schönwiese (1935) considered that bad weather in May and June might end an outbreak. Niklas and Franz (1957) detected a connected sequence of events leading to the decline of an outbreak near Darmstadt in southern German; the initial increase of sawfly density led to (a) an eruption of virus as the most important control factor, and to (b) increased illumination of the forest floor, which stimulated the growth of grass, permitting an upsurge in the small mammal population, which caused 50 to 88 per cent predation.

Rates of parasitism may often be high, but it is seldom asserted that parasites can alone terminate outbreaks, although they probably slow the rate of increase, and combine with other factors to raise mortality to the critical level. The wastage, particularly of larval parasites, is very great, owing to interference with other mortality factors during the cocoon period.

Prolonged diapause possibly protracts the course of outbreaks, particularly in northern regions such as Sweden and Finland, although its effects have not been studied as intensively as might be wished. Probably, as Thalenhorst (1963) found for *D. pini*, prolonged diapause often acts as a mortality factor by leaving the insects exposed to continued parasitism and predation.

Populations of *N. sertifer* in North America have behaved differently from those in Europe. First, there do not appear to have been well-defined periodic outbreaks of short duration. Second, population densities seem to have reached much higher levels. Both differences have most likely been due to the fact that *N. sertifer* was introduced to a new environment without its complex of living natural control agents, particularly the polyhedral virus disease. Until the virus was introduced cocoon densities exceeding one million per acre (25 per square foot) were not unknown (viz. Holling, 1959). In areas where the virus has persisted, sawfly density has remained at low levels (Bird, 1961). Although the natural spread of the virus has not kept pace with the spread of the sawfly, population densities in recent years do not appear to have reached such high levels. This perhaps is because *N. sertifer* is host to a complex of native parasites and predators, several efficient European parasites have become established, and it has been moving into areas where low winter temperatures kill many eggs.

An impression of some population changes in selected plantations near Chatsworth is available from recent studies that have concentrated on the estimation of absolute density for various life history stages and of mortality resulting from all factors that can be identified. In one of the study areas, containing red pines, *N. sertifer* may have appeared as early as 1953. A peak density of 13.7 eggs per square foot was reached at the start of the 1959-60 generation. Since then density has declined, initial egg densities in the next three years being 9.2, 3.6 and 2.0 respectively. Major mortalities have occurred during the egg stage (27 to 40 per cent) due primarily to freezing, during the cocoon period (88 to 92 per cent) mainly from parasitism but also from predation and unknown factors, and during the adult period due to failure of females to oviposit. About 10 parasite species have been recovered from cocoons in the soil. *Pleolophus basizonus* has predominated, accounting for almost 60 per cent of the parasitism. Two native cocoon parasites, *Mastrus argeae* and *Endasys subclavatus*, together accounted for another 18 per cent of the parasitism. A further 18 per cent of the total parasite emergence was by *Exenterus amictorius* and *E. cana-*

densis: these species attacked high proportions of cocoon-spinning larvae, but were greatly reduced in numbers by predation, death of the host larva, and competition from cocoon parasites. The polyhedral virus disease was present in the sawfly population, but caused negligible mortality. Total mortality by the time of adult sawfly emergence has been over 97 per cent each year. In the first two generations, the population trend would have risen had reproduction been successful, but a large part of the reproductive potential was not realized, and density declined.

The trend noted in the red pine study area probably occurred in most nearby plantations, but in at least one other plantation, population events were strikingly different. Here, *N. sertifer* entered the stand about 1960, shortly after tree planting, and has since been increasing 9- to 15-fold per year. In 1962, when the population was first studied intensively, the trees were still small enough to have been covered by snow; mortality in all stages was low, and did not exceed 55 per cent for the entire generation. Egg density in 1963 was over 15 times as great, although a third of the reproductive potential was not realized. Mortality in all stages was higher, owing primarily to low temperatures and parasitism, and reached 94 per cent for the generation, leaving enough female adults to provide for a doubling of density. Aside from the spectacular rate of increase, the main difference between this and the other study plot is that parasitism, which was about 65 per cent in 1963, was almost exclusively by one native species, *Exenterus canadensis*. An element of opportunism is likely operating here; *E. canadensis* predominates because it, rather than some other species, discovered the infestation early.

Several factors make *N. sertifer* in southern Ontario a less than ideal subject for population dynamics studies. For one thing, the environment of *N. sertifer* is naturally unstable. The trees are generally growing rapidly, which induces significant annual change in the microclimate, such as soil temperatures and the location of eggs in relation to snow cover. There is instability in the occurrence of host trees within a locality, since not only may older plantations be removed, but new ones are established where none had previously existed. The discovery of a new plantation by dispersing *N. sertifer* adults leads to a situation that resembles, on a reduced scale, an accidental introduction of a pest without its natural enemies. *N. sertifer* is able to get a head start, so to speak, and to multiply rapidly before parasites and other natural enemies find their way to it from older infestations or from other *Neodiprion* hosts, and before tree growth elevates the egg population above the snow line.

Biological Control

A program of biological control action against *N. sertifer* in Ontario began in 1940 and is still underway. The prompt start was possible because much of the parasite material used in the then large-scale biological control offensive against *Gilpinia hercyniae* (Htg.) in eastern Canada had been collected from *N. sertifer* in Europe. The program has been assessed briefly by Turnbull and Chant (1961), and in detail by McGugan and Coppel (1962), but is worth reviewing here. It seems implicit that the objective of biological control against *N. sertifer* was to bring about a strong reduction of population density by establishing in Ontario the main elements of the natural control complex of *N. sertifer* in Europe. This objective seems without hope of fulfilment, since it demands that the control complex do in Ontario what it does not do in Europe, where damaging outbreaks are frequent and widespread. The most that can be realistically expected is that given the establishment of the main biotic

control agents, *N. sertifer* will be no worse a pest in Ontario than it is in Europe.

The polyhedral virus disease and five parasite species are now established on *N. sertifer* in Ontario. The single most important element has unquestionably been the virus disease, the introduction, establishment and performance of which have been described by Bird (1950, 1952, 1953, 1955, 1961). The effectiveness of the disease is limited by its non-persistence in some stands and by its low rate of transmission. Bird (1961) suggested that larval parasites act as vectors, and that the very low rate of larval parasitism in *N. sertifer* explains why transmission of the virus between trees is slower in *N. sertifer* than in *N. lecontei,* which supports a number of larval parasites. This is an argument in support of continued efforts to introduce larval parasites from Europe, but it is worth noting that even in Europe, where the virus is indigenous and larval parasites often abundant, it has been found necessary to distribute the virus artificially for the control of outbreaks (Butovitsch, Notini and von Wettstein, 1960; Franz and Niklas, 1954; Rivers and Crooke, 1962). The same has been done at many points in Ontario; and in the United States (e.g. Dowden and Girth, 1953; Lowe and Mook, 1960; Schenefelt and Benjamin, 1955; Schuder, 1957). The object of this work has not been simply to establish the disease and let it operate naturally thereafter, in the way that parasites are expected to operate, but to apply it in place of insecticides for the control of defoliation, particularly in Christmas tree plantations, where mortality from virus would otherwise not occur early enough to prevent economically intolerable defoliation.

Some of the more important European parasites have become established on *N. sertifer* in southern Ontario. *Pleolophus barizonus* and *Exenterus amictorius* sometimes attack large numbers of hosts, and where they occur, the density of *N. sertifer* is probably lower than it would otherwise be. *Dahlbominus fuscipennis* is now widely distributed in Ontario (Rose and Sippell, 1964), despite the statement to the contrary by Turnbull and Chant (1961), but appears to parasitize only the most accessible cocoons. This limitation was also noted by Girth and McCoy (1946a) during studies in New Jersey. *Drino bohemica* and *Monodontomerus dentipes* have been recovered consistently at Chatsworth in the last several years, but only in very small numbers.

Three of the four main European parasites, viz. *Exenterus abruptorius, Lamachus eques, Lophyroplectus luteator,* still do not occur in Ontario, although they and other species were released not long after *N. sertifer* first appeared (McGugan and Coppel, 1962). In many cases only a few individuals were released, often at times when the appropriate host stage was not available, so further attempts to establish them are justified.

Biological control work has concentrated on transferring European natural control agents to North America, but there are other possibilities. Pschorn-Walcher (1961) suggests that effective larval parasites against *N. sertifer* might be found in North America itself, particularly in western regions, where its closest relatives presumably occur. Another possibility would be to utilize parasites of the *Neodiprion* sawflies in Ontario whose life cycles resemble that of *N. sertifer,* e.g. *N. p. banksianae,* which in northern Ontario, is host to at least one egg parasite and 10 larval parasites (Griffiths, 1960). Some transfer of parasites from native *Neodiprion* spp. to *N. sertifer* has of course already occurred; the number of such transfers has probably been limited more by lack of opportunity than by host specificity.

No use has been made of predators in the biological control program against *N. sertifer*, although the red forest ant, *Formica rufa* L. and its varieties seem worth considering, since they are known to destroy large numbers of feeding larvae in Europe.

Chemical Control

It is usually considered that the expense of insecticidal control of *N. sertifer* in forest stands is not justified, since tree mortality is rare and the moderate loss of increment occurs for only a short time. In plantations destined for the Christmas tree trade, however, even moderate defoliation may destroy the market value of the crop, and control is a necessity.

Preparations containing lead arsenate were at one time widely used (Hamilton, 1943; Schaffner, 1943; Weiss, 1939), but these have been replaced by various preparations of DDT and other contact insecticides. Solutions of DDT are generally recommended (Libby, 1961; Schenefelt and Benjamin, 1955; Kolonitis, 1962; Haine, 1952), but some European workers (Breny and Detroux, 1950; Joly, 1953) have found it ineffective. The Chemical Control Section of the Canada Department of Forestry recommends the use of either Malathion (50 per cent emulsifiable concentrate at 0.25 per cent in water for sprayers and at 12.5 per cent for mist blowers), or DDT (25 per cent emulsifiable concentrate at 0.5 per cent for sprayers and 25 per cent for mist blowers.) Insecticides should be applied shortly after hatching.

Monro and Kirby (1963) report complete control of overwintering *N. sertifer* eggs after fumigation with methyl bromide at 32 grams per litre for several hours. Development of this technique would guarantee the shipment of sawfly-free nursery stock and thus prevent the accidental spread of *N. sertifer*.

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II. SUBMITTED PAPERS

The Status of Apple Leaf Rollers in Norfolk County, Ontario[1]

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Introduction

Much attention has been given to the rise in population of the red-banded leaf roller, *Argyrotaenia velutinana* Wlk. in many apple orchards shortly after DDT came into general use, for controlling codling moth (Glass and Chapman, 1948). However, little attention has been given to the status of other species of leaf rollers, some of which used to be more abundant and destructive than *A. velutinana* in Norfolk County, Ontario.

Caesar (1915) found the fruit tree leaf roller, *Archips argyospilus* Wlk., the oblique banded leaf roller, *Choristoneura rosaceana* Harr. and box elder leaf roller, *Archips semiferanus* Wlk. causing damage in apple orchards in Ontario. Hall's papers (1929, 1930, 1933) show the presence of seven more species, namely; the three line leaf roller, *Pandemis limitata* Rob., *Choristoneura fractivittana* Clem., the dusky leaf roller, *Amorbia humerosana* Clem., *Argyrotaenia quadrifasciana* Fern., and *Archips purpuranus* Clem., the Palmer worm, *Dichomeris ligulella* Hub., and the red-banded leaf roller, *A. velutinana*. Preserved specimens in the collection of the Entomology Sub-laboratory at Simcoe, Ontario, indicated that trace numbers of *Clepsis persicana* Fitch, *Choristoneura parallela* Rob., *Exartema subnubilum* Heinr., *Hedia chionosema* Zell., *Sparganothis sulfurana Kft., Aphelia pallorana* Rob., were also present in apple orchards in Norfolk County.

Unpublished records at Simcoe indicate that six species previously caused economic loss in apple orchards but that the number of pest species gradually decreased. *D. ligulella* which was mentioned as a pest in 1929 disappeared about 1934. Other species, such as *C. rosaceana, C. fractivittana, P. limitata,* and *A. semiferanus* were minor pests until 1935. Until 1948, *A. argyospilus* was the most abundant species and caused extensive damage; then it declined rapidly and *A. velutinana* increased in abundance and became a major pest in many apple orchards.

This paper compares the status of the leaf rollers in apple orchards in Norfolk County, Ontario in 1962 with that of earlier years.

Methods

The bait pail records were obtained from Hall (1934) and his unpublished data from 1934 to 1952 on leaf roller species which were trapped in solution of fermented molasses in 128 ounce cans. These bait pails were suspended on branches near the tops of apple trees in four sites in the Neff orchard until its demise in 1934. The data after that time were provided by two pails in the Perrett orchard and two in the Jackson orchard.

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In 1962, weekly collections of leaf roller larvae were made from May to September at 9 sites consisting of three commercial orchards, three neglected orchards and three woods. One hour was spent at each site each week collecting leaf roller larvae exclusive of bud moth, *Spilonota ocellana* D.&S. Because species of the larvae could not be accurately determined, especially in the early instars, they were reared singly on apple foliage in vials to the moth stage. This eliminated some species that required other food to complete their development.

Results and Discussion

TABLE 1. The species and number of leaf roller moths captured in bait pails placed in apple orchards in Norfolk County, Ontario, from 1929 to 1952.

	Total number of moths per 4 pails							
	1929-31	1932-34	1935-37	1938-40	1941-43	1944-46	1947-49	1950-52
Archips semiferanus Wlk.	3279	477	103	62	459	316	22	8
Choristoneura rosaceana Harr.	510	253	449	200	575	925	296	142
Pandemis limitata Rob.	1078	584	56	146	391	551	203	10
Argyrotaenia velutinana Wlk.	36	18	4	15	36	88	258	395
Archips argyospilus Wlk.	1222	929	430	981	1581	1996	127	0
Choristoneura fractivittana Clem.	120	169	25	91	347	0	0	0
Amorbia humerosana Clem.	3	0	1	0	6	0	0	0
Argyrotaenia quadrifasciana Fern.	0	0	10	6	4	0	0	0
Choristoneura parallela Rob.	0	0	0	2	0	0	0	0
Clepsis persicana Fitch	0	0	5	2	0	0	0	0
Archips purpuranus Clem.	3	1	0	0	0	0	0	0
Dichomeris liguella Hbn.	56	0	0	0	0	0	0	0
No. of species	9	7	9	9	8	5	5	4

Bait pail records (Table 1) show that of the twelve species of apple leaf rollers trapped in the bait, *A. humerosana, A. quadrifasciana, A. parallela, A. persicana, A. purpuranus,* and *D. ligulella,* were trapped in trace numbers and disappeared from the records by 1943. *A. semiferanus,*

TABLE 2. The species and number of apple leaf rollers collected in sprayed and unsprayed apple orchards and woodland hosts in Norfolk County. Collection made one hour weekly from May to September inclusive, 1962.

Species	Total number of moths recovered		
	Sprayed orchards	Unsprayed orchards	Woodlands
Pandemis limitata Rob.	0	32	26
Pandemis lamprosana Rob.	1	14	13
Pandemis canadana Kft.	0	1	0
Argyrotaenia quadrifasciana Fern.	0	27	4
Argyrotaenia velutinana Wlk.	297	5	6
Choristoneura fractivittana Clem.	0	5	9
Choristoneura rosaceana Harr.	2	119	51
Archips purpuranus Clem.	0	0	9
Archips argyospilus Wlk.	0	8	4
Archips semiferanus Wlk.	0	5	0
Acleris variegana Schiff.	0	19	2
Sparganothis sulfurana Clem.	1	1	0
Aphelia pallorana Rob.	0	1	0
Hedia chionosema Zell.	0	2	1
Hedia ochroleucana Hbn.	0	14	0
Exartema subnubilum Heinr.	0	3	23
Dichomeris liguella Hbn.	0	7	3
Machimia tentoriferella Clem.	1	3	1

C. rosaceana, P. limitata, A. velutinana, A. argyospilus and *C. fractivittana* were more abundant but the number of species gradually declined with the disppearance of *C. fractivittana* in 1943 and *A. argyospilus* in 1949. After this time, with the exception of *A. velutinana,* other species such as *A. semiferanus, C. rosaceana* and *P. limitata* showed a marked decline.

Though 18 species known to feed on apple were recovered from various hosts (Table 2) in 1962, species recovered in sprayed orchards confirmed the trend found in the bait pail catches from 1949 to 1952. The species were restricted mainly to *A. velutinana* and trace numbers of *P. limitata, C. rosaceana, S. sulfurana* and *Machimia tentoriferella* Clem.

With the exception of *A. humerosana, C. persicana* and *A. parallela,* other species, which were formerly recorded in bait pails or as preserved specimens, emerged from one or more of the collection sites in neglected orchards and woodlands and showed that they have not disappeared from the county.

Apparently some factor is interfering with the flight from surrounding unsprayed hosts to the bait traps in sprayed orchards. The coincident disappearance of *A. argyospilus* and reduction of *A. semiferanus, C. rosaceana,* and *P. limitata* around 1949, when DDT came into general use, suggests that bait pail catches were directly or indirectly affected by DDT. The increase in *A. velutinana* can be explained by the fact that the larvae are quite tolerant to DDT (Paradis, 1956, Harman, 1948).

Recovery of hitherto, unrecorded species such as *Hedia orchroleucana* Hbn., *Acleris variegana* Schiff., *M. tentoriferella, P. canadana,* and perhaps *Pandemis lamprosana* Rob., may be new introductions to the county but the possibilities that they were not attracted to the bait and that *P. lamprosana* was not distinguished from *P. limitata* were not discounted.

In conclusion, the moth recovery showed that of the 18 species of leaf rollers known to attack foliage only *A. velutinana* thrives in commercial apple orchards in numbers to constitute a pest. Former pests in sprayed orchards were found in neglected orchards and woodlands in trace numbers.

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An Annotated Check List of the Genus *Andrena* in Ontario (Hymenoptera:Andrenidae)

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The genus *Andrena* represents one of the most abundant groups of bees in the northern hemisphere, both in species and individuals. Their size ranges from 5 to 15 mm. and there is a great variation in color and in the nature of the pubescence. The integument is usually dark brown or black, but several species exhibit some metallic lustre and the females of several others possess a conspicuous red abdomen. Sexual dimorphism is evident in almost all species. Facial foveae are developed in females only, while the clypeus and other parts of the face are yellow in many males, seldom in females.

Specific identification constitutes a major problem on account of the sheer number of species, and all attempts to devise satisfactory subgeneric divisions have so far failed since many transitional forms exist between several of the proposed divisions.

Little is known concerning the bionomics of most of our species but references to literature of this kind are given in the appropriate places in this paper. Generally, most andrenid bees have limited flight periods of one to three months which, in some cases at least, coincide with the flowering period of specific food plants. Males often appear before females, sometimes by as much as several weeks, but they are thought to have a much shorter flight period than the latter. All andrenid bees in this province have but one generation a year, the majority occurring during the spring but a few species appear later in summer and some are not seen until fall.

Males and females mate after emerging from their cells and the female then excavates and provisions several cells in the soil; these are sealed after oviposition. Several such nests may be constructed and their cells provisioned by a single female before she dies. Her progeny, which she has never seen, will then complete their development within the cells and will emerge in the following year. Burrows are often solitary but several species construct nests in close proximity to each other thus forming nesting aggregations. Despite the existence of these colonies, it is evident that no further development toward a higher level of social behaviour has taken place within this group.

The architecture of most andrenid nests as far as known, is simple, consisting of a vertical shaft leading to a series of sessile or semisessile cells. No andrenid nest has been found so far in a vertical bank or in material other than soil, two important points of contrast with nests of halictine bees.

The following list of species is based on specimens studied in the Canadian National Collection (C.N.C.), the Royal Ontario Museum, the Ontario Agricultural College and the authors' collections. Specific and subgeneric classifications were used as outlined by Mitchell (1960), whose book also supplied some of the distributional records.

Further work in this group could profitably be directed toward the elucidation of the distributional patterns of "northern" and "southern" species, their bionomics and ethology and the finding and subsequent description of the missing sexes; 35% of all the described species of eastern North America are known from one sex only.

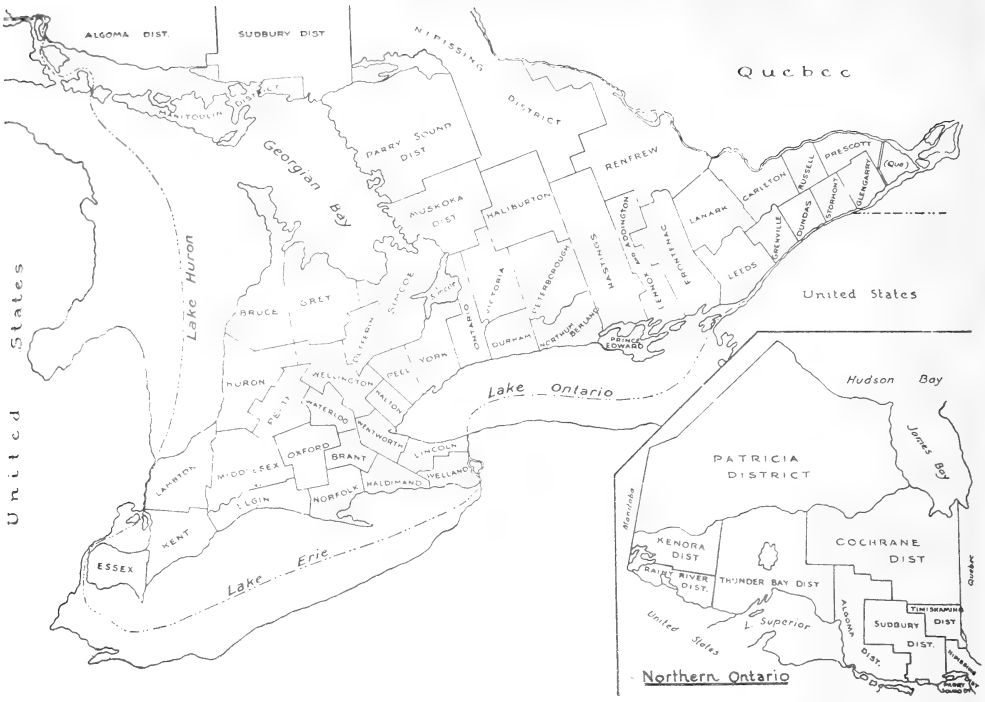

FIG. 1. Map of Ontario showing the location of counties and districts.

ANDRENA Fabricius, 1775
Systema Ent., p. 376.

Andrena (Andrena) clarkella (Kirby) ♀ ♂

Distribution by counties and districts: Carleton, Haliburton, Muskoka, Nipissing, Parry Sound, Simcoe, Sudbury, Timiskaming.

Flower records: *Fragaria, Prunus, Salix.*

Flight period based on our collections: May and June.

Holarctic, being recorded from Europe, Alaska and the northeastern United States (Mitchell, 1960). Large, conspicuous bee with dense black and pale pubescence and bright orange tarsi. Its range seems to be boreal with large populations above the 46th parallel. It is well adapted to the rigours of northern spring weather and has been observed collecting pollen from willows when tempertures were in the low fifties and the skies overcast.

Andrena (Andrena) frigida Smith ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Cochrane, Durham, Frontenac, Haliburton, Hastings, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Parry Sound, Peel, Simcoe, Thunder Bay, Timiskaming, Victoria, York.

Flower records: *Barbarea, Chamaedaphne, Prunus, Salix.*

Flight period based on our collections: April and May.

Large bee with pale, long pubescence. This species appears in late April and is abundant in central and northern Ontario. Over one thousand

males and females were once taken within three minutes on two willow trees near Dorset by one of us (G.K.). Nesting activities were observed in the same area in early spring when burrows were being constructed and provisioned by the females in the sandy soil of dirt roads. These activities usually ceased by the end of May.

Andrena (Andrena) macoupinensis Robertson ♂

Distribution by counties and districts: Essex.

Flower records: *Salix.*

Flight period based on our collections: June.

Only two males were taken on one occasion in the southernmost county of Ontario and it is quite possible that the distribution of this species in Ontario is restricted to that area.

Andrena (Andrena) mandibularis Robertson ♀

Distribution by counties and districts: Frontenac.

Flower records: *Malus.*

Flight period based on our collections: May.

Mitchell (1960) reports this species from Ontario and Nova Scotia and south to Georgia. The single specimen in our collections indicates that the range of the species barely extends into southern Ontario.

Andrena (Andrena) milwaukeensis Graenicher ♀ ♂

Distribution by counties and districts: Algoma, Durham, Haliburton, Muskoka, Nipissing, Peel, Sudbury, Victoria, York.

Flower records: *Acer, Cornus, Crataegus, Fragaria, Prunus, Rubus, Salix, Taraxacum.*

Flight period based on our collections: May and June.

Large bee with conspicuous reddish pubescence on thorax and the first two abdominal terga. It has been collected over a wide range in the province, often singly or in small numbers. Like all other members of this subgenus it appears rather early in spring. Brittain (1933) published some biological notes on this species. Nests have been observed in firm sandy banks partly shaded by pines on Kipawa Lake, just outside the Ontario border, lat. 47°. (Atwood, unpubl. data).

Andrena (Andrena) thaspii Graenicher ♀ ♂

Distribution by counties and districts: Carleton, Durham, Essex, Grenville, Haliburton, Lanark, Muskoka, Parry Sound, Sudbury, York.

Flower records: *Acer, Cornus, Fragaria, Melilotus, Potentilla, Raphanus Rhus, Rosa, Rubus, Salix, Solanum.*

Flight period based on our collections: June to August.

This bee appears in late spring and is remarkable for its frequent visits to the flowers of bittersweet. (*Solanum*).

Andrena (Andrena) tridens Robertson

Mitchell (1960) records this species from Ontario and the neighbouring states of Michigan and New York. A specimen seen in the C.N.C. under this name did not agree with Mitchell's description and was not included in the present list.

Andrena (Bythandrena) acra Mitchell

Mitchell (1960) described this species from a series of males only. One of the paratypes was collected on Pelee Island, Ontario, in June.

Andrena (Bythandrena) carlini carlini Cockerell ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Dufferin, Durham, Elgin, Frontenac, Haliburton, Hastings, Kent, Lanark, Leeds, Lennox and Addington, Lincoln, Muskoka, Nipissing, Peel, Simcoe, Sudbury, Timiskaming, Victoria, York.

Flower records: *Amelanchier, Barbarea, Brassica, Chamaedaphne, Claytonia, Crataegus, Erythronium, Euphorbia, Hieracium, Ledum, Malus, Prunus, Ribes, Rubus, Salix, Scilla, Taraxacum, Uvularia, Vaccinium, Viburnum.*

Flight period based on our collections: April to August.

Large bee with dense pubescence. It is well represented in most parts of the province, as our collections indicate. Males are usually observed on the first spring flowers. Several nesting sites were found in dirt roads near Haileybury in Timiskaming district. Atwood (1933) reported on nest aggregations of this species in Nova Scotia.

Andrena (Bythandrena) dunningi Cockerell ♀ ♂

Distribution by counties and districts: Carleton, Frontenac, Hastings, Lanark, Leeds, Lincoln, Peel, York.

Flower records: *Amelanchier, Barbarea, Crataegus, Malus, Rubus, Salix, Sambucus, Taraxacum, Trillium, Uvularia.*

Flight period based on our collections: April to June.

Large, densely pubescent bee quite common in the southeastern counties, especially on flowers of the family Rosaceae.

Andrena (Bythandrena) erythrogaster erythrogaster (Ashmead) ♀ ♂

Distribution by counties and districts: Elgin, Huron, Kent, Lambton, Lincoln, Wellington, York.

Flower records: *Salix.*

Flight period based on our collections: April to June.

Medium sized bee with short, pale pubescence on head and thorax. Females have a bright ferruginous abdomen, a characteristic shared only by two other species which also occur in the southernmost counties of the province. Rau (1936) published some biological notes concerning this species.

Andrena (Bythandrena) erythrogaster subaustralis Cockerell ♀ ♂

Distribution by counties and districts: Carleton, Durham, Frontenac, Hastings, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Peel, Simcoe, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Prunus, Salix.*

Flight period based on our collections: April and May.

The female in this subspecies lacks the red colour on the abdomen of *A.e. erythrogaster*. Its distribution is more northern than that of the latter.

Andrena (Bythandrena) perplexa Smith ♀

One female from Kent Co. (May 24, 1888) was studied in the C.N.C. No flower host was given.

Andrena (Bythandrena) regularis Malloch ♀ ♂

Distribution by counties and districts: Algoma, Cochrane, Haliburton, Hastings, Lanark, Lennox and Addington, Muskoka, Nipissing, Sudbury, Timiskaming, Victoria.

Flower records: *Acer, Amelanchier, Barbarea, Chamaedaphne, Crataegus, Fragaria, Kalmia, Ledum, Prunus, Rubus, Salix, Sorbus, Taraxacum, Vaccinium, Viburnum.*

Flight period based on our collections. May and June.

Large bee with dense pubescence. It differs from *A. carlini* only by morphological details in its clypeus. Nesting sites were found in a dirt road near Haileybury in Timiskaming district. This species seems to be confined to the more northern parts of the province.

Andrena (Bythandrena) viburnella Graenicher ♂

Distribution by counties and districts: Elgin.

Flower records: *Salix.*

Flight period based on our collections: May.

There is only a single male in the authors' collections and it appears that this species is confined to the southern part of the province.

Andrena (Gymnandrena) commoda Smith ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Hastings, Kent, Middlesex, Northumberland, Simcoe, Victoria, York.

Flower records: *Crataegus, Melilotus, Potentilla, Rhus, Rubus, Rudbeckia, Salix, Trifolium.*

Flight period based on our collections: May to July.

Large bee with short pubescence and infumate wings. Not present in early spring, it is most abundant in June when it visits the flowers of *Melilotus* in numbers.

Andrena (Gymnandrena) nivalis Smith ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Dufferin, Durham, Haliburton, Lanark, Muskoka, Nipissing, Sudbury, Timiskaming, Victoria, York.

Flower records: *Acer, Cornus, Fragaria, Kalmia, Ledum, Leontodon, Melilotus, Potentilla, Prunus, Rhus, Rubus, Salix, Vaccinium, Viburnum.*

Flight period based on our collections: May to July.

Large bee, never very abundant, appears in late spring and lasts well into summer. It seems to be absent from the southern counties. Solitary burrows were found in a shaded footpath along a lake in Muskoka district.

Andrena (Gymnandrena) vicina Smith ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Dufferin, Durham, Elgin, Essex, Frontenac, Grenville, Haliburton, Hastings, Kent, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Ontario, Parry Sound, Peel, Simcoe, Sudbury, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Chamaedaphne, Cornus, Crataegus, Euphorbia, Fragaria, Kalmia, Ledum, Malus, Potentilla, Prunus, Ribes, Rubus, Sambucus, Salix, Scilla, Taraxacum, Vaccinium.*

Flight period based on our collections: April to July.

Large bee resembling *A. carlini* and *A. regularis.* Abundant throughout the province during a large part of the warm season. At times in tremendous numbers, it occurs on a wide variety of flower hosts. The extended flight period is rather exceptional among andrenids of this province. Packard (1869) reported on the nesting habits of the species. Clements and Long (1923) published on some aspects of its ecology.

Andrena (Pterandrena) aliciae Robertson ♀ ♂

A series of two females and three males taken near Toronto in July and August more than seventy years ago were studied in the C.N.C.

Mitchell (1960) records that it shows a host preference for *Bidens* and several related sunflowers which may be the reason why this species is not well represented in collections. The yellow clypeus in both sexes of this rather large bee is remarkable.

Andrena (Pterandrena) asteris Robertson ♀ ♂

Distribution by counties and districts: Dufferin, Elgin, Lincoln, Middlesex, Muskoka, Simcoe, York.

Flower records: *Aster, Cirsium, Solidago.*

Flight period based on our collections: August and September.

Large bee, scattered occurrence during late summer and fall. Females have a plumose scopa, a characteristic they share with few other species in Ontario.

Andrena (Pterandrena) solidaginis Robertson ♀ ♂

Distribution by counties and districts: Dufferin, Durham, Elgin, Haliburton, Halton, Muskoka, Victoria, York.

Flower records: *Cirsium, Solidago.*

Flight period based on our collections: August and September.

Medium sized bee. It sometimes occurs together with *A. asteris* on the flowers of *Solidago*, but seems to have a more extensive range and larger populations. Its female also has a plumose scopa.

Andrena (Ptilandrena) erigeniae Robertson ♀ ♂

Distribution by counties and districts: Carleton, Haliburton, York.

Flower records: *Claytonia, Prunus.*

Flight period based on our collections: May.

Smallish bee with plumose scopa. Less than half a dozen specimens were examined in the various collections.

Andrena (Micrandrena) illinoiensis Robertson ♀

A single record from Carlton Co. taken April 21, 1913 was seen in the C.N.C. No specimens were collected by the authors although Mitchell (1960) gives the range of the species as "transcontinental in southern Canada".

Andrena (Micandrena) melanochroa fragariana Graenicher ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Frontenac, Haliburton, Muskoka, Nipissing, Parry Sound, Peel, Thunder Bay, Timiskaming, York, Wentworth.

Flower records: *Amelanchier, Crataegus, Fragaria, Prunus, Ranunculus, Rubus, Salix, Taraxacum.*

Flight period based on our collections: May and June.

This is the smallest andrenid bee in Ontario. Although it was taken on several flowers, *Fragaria* is apparently favoured as a host and sweeping of strawberry patches sometimes resulted in the capture of several hundred females of this species.

Andrena (Micrandrena) miserabilis bipunctata Cresson ♀ ♂

Distribution by counties and districts: Carleton, Cochrane, Dufferin, Durham, Elgin, Essex, Frontenac, Haliburton, Hastings, Huron, Kent, Lambton, Lanark, Leeds, Lennox and Addington, Middlesex, Muskoka, Nipissing, Parry Sound, Peel, Simcoe, Sudbury, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Brassica, Claytonia, Cornus, Crataegus, Euphorbia, Fragaria, Malus, Prunus, Rhus, Rubus, Salix, Scilla, Taraxacum, Viburnum.*

Flight period based on our records: April to July.

Small bee with shiny, impunctuate clypeus. Well represented in all parts of the province, often in large numbers. Michener and Rettenmeyer (1956) reported on some aspects of its biology.

Andrena (Micrandrena) salictaria Robertson ♀ ♂

Distribution by counties and districts: Carleton, Durham, Elgin, Frontenac, Haliburton, Hastings, Huron, Kent, Lambton, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Parry Sound, Peel, Simcoe, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Claytonia, Chamaedaphne, Crataegus, Prunus, Salix.*

Flight period based on our collections: April to June.

Smallish, slender bee with dull metallic integument. Usually found in large numbers in early spring.

Andrena (Cnemidandrena) canadensis Dalla Torre ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Elgin, Essex, Haliburton, Kent, Muskoka, Thunder Bay, Timiskaming, Victoria, York.

Flower records: *Anaphalis, Aster, Cirsium, Epilobium, Solidago.*

Flight period based on our collections: August and September.
propodeum with all the other members of this subgenus. Several nests were found in the shaded footpath among burrows of *A. nivalis* (q.v.).

Small, resembling *A. nubecula* with which it shares part of its range and flower hosts. Both species occur in late summer and were found nesting gregariously in a sandy slope near Dorset in Muskoka county.

Andrena (Cnemidandrena) hirticincta Provancher ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Elgin, Essex, Halibuton, Hastings, Kent, Lincoln, Muskoka, Northumberland, Simcoe, Stormont, Victoria, York.

Flower records: *Anaphalis, Epilobium, Solidago.*

Flight period based on our collections: August and September.

Medium sized bee with conspicuous, long, yellow pubescence forming complete apical fasciae on the abdominal terga. Males and females of this species appear in summer and remain fairly common until late fall on the flowers of *Solidago.*

Andrena (Cnemidandrena) nubecula Smith ♀ ♂

Distribution by counties and districts: Dufferin, Elgin, Haliburton, Halton, Hastings, Lanark, Muskoka, Northumberland, Peel, Thunder Bay, Victoria, York.

Flower records: *Anaphalis, Aster, Epilobium, Solidago.*

Flight period based on our collections. August and September.

Small bee differing from the related *A. canadensis* mainly by its infumate wings. Nests were found among those of *A. canadensis* (q.v.).

Andrena (Trachandrena) alleghaniensis Viereck ♀ ♂

Distribution by counties and districts: Haliburton, Lanark, Leeds, Lennox and Addington, Muskoka, Sudbury, Victoria.

Flower records: *Amelanchier, Barbarea, Cornus, Crataegus, Ledum, Prunus, Rubus, Salix, Viburnum.*

Medium sized bee with short, orange-colored, scale-like pubescence on scutum and scutellum of the female. Both sexes share the coarsely rugose

Andrena (Trachandrena) ceanothi Viereck ♀ ♂

Distribution by counties and districts: Durham, Frontenac, Haliburton, Lanark, Lennox and Addington, Muskoka, Sudbury, Victoria, York.

Flower record: *Amelanchier, Chamaedaphne, Cornus, Crataegus, Fragaria, Ledum, Prunus, Rubus, Salix, Taraxacum, Vaccinium, Viburnum, Waldsteinia.*

Flight period based on our collections: May and June.

Medium sized bee, never found in large numbers, absent in the more northern parts of the province. The broadly hyaline apical rims of the abdominal terga in both sexes separate this species from related ones.

Andrena (Trachandrena) forbesii Robertson ♀ ♂

Distribution by counties and districts: Algoma, Dufferin, Elgin, Essex, Frontenac, Grenville, Haliburton, Hastings, Kent, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Peel, Simcoe, Wellington, York.

Flower records: *Acer, Amelanchier, Barbarea, Chamaedaphne, Crataegus, Fragaria, Hieracium, Malus, Prunus, Rubus, Salix, Taraxacum.*

Flight period based on our collections. April to June.

Medium sized bee occurring in numbers over most parts of the province.

Andrena (Trachandrena) hippotes Robertson ♀ ♂

Distribution by counties and districts: Dufferin, Durham, Elgin, Essex, Frontenac, Haliburton, Hastings, Huron, Kent, Lambton, Lanark, Leeds, Muskoka, Nipissing, Peel, Sudbury, Timiskaming, Victoria, Wellington, York.

Flower records: *Acer, Amelanchier, Barbarea, Crataegus, Fragaria, Malus, Prunus, Rubus, Salix, Scilla, Taraxacum, Viburnum.*

Flight period based on our collections: April to June.

Medium sized bee, fairly common in most parts of the province. Both sexes are characterized by bright ferruginous tibiae and tarsi.

Andrena (Trachandrena) kalmiae Atwood ♀ ♂

Distribution by counties and districts: Lanark, Timiskaming.

Flower records: *Kalmia, Ledum.*

Flight period based on our collections: June and July.

Medium sized bee with coarsely punctate clypeus. Series of males and females were collected at two very similar locations. In both places, *Chamaedaphne calyculata, Ledum groenlandicum, Kalmia angustifolia* and *Vaccinium* spp. supplied most of the flowers during spring and early summer. Although there was considerable overlapping in the flowering periods of the plants, *Chamaedaphne* was the only bloom available in early spring while *Kalmia* was similarly unique during July. Pollinators on all these flowers were numerous and included members of the Apinae, Bombinae, Halictidae, certain Diptera and Lepidoptera as well as several species of *Andrena.* The latter included *A. vicina, A. carlini* and *A. regularis* which were present during most of the period, showing little host

preference. Flight periods of three other species seemed to coincide with the flowering periods of specific hosts. *A. bradleyi* males and females were found in large numbers on the flowers of *Chamaedaphne* during early May, *A. carolina* appeared one or two weeks later and was seen to collect mainly on *Ledum* while *A. kalmiae* was not found before the middle of June. At that time, newly emerged males and females were seen feeding and mating on the flowers of *Ledum*, but no female was ever observed to collect pollen for the provisioning of new cells from flowers other than *Kalmia*.

Andrena (Trachandrena) mariae mariae Robertson ♀

Distribution by counties and districts: Kent, York.

Flower records: *Salix.*

Flight period based on our collections: June.

Medium sized bee unique in this subgenus by its bright ferruginous abdomen. Despite extensive collecting in the southernmost counties, the authors have only taken one single female. The other record was found in the C.N.C.; the specimen had been recorded from Toronto.

Andrena (Trachandrena) miranda Smith ♀ ♂

Distribution by counties and districts: Bruce, Carleton, Durham, Grenville, Haliburton, Halton, Kenora, Kent, Lanark, Leeds, Muskoka, Nipissing, Peel, Prince Edward, Timiskaming, Victoria, Welland, Wellington, York.

Flower records: *Barbarea, Cornus, Crataegus, Fragaria, Hieracium, Ledum, Melilotus, Potentilla, Prunus, Rhus, Rubus, Salix, Vaccinium, Viburnum.*

Flight period based on our collections: April to July.

Medium sized bee especially numerous toward the northern part of the province.

Andrena (Trachandrena) montensis Mitchell ♀

Distribution by counties and districts: Victoria.

Flower records: *Rhus.*

Flight period based on our collections: July.

There is only one female in our collections. Little is known concerning this species; its male is undescribed.

Andrena (Trachandrena) morrisonella Viereck ♀ ♂

Distribution by counties and districts: Lanark, Muskoka, Nipissing, Timiskaming, York.

Flower records: *Amelanchier, Prunus, Salix.*

Flight period based on our collections: May and June.

Medium sized bee well represented in collections, especially those taken in the more northern parts of the province. A series apparently representing the undescribed male is on hand for later study.

Andrena (Trachandrena) obscura (Robertson) ♀

Distribution by counties and districts: Carleton, York.

Flower records: *Rudbeckia.*

Flight period based on our collections: July.

Quite rare in Ontario. Only four females were collected by the authors, all of them on the same host and date.

Andrena (Trachandrena) rugosa Robertson ♀ ♂

Distribution by counties and districts: Durham, Frontenac, Haliburton, Halton, Hastings, Lanark, Leeds, Muskoka, Nipissing, Parry Sound, Peel, Simcoe, Sudbury, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Crataegus, Cornus, Fragaria, Malus, Prunus, Rubus, Salix, Vaccinium.*

Flight period based on our collections: May and June.

Medium sized bee with coarsely pitted scutum. Fairly common in spring, especially in the northern and eastern parts of the province.

Andrena (Trachandrena) sigmundi Cockerell ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Dufferin, Durham, Frontenac, Haliburton, Hastings, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Ontario, Parry Sound, Peel, Simcoe, Thunder Bay, Timiskaming, Victoria, York.

Flower records: *Amelanchier, Barbarea, Chamaedaphne, Claytonia, Crataegus, Erigeron, Erythronium, Fragaria, Malus, Prunus, Rubus, Salix, Taraxacum, Vaccinium, Waldsteinia.*

Flight period based on our collections: April to June.

Medium sized bee, very numerous at times, especially in the southeastern part of the province.

Andrena (Trachandrena) votula Mitchell ♀

Distribution by counties and districts: Hastings.

Flower records: *Salix.*

Flight period based on our collections: May.

A single female was identified under this name. Little is known about this species as yet; its male is undescribed.

Andrena (Trachandrena) sp. ♀

Distribution by counties and districts: Elgin, Essex, Kent.

Flower records: *Salix.*

Flight period based on our collections: May and June.

This apparently undescribed species is restricted to the southern counties and strongly resembles *A. hippotes.*

Andrena (Mimandrena) imitatrix imitatrix Cresson ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Elgin, Frontenac, Haliburton, Hastings, Huron, Kent, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Parry Sound, Peel, Simcoe, Sudbury, Victoria, Wellington, York.

Flower records: *Amelanchier, Antennaria, Barbarea, Brassica, Claytonia, Crataegus, Cornus, Malus, Prunus, Rubus, Salix, Sambucus, Scilla, Taraxacum, Viburnum, Waldsteinia.*

Flight period based on our collections: April to July.

Medium sized bee well represented in most parts of the province but especially abundant in the eastern counties. Rau (1922) reported on the biology of this species. Clements and Long (1923) investigated aspects of its ecology.

Andrena (Schizandrena) crataegi Robertson ♀ ♂

Distribution by counties and districts: Algoma, Bruce, Carleton, Dufferin, Durham, Elgin, Essex, Frontenac, Grenville, Haliburton, Hastings,

Huron, Kent, Lambton, Lanark, Leeds, Lennox and Addington, Middlesex, Muskoka, Nipissing, Parry Sound, Peel, Simcoe, Sudbury, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Cornus, Crataegus, Euphorbia, Fragaria, Ledum, Malus, Melilotus, Potentilla, Prunus, Raphanus, Rhus, Rosa, Rubus, Salix, Senecio, Taraxacum, Vaccinium, Viburnum.*

Flight period based on our collections: May to July.

Large bee with strongly infumate wings. Both sexes are numerous on the flowers of plants belonging to the family Rosaceae during June and July. Rau (1922) published notes on the biology of this species. Clements and Long (1923) dealt with aspects of its ecology.

Andrena (Leucandrena) erythronii Robertson ♀ ♂

Distribution by counties and districts: Algoma, Cochrane, Frontenac, Haliburton, Leeds, Lennox and Addington, Muskoka, Nipissing, Parry Sound, Peel, Sudbury, Timiskaming, York.

Flower records: *Amelanchier, Barbarea, Fragaria, Prunus, Salix, Taraxacum.*

Flight period based on our collections: May.

Large bee appearing early in spring. Gregarious nesting sites were found in a variety of exposed soils especially in dirt roads, foot paths and playing fields. Michener and Rettenmeyer (1956) published a detailed study on this species.

Andrena (Leucandrena) placida Smith ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Cochrane, Dufferin, Durham, Elgin, Essex, Frontenac, Haliburton, Hastings, Lambton, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Peel, Simcoe, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Chamaedaphne, Cornus, Crataegus, Euphorbia, Fragaria, Malus, Prunus, Salix, Scilla, Taraxacum.*

Flight period based on our collections: April to June.

Medium sized bee commonly found in numbers over most of its extensive range. Clements and Long (1923) published some notes on the ecology of this species.

Andrena (Leucandrena) recta Mitchell ♀

Distribution by counties and districts: York.

Flower records: *Tragopogon.*

Flight period based on our collections: July.

A single specimen taken on goat's beard represents this species in our collections. The male is undescribed.

Andrena (Thysandrena) algida Smith ♀ ♂

Distribution by counties and districts: Algoma, Cochrane, Durham, Frontenanc, Haliburton, Hastings, Lanark, Muskoka, Nipissing, Ontario, Parry Sound, Timiskaming, York.

Flower records: *Barbarea, Chamaedaphne, Fragaria, Prunus, Salix, Taraxacum.*

Flight period based on our collections: April to June.

Medium sized bee more common in the northern parts of the province, although never collected in large numbers.

Andrena (Thysandrena) bisalicis Viereck ♂

Distribution by counties and districts: Frontenac, Haliburton, Muskoka, Nipissing.

Flower records: *Amelanchier, Salix.*

Flight period based on our collections: May.

Only a few specimens were found in the various collections. The males are rather characteristic with white and black pubescence on the face.

Andrena (Thysandrena) geranii Robertson ♀ ♂

Distribution by counties and districts: Essex, Wellington, York.

Flower records: *Geranium.*

Flight period based on our collections: June.

Medium sized bee with bluish integument. Apparently confined to the southern counties, very rare.

Andrena (Thysandrena) lata Viereck ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Cochrane, Dufferin, Durham, Frontenac, Grenville, Haliburton, Hastings, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Northumberland, Parry Sound, Peel, Simcoe, Sudbury, Timiskaming, Victoria, Wellington, York.

Flower records: *Amelanchier, Barbarea, Chamaedaphne, Cornus, Crataegus, Euphorbia, Fragaria, Malus, Melilotus, Prunus, Ranunculus, Rhus, Rubus, Salix, Taraxacum, Trifolium, Vaccinium.*

Flight period based on our collections: April to July.

Medium sized bee abundant in most parts of the province and having a rather extended flight period.

Andrena (Thysandrena) novaeangliae Viereck ♀

Distribution by counties and districts: Algoma, Haliburton, Muskoka, Timiskaming.

Flower records: *Acer, Cornus, Fragaria, Prunus, Rubus.*

Flight period based on our collections: June and July.

This medium sized bee is apparently confined to the more northern regions of the province, but its occurrence is extremely spotty. The male of the species is not known as yet.

Andrena (Thysandrena) sp. 1 ♂

Distribution by counties and districts: Durham.

Flower records: *Nasturtium.*

Flight period based on our collections: June.

No specific identification for this specimen was possible but Dr. W. E. LaBerge thinks it is closely related to *A. geranii.*

Andrena (Thysandrena) sp. 2 ♀

Distribution by counties and districts: Carleton.

No host record is given for these females taken in April (C.N.C.). The specimens have Viereck labels attached designating them as homotypes of *distans* from which however, they differ considerably by the lack of a plumose scopa.

The last two species of this subgenus have been included to make the records as complete as possible and it is hoped that, as more material becomes available, names will be found for these specimens.

Andrena (Conandrena) bradleyi Viereck ♀ ♂

Distribution by counties and districts: Carleton, Cochrane, Haliburton, Lanark, Leeds, Lennox and Addington, Muskoka, Nipissing, Timiskaming.

Flower records: *Chamaedaphne, Crataegus, Ledum, Prunus, Vaccinium.*

Flight period based on our collections: May.

Medium sized bee with polished, elongate clypeus. This species is represented by relatively few specimens in the collections seen by the authors. A strong host preference for early blooming flowers of the family Ericaceae may partly explain this. Collecting in the bog habitat mentioned under *A. kalmiae* showed a wide range with large populations for this species. Both sexes appear at the same time in early spring and visit the flowers of *Chamaedaphne* which is frequently found around lakes in association with *Sphagnum* moss. The period of flight is rather short and usually ends with the disappearance of *Chamaedaphne* flowers. Several males were taken on *Ledum* and *Vaccinium* and one single female was collected on *Crataegus.*

Andrena (Conandrena) carolina Viereck ♀ ♂

Distribution by counties and districts: Algoma, Carleton, Haliburton, Leeds, Lennox and Addington, Sudbury, Thunder Bay, Timiskaming.

Flower records: *Chamaedaphne, Kalmia, Ledum, Prunus, Rubus, Salix, Vaccinium.*

Flight period based on our collections: May to July.

Medium sized bee common in certain habitats, especially frequent on flowers of the family Ericaceae. The head with the elongate clypeus shows great resemblance to that of *A. rufosignata.*

Andrena (Conandrena) rufosignata Cockerell ♀ ♂

Distribution by counties and districts: Algoma, Cochrane, Durham, Haliburton, Muskoka, Nipissing, Parry Sound, Peel, Sudbury, Timiskaming, Victoria.

Flower records: *Acer, Amelanchier, Cornus, Crataegus, Fragaria, Kalmia, Melilotus, Prunus, Rhus, Rosa, Rubus, Salix, Vaccinium.*

Flight period based on our collections: May and June.

Medium sized bee with elongate, punctate clypeus.

Andrena (Gonandrena) dreisbachi Mitchell ♀ ♂

Distribution by counties and districts: Durham, Lanark, Leeds, Peel, Sudbury, Victoria, York.

Flower records: *Cornus, Crataegus, Rubus, Salix.*

Flight period based on our collections: May and June.

Medium sized bee common in June, especially on the flowers of *Rubus.*

Andrena (Gonandrena) fragilis Smith ♀ ♂

Distribution by counties and districts: Bruce, Carleton, Hastings, Lanark, Middlesex, Northumberland, York.

Flower records: *Cornus, Rubus.*

Flight period based on our collections: May to July.

Medium sized bee especially numerous during June on the flowers of *Cornus,* where it usually occurs together with other species of the same subgenus which show a close resemblance to one another.

Andrena (Gonandrena) integra Smith ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Elgin, Frontenac, Haliburton, Lanark, Leeds, Victoria, Wellington, York.

Flower records: *Barbarea, Cornus, Crataegus, Erigeron, Melilotus, Rubus, Salix.*

Flight period based on our collections: May and June.

Medium sized bee especially common on the flowers of *Cornus*. The females are distinguished by their glossy, smooth integument and the lack of pubescence.

Andrena (Gonandrena) peckhami Cockerell ♀

Distribution by counties and districts: York.

Flight period based on specimens examined: June and July.

Medium sized bee, usually poorly represented in the collections seen by the authors. No host record was available.

Andrena (Gonandrena) persimulata Viereck ♀ ♂

Distribution by counties and districts: Bruce, Carleton, Dufferin, Durham, Elgin, Haliburton, Lanark, Leeds, Middlesex, Simcoe, Victoria, Wellington, York.

Flower records: *Antennaria, Cornus, Crataegus, Erigeron, Euphorbia, Prunus, Rhus, Rubus, Salix.*

Flight period based on our collections: June and July.

Medium sized bee commonly found on the flowers of *Cornus,* sometimes in large numbers. The female differs from all other species of *Andrena* by a conspicuous tubercular process originating from the mesopleura.

Andrena (Gonandrena) platyparia Robertson ♀

Distribution by counties and districts: Lanark, York.

Flower records: *Cornus, Crataegus.*

Flight period based on our collections: June.

Together with *A. fragilis, A. integra,* and *A. persimulata,* this species shares a host preference for the flowers of *Cornus*. The male has not been associated with the female as yet and a thorough study of all four species is needed to clarify their taxonomic status in view of their remarkable resemblance to each other.

Andrena (Gonandrena) robertsonii Dalla Torre ♀ ♂

Distribution by counties and districts: Bruce, Carleton, Dufferin, Durham, Essex, Hastings, Middlesex, Northumberland, Peel, Simcoe, Victoria, Wellington, York.

Flower records: *Cirsium, Melilotus, Potentilla, Rhus, Rubus.*

Flight period based on our collections: June and July.

Medium sized bee strongly resembling *A. dreisbachi* from which it differs by its smooth, shining basal abdominal tergum. Both males and females were found to be common on the flowers of *Rhus typhina* in late June and early July.

Andrena (Parandrena) andrenoides andrenoides (Cresson) ♀

Distribution by counties and districts: Elgin.

Flower records: *Salix.*

Flight period based on our collections: May.

Small bee unique among Ontario andrenids by the possession of two instead of three submarginal cells in its forewing. Confined to the southernmost counties, apparently very scarce even there.

Andrena (Parandrena) andrenoides clarigastra Viereck ♀ ♂

Distribution by counties and districts: Essex, Huron, Kent, Lambton.

Flower records: *Salix.*

Flight period based on our collections: May and June.

This form differs from the preceding one by the bright ferruginous abdomen in the female. This is the smallest of the three "red" species characteristically found in the more southern counties of the province.

Andrena (Simandrena) nasonii Robertson ♀ ♂

Distribution by counties and districts: Carleton, Dufferin, Durham, Elgin, Frontenac, Haliburton, Hastings, Huron, Kent, Lanark, Leeds, Muskoka, Parry Sound, Peel, Renfrew, Victoria, Wellington, York.

Flower records: *Amelanchier, Antennaria, Barbarea, Cornus, Crataegus, Fragaria, Malus, Prunus, Rubus, Salix, Scilla, Taraxacum, Waldsteinia.*

Flight period based on our collections: April to June.

Smallish bee, usually occurring in great numbers, especially in the southern and southeastern parts of the province.

Andrena (Simandrena) wheeleri Graenicher ♀ ♂

Distribution by counties and districts: Carleton, Durham, Haliburton, Lanark, Muskoka, Thunder Bay, Timiskaming, Victoria, York.

Flower records: *Crataegus, Fragaria, Prunus, Rubus, Salix, Taraxacum, Vaccinium.*

Flight period based on our collections: May and June.

Medium sized bee quite numerous in the northern parts of the province, especially on early willows.

Andrena (Opandrena) cressonii Robertson ♀ ♂

Distribution by counties and districts: Elgin, Essex, Haliburton, Hastings, Huron, Kent, Lanark, Leeds, Lennox and Addington, Muskoka, Northumberland, Parry Sound, Peel, Sudbury, Timiskaming, Victoria, York.

Flower records: *Amelanchier, Barbarea, Brassica, Crataegus, Fragaria, Ledum, Prunus, Rubus, Salix, Senecio, Taraxacum, Viburnum.*

Flight period based on our collections: May and June.

Medium sized bee with an extensive range and usually large populations.

Andrena (Taeniandrena) wilkella (Kirby) ♀ ♂

Distribution by counties and districts: Algoma, Bruce, Carleton, Dufferin, Dundas, Durham, Elgin, Essex, Frontenac, Grenville, Haliburton, Halton, Huron, Kent, Lambton, Lanark, Leeds, Lennox and Addington, Muskoka, Ontario, Parry Sound, Peel, Simcoe, Sudbury, Thunder Bay, Timiskaming, Victoria, Wellington, Wentworth, York.

Flower records: *Allium, Antennaria, Barbarea, Cornus, Crataegus, Erigeron, Euphorbia, Fragaria, Heiracium, Ledum, Malus, Medicago,*

Melilotus, Potentilla, Prunus, Ranunculus, Rhus, Rubus, Salix, Senecio, Solidago, Taraxacum, Tragopogan, Trifolium, Viburnum, Vicia, Viola.

Flight period based on our collections: May to August.

Fairly large bee, holarctic in distribution. Both sexes have conspicuous abdominal fasciae and appear late in May. During most of the summer, they are the predominant bee over most of the province. This species has a remarkably wide spectrum of flower hosts. Notes on some aspects of the species' biology were published by Brittain (1933) and Atwood (1933).

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Observations on the Biology of *Centistes excrucians* Haliday (Hymenoptera: Braconidae)

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Centistes excrucians Haliday (=*lituratus* Haliday) is a blacine braconid reported from the Ukraine (Grossheim 1928) and Canada (Loan, 1963). It is an internal parasite of adult *Sitona* weevils and is specific for *Sitona scissifrons* Say in Canada though known from other species in

Europe. The internal stages of *C. excurcians* were described and compared with those of *Microctonus sitonae* Mason and *Pygostolus falcatus* (Nees), which also parasitize *S. scissifrons*, in a previous paper (Loan, 1963). The present paper adds new information to Grossheim's (1928) brief account of the life cycle of *C. excrucians* in the Ukraine.

The behaviour of *C. excrucians* was observed in the laboratory, as the species was never seen in the field except as specimens swept from vetch, *Vicia cracca* L., in early June. Field development was followed from May to August, 1961, by dissection of about 100 weevils collected weekly from vetch on the Canadian National Railways right-of-way near Belleville, Ontario; other weevils were held in emergence cages in the insectary and laboratory to recover the mature larvae. Adults of *S. scissifrons* were exposed to field-collected *C. excrucians* for a known time, usually eight hours, held at 23°C., and subsequently dissected live at daily intervals to determine parasite development. These weevils were believed to be free of parasites as they were collected in early May when field parasitism was absent in samples of 100 weevils.

Identification

C. excrucians is a parthenogenetic, thelyotokous species like *P. falcatus*, which is also a blacine braconid. Males were not found in or reared from field collections and no progeny of reared material were males.

C. excrucians is black but the legs and anterior sides and undersurface of the abdomen are light orange. The abdomen is distinctly curved downward, terminating in a subexerted ovipositor. Braconid parasites reared from adults of *S. scissifrons* can be separated as follows:

Radial cell long, extending almost to apex of wing; first cubital and first discoidal cells separate.

Ovipositor subexerted ..... *Centistes excrucians* Haliday

Ovipositor exerted ..... *Pygostolus falcatus* (Nees)

Radial cell short, terminating far from apex of wing; first cubital and first discoidal cells confluent ..... *Microctonus sitonae* Mason.

Behaviour

The cocoon is dirty white and covered with particles of earth. It is opened by the partial removal of a cap which is not thrown back even though it is completely severed, and the emergence opening is irregularly broken by diagonal cuts. *Pygostolus falcatus* also removes the tip of the cocoon but the cap is longer and hangs from the cocoon by several strands of silk, and there are no diagonal cuts around the opening. The cocoon of *C. excrucians* is spun in soil like those of the euphorine parasites of *Sitona*, whereas *P. falcatus* spins up on foliage or other objects next to the host weevil. In the laboratory the adults emerged from soil during either day or night. They avoided open screening and other exposed areas and gathered in corners and along the inside edges of the cage. Newly-emerged parasites fed immediately on water and undiluted honey. They had no preoviposition period and began to attack and parasitize weevils immediately.

The parasite seizes the weevil by the thorax and abdomen and simultaneously thrusts its ovipositor between the head and prothorax or between the prothorax and mesothorax. Of 39 eggs recovered in dissection, 17 were in the mesothorax, 21 in the prothorax, and one in the head of the weevil. The female remains motionless on the weevil for a short time with her wings raised and held together. She rests slantwise on the prothorax and anterior part of the weevil's elytra, her forelegs well back, wings raised,

and head directed toward the weevil's side and rear. Some weevils, especially small males of *S. scissifrons,* were lifted and held during parasitism. An exudate appeared at the mouths of attacked weevils and some became cataleptic when attacked.

Despite the partial mixing of populations of *Sitona hispidula* (Fabr.) *S. cylindricollis* Fahr., and *S. scissifrons* in the Belleville area, *C. excrucians* parasitized only *S. scissifrons* in the field. In the laboratory all three species were parasitized and supported parasite development, though *S. scissifrons* was parasitized and superparasitized more than the other two. Grossheim, (1928) noted that *C. lituratus* was the most common parasite of adult weevils in the Ukraine but did not list the host species.

Life Cycle

The mean length and width (and standard deviation) of the egg at deposition are 247.5 ± 22.5 μ by 95.4 ± 4.9 μ (10 eggs measured). Structural changes during development are very similar to those Loan and Holdaway (1961) described and illustrated for *P. falcatus.* The egg increases in volume as nutrients are absorbed from the weevil's hemolymph. The largest egg recovered from *S. scissifrons* was 563 μ long and 405 μ wide. The embryo develops within a sac-like trophamnion which dissociates into independent cells at the end of the embryonic period. The maturity of the egg was indicated by slight movement of the embryo and fragmentation of the trophamnion into discrete cells and groups of cells. In some way, whether by movement of the mandibles or of the body, the larva I escapes from the chorion, which probably ruptures easily as it is greatly stretched by the swelling of the egg.

After hatching the larva moves to the abdomen of the weevil. Smith (1952) reported a similar movement of the larva I of *Microctonus vittatae* Mues. from the thorax of its host *Phyllotreta striolata* (Fab.). Whether this movement is a passive displacement by circulation of hemolymph or a positive orientation is unknown. In any parasitized weevil only one larva survives and develops past the larva I stage. Supernumaries only a few hours old were motionless except for slight twitching of the mandibles or abdomen, whereas the successful larva, though no larger than the others, appeared active and healthy. The larval instars are found in any area of the hemocoel, though the mature larva (larva V within the unsclerotized cuticle of larva IV) is situated so that its head presses against the apical segments of the weevil. The larvae are chiefly hemophagous but also ingest fat bodies and the fatty contents of the greatly expanded cells of the trophamnion. Ovaries of weevils parasitized by larvae I were shrunken with ripe eggs that were misshapen, discoloured, and retained in the oviducts. The cause of this may be physiological; Loan and Holdaway (1961) showed that the egg of *P. falcatus* inhibited oviposition of gravid *S. cylindricollis* within 24 hours of deposition.

A summary of data on the developmental time of the egg and larva of *C. excrucians* is given in Table I. Hatching began on the fourth day after egg deposition and was completed by the sixth day. Larvae I were dissected from weevils each day starting on the fourth. This stage persisted because of diapause of some normal larvae and the effects of superparatism on others. The developmental time of each instar could not be determined accurately as too few advanced larvae were found. Time variation was considerable: mature larvae emerged from their hosts between 13 and 17 days after egg deposition, partly because of the inconsistent development of the larva I. If most of the eggs hatched on the fourth day, as the data

TABLE 1. Development in days (plus 0-8 hours) of *Centistes excrucians* in *Sitona scissifrons at* 23° C.

Date of dissection	Number of weevils Dissected	Parasitized	Age of parasite in days	Number of Immature Parasites								
				Eggs			Larva I		Larva II-V			
				Developing	Hatching	Dead	Live	Dead	II	III	IV	V (Emerged)
June 21	14	6	1	8	0	0	0	0	0	0	0	0
22	6	3	2	5	0	0	0	0	0	0	0	0
23	10	2	3	7	0	0	0	0	0	0	0	0
24	12	12	4	12	5	3	17	6	0	0	0	0
25	8	7	5	2	2	1	17	8	0	0	0	0
26	5	5	6	0	0	0	9	4	1	0	0	0
27	12	12	7	0	0	1	39	6	1	0	0	0
28	25	6	8	0	0	0	6	2	0	2	0	0
29	3	1	9	0	0	0	1	0	0	1	0	0
30	22	7	10	0	0	0	7	4	0	0	1	0
July 1	13	8	11	0	0	0	6	1	0	1	0	0
2	10	3	12	0	0	0	2	5	0	0	1	0
3	10	6	13	0	0	0	4	4	0	0	0	1
4	9	7	14	0	0	0	7	10	0	0	1	3
5	10	5	15	0	0	0	5	12	0	0	0	5
6	12	7	16	0	0	0	9	9	0	0	0	11
7	10	5	17	0	0	0	7	16	0	0	0	2
Totals	191	102		34	7	5	136	87	2	4	3	22

indicate, the developmental time of the non-diapause larva I was 2-3 days as larva II were found 6-7 days after egg deposition. Similarly the developmental time of larva II was estimated at 2 days; larva III, 2-3 days; and larva IV, 3 days. The larva V stadium, of about 24-30 hours, is the period between the emergence of the larva from the weevil and the transformation to the prepupa in the cocoon.

The field development of *C. excrucians* is synchronized with the life cycle of *S. scissifrons* which has one generation in the year and overwinters in the adult stage. *S. scissifrons* feeds and breeds chiefly on vetch, a perennial legume that forms thick patches along railways and highways. The Canadian National Railways in the Belleville area attempt to control vetch and other vegetation on the right-of-way by burning in the spring and applying herbicides in midsummer. Despite these measures the weevil and its parasites persist from year to year. *C. excrucians* overwinters as immature larvae I in adult weevils. Its incidence before emergence in the spring of 1961 was less than one larva per 100 weevils. It develops and emerges from the weevil in late April or May, depending on seasonal temperatures. In the insectary in May, 1961, the adult emerged three to four weeks after cocoon formation. The new parasite adults emerge while *S. scissifrons* is feeding and mating on young vetch. They were first swept from vetch on May 29 and were found most abundantly between seven and ten days later. On June 6, in the mid-morning of a warm day, 38 *C. excrucians* were swept in about two hours. The number decreased by mid-June, which indicated a period of parasite activity of about three weeks.

The immature parasites of the summer generation were first found on June 12. Larvae but no eggs were found in the weekly dissections. Two larvae (LI) per 100 weevils were found on June 12; 7 (2 LI, 5 LII-IV) per 100 on June 19; and 3 (LIII-IV) per 100 on June 26. This incidence follows the curve of abundance of *M. sitonae*, though it is much less than the maximum of 33 parasites per 100 weevils noted for that species in 1961 by Loan (1963). Larvae of *C. excrucians* emerged in the insectary from June 16-27 from weevils collected May 31-June 15. Adults emerged from cocoons from June 26-July 9. The annual life cycle of *C. excrucians* is completed by parasitism of the summer-emerged weevils. This parasitism, however, was not detected in 1961 as the population of diapause larvae I was too low to detect in samples of 100 weevils, and no adult parasites were found in the field after the over-wintered population declined in June. Larvae presumably must diapause until the following spring, as no mature larvae emerged from new weevils collected in July, August, and September.

Acknowledgments

I would like to thank Dr. W. R. M. Mason, Entomology Research Institute, Canada Agriculture, Ottawa, for the identification of *Centistes excrucians*. I am grateful to Miss Dorothy J. Jackson, St. Andrews, Scotland, for providing me with some unpublished observations on parasites of *Sitona* weevils.

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Diapause in *Euxesta notata* (Wiedemann) (Diptera: Ortalidae)[1]

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The ease with which *Euxesta notata* can be reared makes it an ideal insect for toxicological studies (Harris *et al.*, 1962). If this insect had a diapause it would also be an excellent test animal for many basic physiological studies of this phenomenon. This insect has been found to be a secondary invader of onions (Merrill and Hutson, 1953), and is common in the tobacco belt of southwestern Ontario (Begg, 1962). No information is available on the overwintering condition of *E. notata.*

Methods and Materials

Adults of *E. notata* were allowed to oviposit in 20-ounce waxed cardboard containers filled with soil and a piece of bait (Harris and Svec, unpublished). The containers were placed in constant temperature BOD incubators wired with a 15-watt fluorescent light. The photoperiod was controlled with a 24-hour time clock.

Results and Discussion

If larvae are reared at 25° C. the length of time from the egg to 90% pupation is about 20 days regardless of the photoperiod. The pupal period at 25° C. is independent of the larval rearing temperature and photoperiod and is always 9-11 days. Thus there would seem to be no pupal diapause. However, when larvae were reared at 20° C. and 8, 10, 12, or 16 hours of light per day, 90% pupated within 30 days at 12 or 16 hours of light but only 5-10% pupated in the same time at 8 or 10 hours of light. Thus there appears to be an arrested state of development in the larval stage.

A large group of larvae that did not pupate were set up at 5° C. to determine if chilling had any effect on this diapause. Larvae were removed at weekly intervals and placed at different temperatures and photoperiods. The results of this experiment are shown in Table 1. Each value is the average of 4 replicates of 25 larvae each.

It appears from Table 1 that there is an effect of chilling on the average time to pupation, but, if the days' chilling are added to the average time to pupation of both 20° C. treatments, the total elapsed time from the beginning of chilling is higher in each case than that with 0 day's chilling. If chilling had a real effect the total elapsed time should have become shorter.

[1]Contribution No. 45, Entomology Laboratory, Canada Department of Agriculture, Chatham, Ontario.

TABLE 1. The average time to pupation after chilling as affected by chilling and holding condition.

Holding condition after chilling	Days of chilling					
	0	7	14	21	28	35
20° C. 8 hours	41	39	37	29	24	12
20° C. 16 hours	29	23	20	16	9	7
25° C. 16 hours	9	8	7	6	6	4

The differences among the holding conditions are highly significant. The average time to pupation of the 25° C. treatment as compared to the 20° C. treatment seems to be much shorter than the 5° C. difference could explain. In other preliminary experiments at 25° C. photoperiod seems to have little effect on diapause termination. It appears that a temperature of 25° C. negates any effect that photoperiod might have.

Thus, although *E. notata* has a larval diapause, it never reaches the point where it cannot be terminated by the correct environmental conditions of temperature and or photoperiod. This agrees to a certain extent with data on the European corn borer (*Ostrinia nubilalis*) (McLeod and Beck, 1963). It too will resume development in the correct photoperiodic regime.

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A Synopsis of *Merycomyia* (Diptera:Tabanidae)

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The genus *Merycomyia* was established by Hine (1912, p. 515). He included two species, *geminata* and *mixta*, both described as new in the above paper with *geminata* designated as type species.

Hine related *Merycomyia* to *Tabanus*, "but distinct on account of the presence of well developed ocelli in both sexes and the anomalous antennae which show only three annulations in the third segment instead of five, although this last character shows some tendency to vary". Subsequent workers for some years followed Hine in placing *Merycomyia* near *Tabanus* in the subfamily Tabaninae. Stone (1938, p. 6) pointed out that the presence of small but distinct spurs at the apex of the hind tibiae along with

the presence of ocelli and the structure of the female frons and palpus indicated that *Merycomyia* belonged in the subfamily Pangoniinae. Stone also mentioned that *M. geminata* Hine was a synonym of *Tabanus whitneyi* Johnson (1904, p. 15).

Philip (1941, p. 4) placed *Merycomyia* in the Pangoniinae and erected a separate tribe Merycomyini for the genus. Stone (1953) described two new species under *Merycomyia, brunnea* from New Smyrna Beach, Florida and *haitiensis* presumably from Haiti. Stone recognized four species in the genus, *whitneyi* (Johnson) (= *geminata* Hine), *mixta* Hine, *brunnea* Stone and *haitiensis* Stone. In the same paper he described a new species and genus from Texas, *Asaphomyia texensis,* which he placed in the Merycomyini. Stone altered the spelling of the tribal name to Merycomyiini.

Mackerras (1954, p. 438) placed *Mercomyia* in the tribe Bouvieromyiini in the reconstituted subfamily Chrysopinae. Mackerras regarded the Bouvieromyiini as the most ancient element of the Chrysopinae and he included *Merycomyia* with the more generalized genera of the tribe. Mackerras later (1955a, p. 463) transferred *Asaphomyia* to the tribe Pangoniini in the subfamily Pangoniinae. In a subsequent paper (1955b, p. 595) he further characterized *Merycomyia.*

The rearrangement proposed by Mackerras is generally accepted by workers in the Tabanidae. This leaves *Merycomyia* as the only Nearctic representative of the Bouvieromyiini. The tribe is strongly developed only south of the equator in South America, Africa and Australia with rather close relationships among the genera of these areas. Two genera with a limited number of species are found in the Oriental region and two species of one of these reach the Palaearctic region. Two monotypic genera, as noted below, are found in the eastern Palaearctic region.

Philip and Mackerras (1961, p. 285) point out that Stone's *haitiensis* actually is from Haitien, a suburb of Peiping, China, and they erected a new genus *Thaumastomyia* for its reception. *Thaumastomyia* is probably the closest living representative of *Merycomyia* but may be separated by the hairy eyes. The inflated subcallus and parafacials mentioned by Philip and Mackerras as additional differentiating characters may be present to some degree in *Merycomyia* and the somewhat different shape of the antennae is of doubtful significance.

The monotypic genus *Nagatomyia* recently described by Murdoch and Takahasi from Japan (1961, p. 111) also belongs to the Bouvieromyiini. *Nagatomyia* has affinities both with the Ethiopian genus *Mesomyia* and with *Thaumastomyia* which, as noted above, shows a relationship with *Merycomyia.* This strengthens the supposition of Philip and Mackerras that the ancestors of *Merycomyia* may have entered North America from Eastern Asia rather than from South America.

Through the kindness of Dr. Howard E. Evans of the Museum of Comparative Zoology I have been able to study Johnson's type material of *Tabanus whitneyi.* Dr. Charles A. Triplehorn, The Ohio State University, also was kind enough to send me Hine's type material of *M. geminata* and *M. mixta.*

Johnson did not designate a type of *Tabanus whitneyi.* However, the male carries a red label "Type 14523" and the female a red label "Allotype 14523". This was noted by Philip (1959, p. 204) who designated the male as lectotype, although the specimen is not so labeled. The male specimen was originally deposited by Johnson in the Museum of Comparative Zoo-

logy; the female was deposited by Johnson in the collections of the Boston Society of Natural History and is now in the Museum of Camparative Zoology.

Comparison of the lectotype male of *whitneyi* with the type male of *geminata* indicates they are the same species. The lectotype of *whitneyi* is smaller (17 mm) and with paler integument and hairs than the type of *geminata* (21 mm). However, there is little doubt that the lighter color of *whitneyi* is due to the age of the specimen and the difference in size is not likely to be significant although most specimens studied are 20 mm. or more in length.

Comparison of the female which Hine associated with the type male of *geminata* with the "allotype" female which Johnson associated with his male *whitneyi* shows these are the same. Comparison of both of these specimens with the holotype of *mixta* shows they are all the same species. In the writer's opinion the lectotype male of *whitneyi* and the holotype female of *mixta* are two sexes of the same species. Also a comparison of all other females of *Merycomyia* available to the writer show they match the holotype of *mixta* with only slight variations. All carry the characteristic white abdominal patches associated with *whitneyi* and which are also present on the holotype of *mixta* but not described or illustrated by Hine. The holotype of *mixta* has patches of an opaque film sublaterally on the abdomen and the specimen shows evidence of cleaning with a liquid. It is likely the cleaning was done subsequently to Hine's description and the white patches may have been covered when he studied the specimen. In addition to the large patches on the fourth and fifth tergites there are two very small patches on the sixth tergite. The wing veins of Hine's female *geminata* are only slightly less outlined with brown than in his holotype of *mixta* but this is not mentioned in his description. His selection of the male as the type of *geminata,* which was contrary to Hine's usual practice, may indicate he had some reservations concerning the distinctness of the two females. The infuscation along the wing veins of Johnson's "allotype" female of *whitneyi* is only slightly less than in the holotype of *mixta.*

In the writer's opinion we are dealing with a single species in which the intensity of infuscation along the wing veins is a variable character in the females. Two females from North Carolina and three females from Florida show more extensive and heavier infuscation along the veins than does the holotype of *mixta;* in all other females studied, the infuscation is the same as in the holotype of *mixta* or somewhat less intense. In all the males studied such infuscation is barely indicated. However, it is unlikely that all males collected represent one species and all females a second species.

A female from Escambia County, Florida is darker brown than most other specimens studied. The specimen is somewhat teneral and the infuscated area along the veins is faint. However, it is apparent that if the dark areas had developed to full intensity, the hyaline portions of the wing would have been reduced to sub-hyaline areas in the center of the cells. The white patches on the abdomen are reduced in size and have a yellowish cast similar to the sublateral areas of the second and third tergites. The teneral and greased condition of the specimen is probably responsible for this aberrant pattern. A female from Southern Pines, North Carolina is similar to the Escambia County, Florida specimen in color. The dark infuscation of the wing is so extensive that only subhyaline areas remain in the cells. However, the white patches on the fourth and fifth tergites are normal in color and extent. A somewhat greased male from Maine ap-

parently lacked white abdominal patches but a few drops of ethyl acetate revealed they were present and of the usual size.

In the females of *whitneyi* seen by the writer, the height of the frons in relation to its width at base varied from 2.15 to 2.80 with a median of 2.66 and a mean of 2.61.

The writer saw the holotype of *Merycomyia brunnea* a few years ago and did not reexamine it during the present study. However, Dr. Alan Stone and Dr. Calvin M. Jones each kindly lent a male and female of this species. The small size (the holotype and one female and two males studied are 12 mm. long and one female 14 mm.), uniformly brown color and the wider frons (twice as high as wide in holotype and two other females studied) show it to be amply distinct from *whitneyi*. The genae are more swollen than in *whitneyi* but less so than in *Thaumastomyia haitiensis*. In the male, the areas of large and small eye facets are distinctly demarcated while in the male of *whitneyi* the facets are practically uniform in size.

All the specimens of *M. brunnea* studied were individuals reared by Dr. Calvin M. Jones and Dr. Jones also supplied information about additional reared and field collected specimens of *brunnea*. A publication in press (Jones and Anthony) will give details on the biology of this species. In addition to the type locality, New Smyrna Beach, Florida, *M. brunnea* has been taken at the following Florida localities: Umatilla (Lake Co.), Gainesville (Alachua Co.) and Steinhatchee Game Reserve (Lafayette Co.).

Merycomyia whitneyi and *M. brunnea* remain "mystery" insects. These two species are the only known Nearctic representatives of their tribe. *M. brunnea* is known from only a few specimens and *whitneyi*, in spite of its large size and conspicuous pattern, is rarely collected being known from 20 specimens. Of the material studied two *whitneyi* and four *brunnea* were reared from larvae. This is a high percentage of the known specimens and raises the suspicion that adults are more common than collection records indicate but have obscure habits. Dr. Frank R. Shaw informs me that the male *whitneyi* he collected was hovering about 8 to 10 feet from the ground above the treeless top of Sargent Mountain.

Since the writer has seen most of the known specimens of *M. whitneyi*, it seems appropriate to list these along with pertinent collection data, length of specimen and present location with a map showing the known range of the genus (Fig. 1). It should be noted that each locality for *whitneyi* indicated on the map, with one exception, represents the collection of a single specimen; two specimens are known from Lakehurst, New Jersey.

Males[2]

N.Y. (Osten Sacken). Lectotype of *whitneyi*. 17 mm. M.C.Z.

Sargent Mountain, Mt. Desert Island, Maine "hovering", 27 July 1955 (F. Shaw). 22.25 mm. C. B. Philip.

Lyme, Connecticut, 20 August 1910 (B. H. Walden). Type of *geminata*. 21 mm. Ohio State.

Lakehurst, New Jersey, 16 Sept. 1907. 20 mm. L. L. Pechuman.

Hamilton, Ontario, 4 August 1947 (W. Judd). 21 mm. C. B. Philip.

Ben Ranch, Johnson, Florida (C. M. Jones); pupated 27 April 1952; adult emerged 15 May 1952. 18 mm. U.S.N.M.

[2]Since this paper went to press two males of M. whitneyi were reared by H. J. Teskey from larvae collected at Gilmour, Hastings County, Ontario.

Females

Wellesley, Massachusettes (A. P. Morse). "Allotype" of *whitneyi*. 20 mm. M.C.Z.

Providence, Rhode Island. 21 mm. M.C.Z.

Clove Valley, Staten Is., New York (C. L. Pollard). 20 mm. C. B. Philip.

Wheatland, Indiana, 28 July 1909. 20.5 mm. Ohio State.

Dyke, Virginia, 16 July 1916 (W. L. McAtee). 19 mm. U.S.N.M.

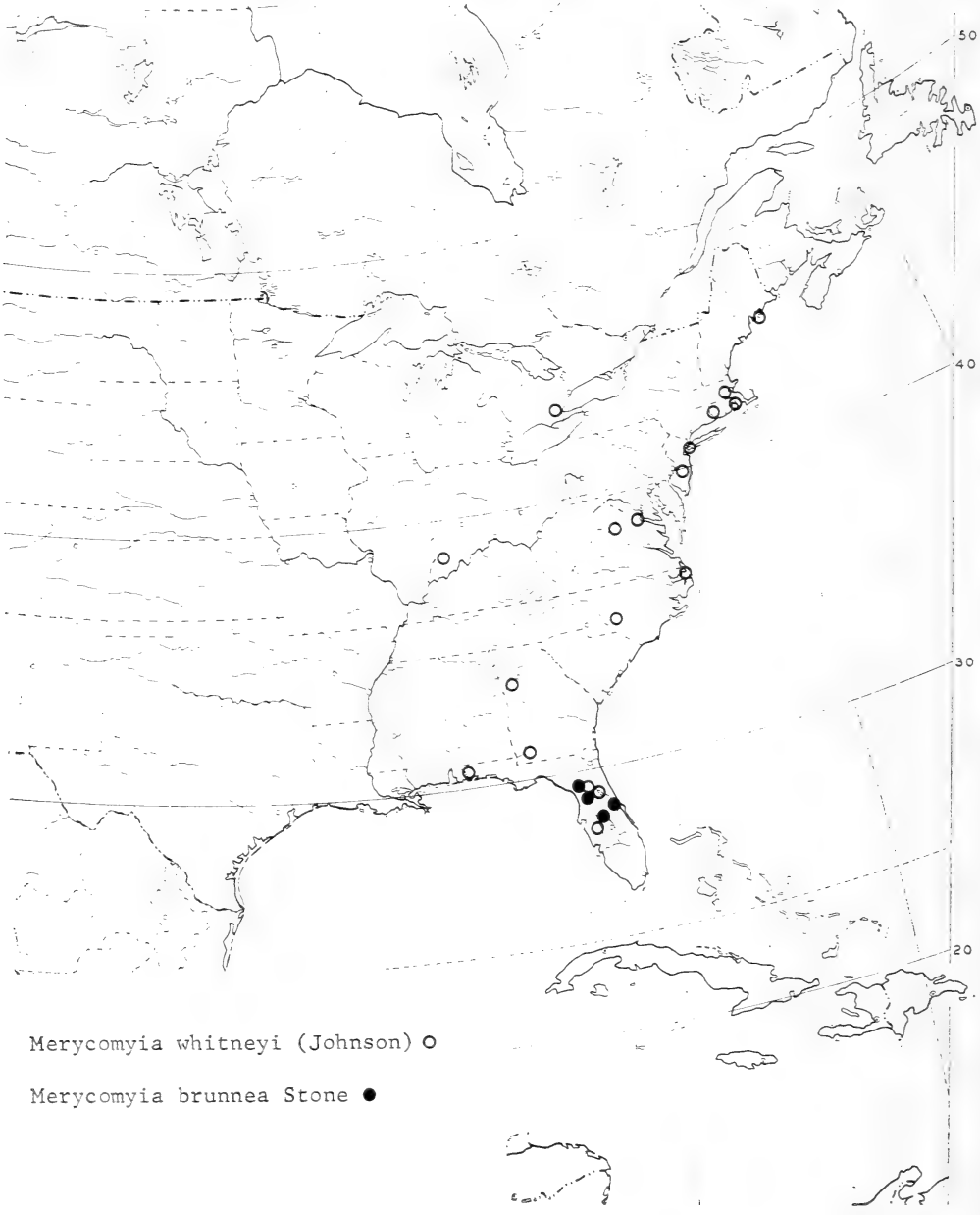

FIG. 1. The known range of the genus *Merycomyia*.

Mt. Vernon, Virginia, 6 June 1918 (E. Shoemaker). 20 mm. M.C.Z.

Southern Pines, North Carolina, 2 September 1961 (C. V. Covell). 21 mm. L. L. Pechuman.

Kill Devil Hills, North Carolina, 30 June 1954 (K. V. Krombein). 21 mm. L. L. Pechuman.

Bainbridge, Georgia, 2 June 1911 (J. C. Bradley). Holotype of *mixta*. 22 mm. Ohio State.

4-H Club Lake, Escambia Co., Florida (M. Tidwell); pupated 20 March 1963; adult emerged 1 April 1963. 18 mm. Auburn University.

Alachua Co., Florida, 30 May 1938 (H. Hixon); damaged specimen, length unknown. Calvin M. Jones.

Bushnell, Florida, 19 May 1943 (C. C. Deonier). 21 mm. Florida Dept. of Agriculture.

In addition to the specimens noted above there is a female in fragmentary condition in the collection of C. B. Philip, from Lakehurst, New Jersey, 23 July. Fattig (1946, p. 12) reports a specimen from Douglasville, Georgia, 15 July 1927. This specimen has probably been destroyed.

The cooperation of those who lent material is appreciated. Specimens were received from Dr. Howard E. Evans, Museum of Comparative Zoology, Dr. Kirby B. Hays, Auburn University, Dr. Calvin M. Jones, Entomology Research Division, U.S.D.A., Dr. Cornelius B. Philip, Rocky Mountain Laboratory, Dr. Alan Stone, U. S. National Museum, Dr. Charles A. Triplehorn, The Ohio State University and Dr. Howard V. Weems, Jr., Florida State Department of Agriculture.

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Induction of Diapause in the Tomato Hornworm, *Protoparce quinquemaculata* (Haw.)[1]

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Introduction

Research on the tomato hornworm, *Protoparce quinquemaculata* (Haw.), has often been hampered by inability to maintain a laboratory culture of this species. A chief obstacle to rearing has been the existence of a seemingly irregular diapause in the pupal stage.

In southwestern Ontario the tomato hornworm produces one or two generations per year. Stirrett and Wood (1940) noted that in 1938 and 1939 only one generation per year occurred. McClanahan (1955) stated that there is a second generation in some areas, the adults emerging about the middle of August after a pupation period of 17 to 22 days. Begg (unpublished) found that in 1959 unseasonable numbers of second generation hornworm larvae were feeding on sucker growth of harvested burley tobacco. It appears from these reports that the occurrence of a second generation of the tomato hornworm is determined by climatic conditions occurring during the first generation. The experiments reported here were conducted to determine if temperature or photoperiod influenced the induction of diapause in this species.

Methods

Larvae were reared individually in waxed cardboard containers, two-thirds filled with sandy loam containing 10 to 12 per cent water. Identical containers inverted, and with the rims removed, were used as covers. The larvae were fed fresh tobacco suckers daily until they burrowed into the soil to pupate. Subsequently, the soil could be easily removed and the pupae recovered in their well-formed pupal cells. Shortly before the adults emerged a five-inch wooden stake was placed in each container as a "holdfast" for newly emerged moths. Preliminary experiments showed that adults emerged from non-diapausing pupae after 21 days at 27° C. A pupa was, therefore, considered to be in diapause if the adult had not emerged after 30 days at 27° C., and if abdominal movements, indicating that it was alive, could be elicited at this time.

Results and Discussion

In one experiment 310 fifth-instar larvae were collected in tobacco fields in the vicinity of Chatham, Ontario. Of these larvae 180 were placed at 30° C. and 130 at 22° C., both groups under a 12 hour photophase. After eight to nine days both groups of pupae were transferred to 15.5° C. After 44 days 110 moths had emerged from the group originally exposed to 30° C., while none had emerged from the group exposed to 22° C. Subsequent exposure to a temperature of 4 to 5° C. killed the remainder of the 30° C. group. The pupae from 22° C. were in diapause.

In a second experiment 25 hornworms were reared at 33° C. until they burrowed into the soil. Within one to three days after entering the soil they were placed, in groups of five, at five different temperatures under a 16 hour photophase. Table 1 shows that all pupae at 18° C. entered diapause, while moths emerged from all pupae at 27° C. and 33° C. At

[1]Contribution No. 36, Entomology Laboratory, Canada Department of Agriculture, Chatham, Ontario.

the intermediate temperatures diapause was induced, on the average, in 60 per cent of the hornworms.

TABLE 1. Influence of temperature on diapause induction in the tomato hornworm, *Protoparce quinquemaculata* (Haw.)

Temperature ° C.	Number of hornworms	Per cent emerged
33	5	100
27	5	100
22	5	40
20	5	80
18	5	0

A further test was done to determine, more exactly, the stage of development in which diapause may be induced. Larvae reared at 27° C. were placed at 17° C., (1) one or two days after entering the soil at which time they were still prepupae, and (2) five to seven days after entering the soil (pupae). None of the six animals transferred as prepupae emerged but all five of those transferred as pupae emerged. Apparently diapause may be induced prior to pupation. Other experiments have shown that diapause inducing conditions must continue for at least seven days; if pupae are returned to 27° C. before this time, development to the adult ensues.

The above data indicate that temperature rather than photoperiod is the major factor influencing diapause induction in the tomato hornworm. A photoperiodic effect in the field should be manifested through the decreasing daylength in August when first generation hornworms mature and enter the soil to pupate. The daylength at this latitude decreases 80 minutes between August 1 and August 31. To determine if decreasing daylength during larval development was a factor in diapause induction, fifth-instar hornworms were collected at weekly intervals throughout August and maintained at either 33° C. or 20° C. with a 16 hour photophase. Table 2 shows that, regardless of when the larvae were collected, diapause occurred only at the colder temperature. Within the range of natural photoperiod experienced in August at this latitude, light apparently has no influence on diapause induction.

TABLE 2. Incidence of diapause in *Protoparce quinquemaculata* (Haw.) collected from the field during August and maintained at two different temperatures.

Date larvae collected	Temperature ° C.	Number of hornworms	Per cent emerged
August 7	33	2	100
7	20	2	0
14	33	2	100
14	20	2	0
21	33	2	100
21	20	2	0
28	33	2	100
28	20	2	0

Although many details require further investigation, it appears that diapause is induced in *P. quinquemaculata* by exposure during prepupal and pupal stages to temperatures of 22° C. or lower. Photoperiod evidently has no effect on diapause induction. These facts may explain the irregular occurrence of second generation hornworms in this area.

Acknowledgments

I am grateful to Doctors C. A. Barlow, C. R. Harris, and D. G. R. McLeod for their advice during this investigation and for assistance in preparing the manuscript.

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III. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDREDTH MEETING OF THE ENTOMOLOGICAL SOCIETY OF ONTARIO

The Society held its 100th Annual Meeting at Carleton University, Ottawa, September 3 to 6, 1963, as a joint meeting with the Entomological Society of Canada to celebrate the Centennial of Entomology in Canada.

As a full account of this outstanding gathering has been published in the special Centennial edition of the Canadian Entomologist (Jan-Feb, 1964), the following pages are chiefly confined to matters directly concerning the business of the Ontario Society. Brief mention should be made however of some of the highlights of the meeting.

Nearly all papers read at the meeting were by invitation. The high quality of these papers, from the opening address of Prof. G. J. Spencer to the closing comments on entomology in the university curriculum by Dr. W. E. Beckel, is a tribute to the first-class ability of the speakers and to the efforts of the program committee under the chairmanship of Prof. J. G. Rempel.

The new honour of Fellow of the Society was conferred for the first time on Prof. A. W. Baker, Dr. C. R. Twinn, and Prof. E. M. Walker. Suitably engraved certificates were presented to these three distinguished entomologists by the President, Prof. W. E. Heming, at a banquet held at the Chateau Laurier on September 4.

ANNUAL BUSINESS MEETING

The annual business meeting of the Society was held in Southam Hall, Carleton University, Ottawa, at 4:30 p.m., September 4, 1963. The President, W. E. Heming, was in the chair.

Minutes of the last Meeting

The minutes of the last business meeting (Belleville, November 16, 1962) having been printed in Vol. 93 of the "Proceedings" were adopted on motion from the floor.

President's Report

The President, W. E. Heming, briefly reviewed the events of the year. He commended the efforts of the Joint Centennial Committee and its subcommittes for the excellent and thorough work done in preparation for the present meeting. The posting of D. G. Peterson to Ghana for a year had necessitated finding a new Editor for the "Proceedings" on very short notice, and the Society was fortunate in having persuaded Dr. W. C. Allan to take over the position. The President concluded with a review of the committee reports and an outline of the agenda of the annual meeting.

Grant to Zoological Society of London

It was moved by H. R. Boyce, seconded by H. E. Welch, that a grant of $100.00 be made to the Zoological Society of London to help in publishing the "Zoological Record". Carried.

Secretary-Treasurer's Report

The Secretary-Treasurer presented an interim financial statement for the year up to August 26, 1963 (Appendix I). The annual balance sheet for 1962 was printed in Vol. 93 of the "Proceedings" and copies distributed to members.

Referring to the interim financial statement, the amount of $500.00 voted at the last annual meeting has been paid to the Centennial Committee as a contribution to the expenses of the present meeting. Dr. W. C. Allan is continuing to catalague the library and $157.50 out of the $200.00 voted last year has so far been paid for this work. It was decided at the last meeting of the board of Directors that the sum of approximately

$500.00 which at present is kept as a reserve fund to meet expenses of annual meetings, etc., should be transferred to the general account, and this will be done on the annual balance sheet at the end of the year.

The Secretary-Treasurer read the results of the mail ballot for election of directors held during the summer. The following were declared elected directors of the Society for the year 1963-64:

T. A. Angus
W. F. Baldwin
H. R. Boyce
A. W. A. Brown
D. A. Chant
D. H. Pengelly
H. E. Welch

In the mail ballot for the election of Fellows, the following nominees received more than the two-thirds majority required and were declared elected:

A. W. Baker
C. R. Twinn
E. M. Walker

The reports of the library and publications committees, prepared by Dr. W. C. Allan, were tabled by the Secretary-Treasurer (Appendix II).

Membership stands at 236, including three honorary members. In accordance with a Resolution passed at the last annual meeting, letters of good wishes had been written to a number of old members now retired.

On motion of D. A. Chant and H. J. Teskey the Secretary-Treasurer's report was accepted.

Resolutions

Two resolutions, expressing the thanks of the Society to Carleton University and to the Joint Centennial Committee, were moved by T. A. Angus and D. A. Chant, and unanimously approved by the members (Appendix III).

Location of 1964 Meeting

The President, W. E. Heming, stated that an invitation had been received from the Ontario Agricultural College to hold the Society's 1964 annual meeting at Guelph. On motion of H. A. U. Monro and T. A. Angus, it was unanimously decided to accept this invitation, the date of the meeting to be decided later.

Auditors for 1964

On motion of E. C. Becker and D. A. Chant, C. J. Payton and R. Saunders were appointed auditors for 1964.

There being no further business the meeting was declared ended at 5:10 p.m.

APPENDIX I—*Financial Reports*

Interim Financial Statement, to August 26, 1963

RECEIPTS		EXPENDITURES	
Membership dues received	$1,903.00	Dues sent to Ent. Soc. of Canada	$1,508.00
Sale of "Proceedings"	23.60	Library — cataloguing	157.50
Sale of reprints	528.00	Postage & Express	125.54
Grant from Ontario Minister of Agriculture	300.00	Printing of reprints	430.25
Balance of 1962 Annual Meeting expenses received	32.69	Printing and Stationery	103.04
Bank exchange on cheques	8.89	Grant to Zoological Society of London	100.00
Bank interest	16.29	Auditors' fee	5.00
Bank balance, Jan. 1, 1962	1,112.40	Contribution to Centennial of Entomology expenses	500.00
		Miscellaneous	4.12
		Bank balance, Aug. 26, 1963	957.35
		Cash on hand	34.07
	$3,924.87		$3,924.87
Victory Bonds	400.00	Victory Bonds	400.00

Guelph, August 26, 1963.

C. C. Steward, *Secretary-Treasurer*

Annual Financial Statement, 1963

RECEIPTS		EXPENDITURES	
Membership dues received	$2,081.00	Dues sent to Ent. Soc. Canada	$1,644.00
Exchange on cheques	9.24	Exchange on cheques	3.60
Sale of reprints	859.00	Library, binding & cataloguing	199.75
Sale of "Proceedings"	27.60	Postage & Express	177.26
Grant from Ontario Minister of Agriculture	300.00	Printing & Stationery	208.66
Bank Interest	33.18	Printing of reprints	685.75
Credit balance of 1962 Annual Meeting, sent from Belleville	32.69	Dues refunded	6.00
Interest on Bonds, 1962 & 1963	36.00	Auditors	5.00
Transfer from Special Account	528.52	Contribution to "Centennial of Entomology" Expense Fund	500.00
Bank balance, Jan. 1, 1963	1,112.40	President's Prize (Ottawa Centennial Meeting)	50.00
		Grant to Zoological Society of London	100.00
		Library Insurance	25.00
		Secretary-Treasurer, honorarium	50.00
		Secretary - Treasurer, Fidelity bond	8.00
		Bank balance, Dec. 31, 1963	1,356.61
	$5,019.63		$5,019.63
Can. Govt. Bonds	400.00	Can. Govt. Bonds	400.00

Auditors
C. J. Payton
R. Saunders

C. C. Steward,
Secretary-Treasurer
January 1, 1964

APPENDIX II—*Committee Reports*

Library Committee

As requested by the Board of Directors an up-to-date list of all journals and periodicals being received by our library has been prepared and a copy will be sent to each member with Volume 93 of the "Proceedings".

The library has been completely sorted and many volumes have been placed in binders. Library Loan requests continue to mount and we have been able to fill most of those received.

Owing to lack of response this Committee was forced to cancel the exchange agreement between the Society and the Natural Historia Sociedad, Havana, Cuba.

W. C. Allan, *Chairman*

Publications Committee

This Committee received quite a jolt when its Chairman and Editor of the "Proceedings" was posted to Ghana in January. Fortunately much of the preliminary spade work had been done in preparation of Volume 93 of the journal before he left. As an emergency measure, W. C. Allan was appointed Associate Editor and was successful in getting all manuscripts in order and to the printer.

It had been hoped that the "Proceedings" would have been issued by this time but last minute hold-ups have held back the final runs. However, Volume 93 is rolling off the press at the moment and copies will be mailed next week.

W. C. Allan, *Associate Editor*

APPENDIX III—*Resolutions*

The following two resolutions were proposed by T. A. Angus, seconded by D. A. Chant and unanimously passed at the Centennial Business Meeting, September 4, 1963:

1. WHEREAS Carleton University by extending to our Society the facilities both of its excellent accommodations and its efficient services, has contributed in the most outstanding manner to the success of this Centennial Meeting,

NOW THEREFORE BE IT RESOLVED that the Society, through its Secretary-Treasurer, express to the President of Carleton University, and to Dean H. H. J.

Nesbitt, its appreciation of the many courtesies received and its sincere thanks for the services so generously placed at the disposal of our members.

2. WHEREAS the Centennial Executive Committee, by its excellent and thorough organization involving the time and exertions of so many workers, has presented the Society with a meeting outstanding in every respect and fully worthy of the occasion it celebrates,

NOW THEREFORE BE IT RESOLVED that the Society, through its Secretary-Treasurer, express to Dr. G. P. Holland, General Chairman of the Centennial Executive Committee, and through him to all members of the working committees organized under his direction, its appreciation of and sincere thanks for their collective effort.

FELLOWSHIPS

The Society, by an amendment to its Constitution in 1960, now confers the distinction of Fellow on entomologists who have made outstanding contributions to the advancement of science. The Centennial Meeting was the occasion of the first awards of such Fellowships, when, at the banquet on September 4, 1963, Professor W. E. Heming, the President, presented Fellowship certificates to three distinguished Canadian entomologists.

Albert Wesley Baker

For over forty years, Professor Baker was a stimulating and inspiring teacher at the Ontario Agricultural College, Guelph, and from 1911 to his retirement in 1955 was active in furthering entomology in Ontario and in Canada. During the critical years of the two world wars and the intervening depression, he, more than anyone else, kept the Ontario Society in existence, and maintained the publication of the "Canadian Entomologist" when many other scientific societies and journals were unable to survive. As Secretary-Treasurer of the Society for 15 years (1911-1926), as Director and as President (1927-1929), he provided energetic and capable leadership. Together with the late W. A. Ross, Professor Baker had a major share in the founding of the present Entomological Society of Canada in 1950. Now retired, he still maintains an active interest in entomology and in the fortunes of his old associates and students.

Cecil Raymond Twinn

Dr. C. R. Twinn retired in 1957 after 35 years of distinguished service with the Canada Department of Agriculture. His first appointment was as a junior entomologist, and he early achieved a reputation as an authority on biting flies and household insect pests. In 1947, he initiated the extensive study of the biting flies of northern Canada, and in 1948, was appointed Head of the newly-formed Household and Medical Entomology Unit which, in 1952, became the Veterinary and Medical Entomology Unit, with important laboratories across Canada. Dr. Twinn's achievements have been recognized by the award of the Coronation Medal (1953) and by his election as President of the American Mosquito Control Association. He has written over 100 entomological papers, is a Fellow of the Entomological Society of London, and was a member of the W.H.O. Expert Advisory Panel on Insecticides. Since his retirement, Dr. Twinn has spent his winters in Florida and his summers at his home at Aylmer, Quebec.

Edward Murton Walker

Professor Walker was born in 1877 at Windsor, Ontario. Following his training at the universities of Toronto and Berlin, he devoted his active years to teaching at the University of Toronto, becoming Head of the Department of Zoology, a position he held until his retirement thirteen years ago. He has gained wide recognition as an authority on the Odonata and the Orthoptera, and by his discovery of *Grylloblatta* and his detailed study of the anatomy of this remarkable insect. Dr. Walker joined the Society in 1899, and was its President from 1910 to 1920. He is a Fellow of the Royal Society of Canada, and received the Flavelle Medal of that Society in 1960. He was President of the American Entomological Society in 1939. Dr. Walker's activities represent the finest traditions of this Society and no one is more deserving of the honour of being one of the first Fellows of the Entomological Society of Ontario.

PRESIDENT'S PRIZE

Four papers were presented by students at the Centennial Meeting in the third annual competition for the President's Prize. These were:

"Some properties of the oral secretion of mosquitoes" *by* J. R. Allen, Queen's University, Kingston.

"DDT-dehydrochlorinase in *Aedes* and *Culex* mosquitoes" *by* T. Kimura, University of Western Ontario, London.

"The effects of oviposition by *Pimpla turionella* (L.) on adult emergence of its host, *Galleria mellonella* (L.)" *by* G. B. Loughton, Queen's University, Kingston.

"Deutero-DDT and antiresistant-DDT as countermeasures for DDT-resistance in *Aedes aegypti* (L.) *by* M. K. K. Pillai, University of Western Ontario, London.

In the opinion of the judges, F. P. Ide, Toronto, H. H. J. Nesbitt, Ottawa and B. V. Peterson, Ottawa, Mr. Allen's paper was the best. The fifty dollar prize, together with a Certificate of Award, were presented to Mr. Allen by Professor Nesbitt at the Banquet at the Chateau Laurier.

Mr. Allen was born at Thornton, Lancashire, and matriculated into Cambridge University in 1950. He read Natural Sciences and in 1954 was graduated with the degree of Bachelor of Arts. He remained at Cambridge to graduate with the degree of Bachelor of Veterinary Medicine in 1958, and become a Member of the Royal College of Veterinary Surgeons. Meanwhile, the University had admitted him to the degree of Master of Arts.

Mr. Allen undertook postgraduate studies in parasitology from 1958 to 1960 at the Ontario Veterinary College, Guelph, Ontario, under the supervision of Dr. A. A. Kingscote, and was admitted to the degree of Master of Veterinary Science. He then proceeded to Queen's University, Kingston, where in the Department of Biology and under the supervision of Dr. A. S. West, he undertook a study of mosquito bites and allergy. Mr. Allen was admitted to the degree of Doctor of Philosophy early in 1964. He has remained at Queen's University as a Research Associate in the Department of Biology.

MEMBERSHIP LIST

Members are requested to check their addresses on this list. The Secretary-Treasurer will be grateful for any errors and omissions brought to his attention.

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Dr. D. H. Pengelly, Dept. of Zoology, University of Guelph

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Homoptera: Chermidae

A Review

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Introduction

Since 1894, when the pear psylla, *Psylla pyricola* Foerster, first appeared in Halton County, Ontario, as a migrant from neighbouring New York State, pear growers have been concerned over the erratic, sporadic outbreaks of this pest. It is now present in all pear growing areas of the Province. Its erratic nature has been noted in North America (Dabney, 1895) since its first appearance about 1832 in the State of Connecticut, U.S.A. It came from Europe where it had been known as an occasional pest of pear orchards. By 1891 it had spread to many areas of New York State including pear growing areas near the Ontario border (Slingerland, 1892).

The pear psylla has not been studied as intensively in Ontario as have such pome fruit pests as the codling moth, *Carpocapsa pomonella* (L.), and the apple maggot, *Rhagoletis pomonella* (Walsh). Psylla investigations from 1917-1944 in this province by W. A. Ross and T. Armstrong (Ross, 1918, 1926; Ross and Armstrong, 1943) of the Entomology Laboratory, Canada Department of Agriculture, Vineland Station, were concerned mainly with life-history and chemical control. Since 1945 most of the newer insecticides have been tested for psylla control (Armstrong, 1926-1958; Simpson, 1963) at the Vineland Laboratory. Professors Lawson Caesar (Caesar, 1948), R. W. Thompson, and H .W. Goble (Goble, 1963) of the Ontario Agricultural College have been concerned with spray calendar recommendations for control of this orchard pest.

Briefly, chemical control in Ontario started around 1900 with the use of kerosene emulsion sprays as recommended in the eastern United States. Later, such materials as lime-sulphur, nicotine sulfate, lubricating oil emulsions, rotenone, benzene hexachloride, pyrethrum, hexaethyl tetraphosphate, parathion, and Guthion were tested in Ontario. Varying degrees of psylla control were obtained with these compounds. However, toxicity to operators, lack of precise timing in application, psylla resistance, and residue requirements affected their efficiency so that improved controls are still being sought.

Psylla infestations seem less erratic now than they were before the use of DDT and organophosphates. At present, damaging infestations can be expected most years unless sprays are applied.

Life History

Pear psylla overwinters in Ontario as an adult. It can be found crawling on the bark of pear trees on warm, sunny days during late winter and early spring. It can also be found in crevices in the ground or under leaves and debris near the base of pear trees during periods of extreme cold (Ross, 1926; Goble, 1963). From mid-March on, the overwintering females begin to lay eggs on bud spurs and twigs of pear. Pear is the only known host of the psylla. The eggs are extremely small (0.5 mm or less). They are white when laid and become yellowish-white 48-96 hours later. Eggs of the spring generation are laid in strings of up to 10 to 15 within twig recesses (Fig. 1). Most eggs of the early summer generation are laid on the underside of the leaf along the mid-vein near its base. These eggs are firmly attached to host tissue (Bollow, 1960). As the season progresses, eggs are laid on both upper and lower leaf surfaces. Depending on temperature, eggs can develop in as short a time as 6-7 days (temperatures above 70°F) or take as long as 35 days when temperatures are below 38-40°F. Development from egg to adult can vary from 3-7 weeks. There are two generations and a partial third per season in Ontario. The size of the partial third generation depends on temperatures in September and October.

Egg-laying rates vary from generation to generation. The overwintering generation lays from 180-350 eggs per female, the first summer generation from 250-500, while the second summer generation, depending on temperatures and tree condition, will lay from 200-400 eggs. Climate and temperature have an effect on egg-laying rates as psylla will not lay on trees showing incipient wilting or minor physiological damage caused by extreme heat (Wilde and Watson, 1963).

The nymphal stage consists of five instars, the first of which is no bigger than the egg. After the next three moults the nymph reaches the "hardshell" stage and becomes very mobile (Fig. 2); it is nearly 2 mm long, approximately as big as the adult. Honeydew is produced by the first four nymphal stages but little or no honeydew is produced by the "hardshell" stage. Rate of nymphal development is also affected by climate and temperature. Cool spring weather slows nymphal development while high temperatures during July and August cause withering of developing nymphs. Driving rains of as little as 0.3 inch per hour in the Paris-Woodstock and Georgian Bay areas eradicated nymphs by washing them off trees in 1964. When these rains occurred, nymphs perished in the cover crop as they were unable to feed on anything but a *Pyrus* host.

The adult, 1.5-3 mm long, carries its wings folded over its body (Fig. 3). There are pronounced colour differences between aestival (summer) and hibernal (winter) adults, the former being pale brownish-green in colour as compared to dark brown or grey of hibernal adults. This colour variation probably provides protection from predators as it enables the psylla to blend in well with its seasonal background.

Economics

Pears have not constituted the major portion of fruit growers' income in Ontario, but there has been a steady increase in acreage and yield since 1920. By 1940 pear production in Ontario reached 264,300 bushels, and by 1963 the yield was approximately one million bushels (Anon. 1960) with a value of nearly two million dollars. Years of psylla outbreaks could reduce these yields by as much as 20% in orchards where control measures were not thoroughly applied. Also, weakening of the trees by psylla would affect later crops.

All varieties of pear in Ontario are attacked by the psylla. Bartlett is one of the most severely attacked varieties while Flemish Beauty is only lightly attacked.

Damage caused by the psylla in Ontario is chiefly leaf necrosis and sooty mold on leaves and fruits (Fig 4). The sooty mold develops in the honeydew deposited by the nymphs on leaves, twigs and fruits. These moldy depositions, grey to black in colour, reduce the value of the mature fruits. The mold can be removed by washing and wiping the fruit, though this is seldom done by commercial growers in Ontario.

Heavy psylla populations reduce terminal growth and fruit bud set for the following season. Sometimes these heavy psylla populations cause premature leaf drop, the leaves becoming very scorched in appearance before dropping (Ross, 1926). Accompanying premature leaf drop is a decrease in tree vigor. This can affect the tree's ability to survive a moderate to severe winter.

Pear Decline Condition is a serious disease affecting pear orchards in California, Oregon (Hartman, 1961), and Washington (Lindner et al. 1961, 1962) where it is transmitted by the pear psylla. This disease or condition has not been shown to be present in Ontario. The pear psylla is a suspected vector of fire blight *(Irwinia amylovora)* but this has not been proven in Ontario.

Research in Ontario

W. A. Ross of the Canada Dept. of Agriculture, Vineland Station, was the first to conduct control experiments on the pear psylla in Ontario (Ross, 1926). In this work he was later joined by T. Armstrong (Ross and Armstrong, 1943). Results of these early investigations were that dormant oil sprays were recommended for the control of pear psylla in Ontario. They are still used by many Ontario pear growers. The limitations of dormant oils are that they can only be used in the dormant period, otherwise phytotoxicity occurs. In some years growers cannot apply dormant sprays in their orchards because of extreme conditions caused by spring breakup and rains. Also, in years favourable for psylla development, the dormant oil may not give control throughout the season.

The dormant oils most commonly used for psylla control in Ontario have a viscosity of 170-200 (Say.). When first recommended, the emulsions were prepared by the growers using Bordeaux mixture or calcium caseinate as the emulsifier (Ross, 1926); later, blood albumin was also used. The concentrated oil emulsion was diluted with water to a 3% strength for use. More recently, the self-emulsible oils have largely replaced the home-made oil emulsion and some growers are using oils of lower viscosity of the "superior" type.

At present azinphos-methyl (Guthion), parathion, and malathion are some of the insecticides used against the psylla in Ontario orchards. However, as psylla resistance has appeared in other areas of North America to all these compounds, it is assumed that resistance will develop in Ontario, so that new control chemicals will have to be found in the future. A systemic, dimethoate, offers good possibilities as an ovicide. It can be sprayed on the tree or applied by painting scaffold limbs; the latter method of application decreases mortality of orchard predators usually eliminated by conventional spraying. It is not yet used in Ontario orchards because of residue requirements in countries importing Ontario pears, particularly the U.S.A.

Minor investigations were made by Ross (1926) on the life-history of pear psylla in Ontario orchards, and on the horticultural aspects of pear control. In this phase of his investigations he reported "the psylla is primarily a pest of large orchards and is of comparatively little importance in small plantings, unless the latter are sheltered by tall hedges or tall trees". He noted that climate influenced psylla numbers and that they thrived best on trees with thick, dense foliage, and in orchards where pear trees were closely planted. Similar observations have been reported by workers in Israel (Swirski, 1953), Europe (Bonnemaison and Missonnier, 1956), and western North America (Wilde and Watson, 1963). New pear orchards planted in these areas now take into account a need for good air drainage, proper planting distances, avoidance of wind breaks, correct tree shape, and plantings located away from depressions or low spots.

Biological control of the pear psylla received little attention in Ontario until investigations were made in 1946 by T. Armstrong and in 1963 by the Ontario Agricultural College. In 1946, Armstrong (Ann. Rep. Entomol. Lab., Vineland Station for the year 1946) studied the life-history of a nymphal parasite, the encyrtid *Trechnites* (= *Psylle-dontus*) *insidiosus* (Crawford) and stated that it parasitized high percentages of the psylla nymphs in several orchards in the Niagara Peninsula. It has not been noticed recently and may not have survived DDT and organophosphates.

No parasites have been found during the current study by the Ontario Agricultural College but several efficient native predators have been found in abundance in some pear orchards. These include two species of green lacewings (*Chrysopa* spp.), three species of ladybird beetles (*Hippodamia* sp., *Cycloneda* sp., and *Ceratomegilla* sp.), one species of *Anthocoris,* and one species of *Orius,* all of which were observed preying on egg, nymph, or adult stages of pear psylla. Whereas anthocorids are the most efficient predators of pear psylla in British Columbia (Watson and Wilde, 1963), lacewings are the most abundant and efficient predators in Ontario pear orchards. One efficient anthocorid predator from British Columbia, *Anthocorus melanocerus* Reuter, has been imported and released in an orchard area near Paris, Ontario.

It is hoped that further investigations of natural control of the pear psylla will lead to improved measures by integrating chemical and biological controls to the best advantage.

In the Zoology Department of the University of Guelph, Dr. Musgrave has commenced an expansion of his mycetome studies to include work on the mycetome of *P. pyricola.* There is some evidence that the microorganisms in mycetomes of insects are of benefit to the host (Musgrave, 1964). The part played by these in the mycetomes of pear psylla is obscure. The following brief decription of the mycetome is based partly on unpublished observations of Drs. Musgrave and S. B. Singh and mostly on material derived by Musgrave from the literature (Buchner, 1953). The mycetome is bright orange in colour and is situated on the ventral side

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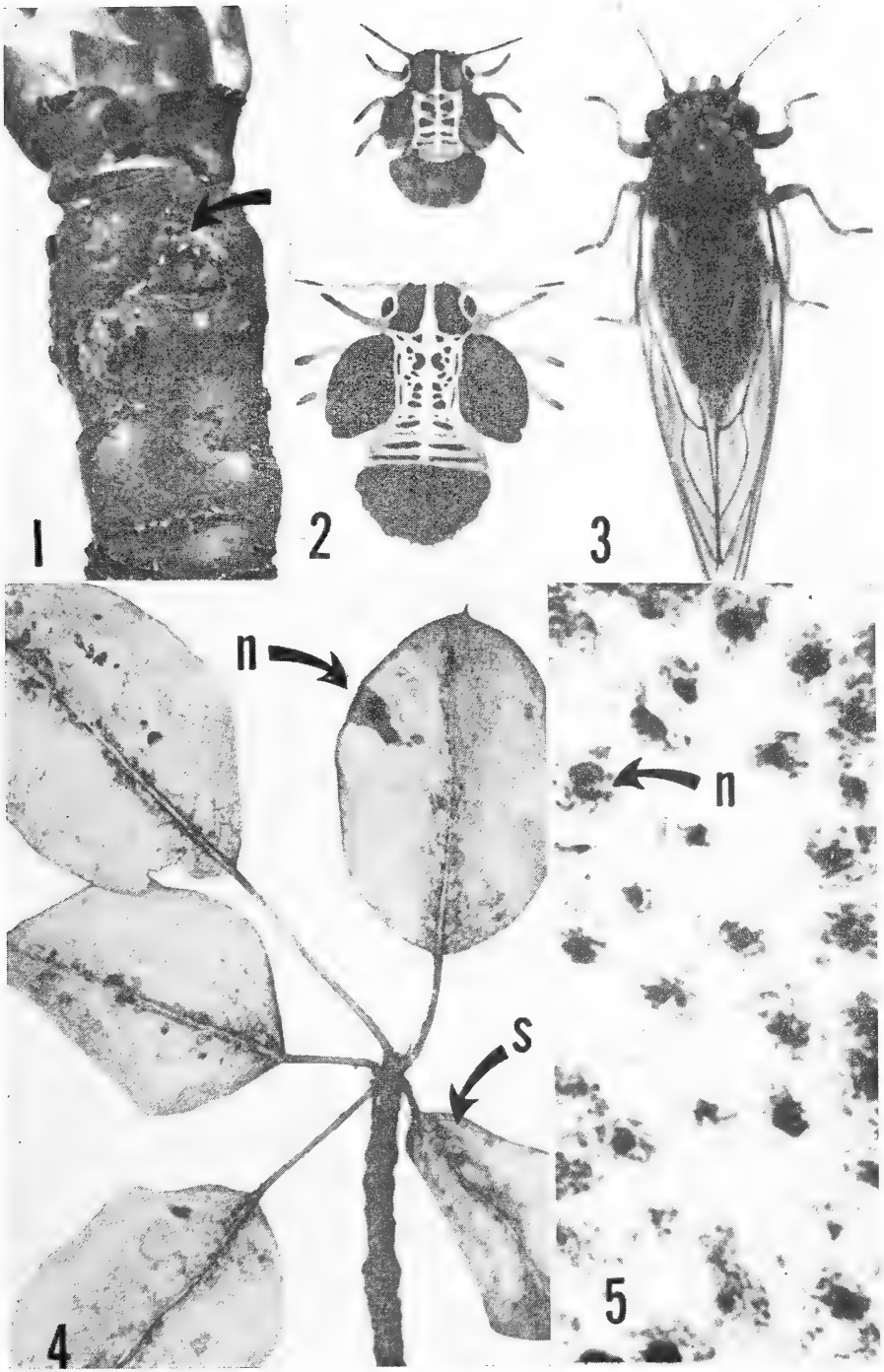
FIG. 1-3. Stages in the life cycle of the pear psylla (*Psylla pyricola* Foerster). 1. Eggs on Bartlett twigs. Mag. 6 x. 2. Nymphal instars: fourth instar above, "hardshell" instar below. Mag. 20 x. 3. Adult. Mag. 30 x.

FIG. 4. Sooty mold (s) and necrosis (n) caused by honeydew accumulation on pear leaves.

FIG. 5. Photomicrograph of a mycetome of *Psylla pyricola* Foerster showing a nucleus (n). Actual nucleus size, 20μ. Photo: S. B. Singh.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of the abdomen. It is well supplied with tracheae, comparable to the condition in *Sitophilus* (Musgrave, 1964).

There seem to be a number of different types of association, but in general the mycetome of Psyllidae is divisible into a cellular part and a syncitial part, each part having a different microorganism (Fig. 5). Microorganisms are inherited transovarially.

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THE ARMYWORM *PSEUDALETIA UNIPUNCTA* (HAWORTH) IN ONTARIO IN 1964

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Introduction

The Programme Committee of the Entomological Society of Ontario suggested that the 1964 armyworm outbreak be recorded in a manner similar to that of 1914 and 1938 (Baker 1914, 1938).

Those concerned with an extension programme of control to reduce crop damage were so occupied during July that systematic surveys of damage and scientific assessment of insecticide sprays and poison baits were not made. As a result, the remarks must be general.

Serious armyworm infestations are not confined to specific areas in Ontario and occur at irregular intervals (Fig. 1,2). Populations large enough to be called "outbreak" epidemics since the turn of the century occurred in 1914, 1938, 1954 and 1964, periods of 24, 16 and 10 years apart. There were some farms in Brant County with destructive populations in 1957 (McNay, 1957), but this was not a general Ontario infestation. The 1954 report (MacNay, 1954) stated, "In Ontario, the attack affected all areas where cereal crops are grown except the counties bordering on Lake Erie". Later in this paper it is reported that Essex and Kent counties on the north shore of Lake Erie were very heavily infested in 1964, the reverse situation from the 1954 outbreak.

Distribution in 1964

The following has been taken from questionnaires received from the Agricultural Representatives in Ontario and from information supplied by Drs. G. F. Manson and R. J. McClanahan, Entomology Laboratory, Chatham and by colleagues in the Department of Zoology, Ontario Agricultural College.

The three most heavily infested areas were Essex and Kent Counties, part of Lambton, the northern parts of Waterloo and Wellington Counties, and an area near Ottawa. Areas where infestations were light and with very little crop damage included the Niagara Peninsula and along Lake Erie to Elgin County, counties on the north shore of Lake Ontario west of Toronto, and many districts in Northern Ontario.

If the above records from 1914 to 1964 are examined, it will indicate that there has been no area in Ontario more susceptible to attack than another. Therefore any area producing cereal crops, hay, and pasture may be affected in the next outbreak.

Host Plants (Crops)

Oats and barley were the crops most commonly infested in 1964 with most of the crop loss being on oats (Fig. 3). The caterpillars cut the panicles on oats so that the grain dropped to the ground. In Essex and Kent, fall wheat was infested and the leaves were eaten but the grain was too ripe to be attractive to the armyworms. This resulted in considerable migration from wheat to other crops. Corn infestations were almost all initiated by migration from wheat, oats, and barley; thus almost all feeding on corn was at the edges of the fields. There were very few reports of infestations in hay and pasture, this being different than in previous outbreaks. Foxtail, barnyard grass, crabgrass, and twitch-grass were readily eaten.

Most other crops such as tomatoes, sugar beets, beans, turnips, peas, and potatoes were not attacked. Armyworms did not eat weeds such as

lamb's quarters, wild buckwheat, thistles, and pigweed. Unfortunately, some crops such as tomatoes and sugar beets that are not hosts of the armyworm, were sprayed because caterpillars were in the fields during migration from wheat and oats and, in a few cases, hail damage was thought to be armyworm feeding.

Control Cost and Crop Loss

One should consider the cost of treatment plus the crop damage to arrive at the total loss. An estimate of the number of acres treated[1] was (a) 38,180 acres by aeroplane and helicopter, (b) 36,560 acres by ground sprayers, and (c) 4,260 acres by poison bran bait. The cost of aerial spraying was in the range of four to six dollars per acre with most fields treated for about four dollars and fifty cents. Ground sprays, and poison bait were usually applied by the grower. If the estimated average cost of four and one half dollars for aerial treatment and three dollars for ground spraying and baiting is used, the total cost in 1964 was 294,270 dollars.

An estimate of crop loss is difficult to assess, as the injury varied so widely. The damage to oats was greater than to other crops partly because panicles were cut off. In the three areas of heavy infestation it is estimated that from 2-3% of the oats (grain itself) was destroyed. The losses in some oat fields were reported as being from 70-100%. The injury to barley and wheat was small. Since the caterpillars fed on grass weeds and the suckers on corn first, the loss on this crop was negligible. Only a few pasture fields were injured and no reports of damage to hay were received.

Natural Control

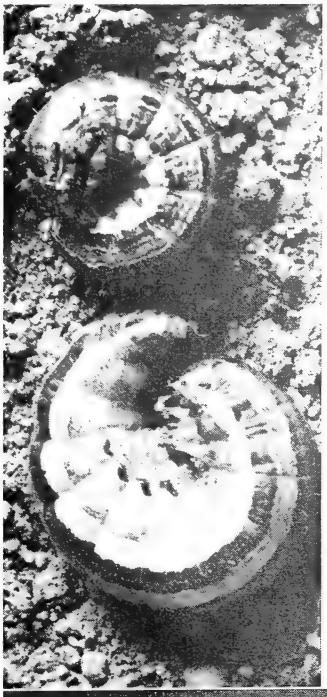
Parasites and other beneficial factors were present in considerable numbers from early in the outbreak. Unfortunately many caterpillars developed to the last larval instar and thus caused some damage before being destroyed by parasites, a virus, predators, and other biological factors. Parasitism in the 1914 outbreak was also quite high but it was not reported to be in 1938 and 1954.

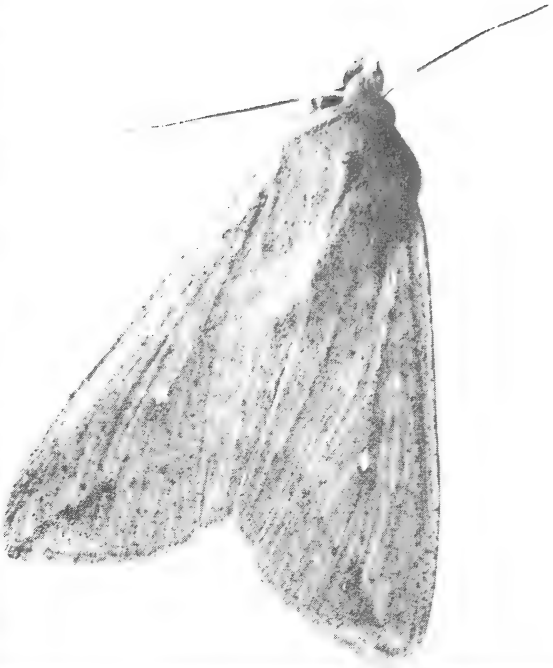
Dr. R. J. McClanahan, Entomology Laboratory, Chatham, collected 500 armyworms from a heavily infested oat field and found that 35% succumbed to a nuclear polyhedrosis virus *Borrelinavirus* sp. Also 20% were parasitized by two species of *Apanteles*, 3.3% by other Hymenoptera, and 1% by dipterous insects. In a heavily infested corn field at Guelph, nearly all large caterpillars were carrying eggs of the tachinid fly, *Winthemia* sp. on their backs. This was the most important parasite in the Guelph area. Birds consumed large numbers in Essex and Kent Counties. The biological control was of such magnitude that it is predicted there will not be a destructive infestation in 1965, especially in areas where the numbers were large in 1964.

Chemical Control

The Ontario Department of Agriculture in its Publication 296 recommended carbaryl (Sevin), malathion, and parathion to be used as sprays if populations of armyworms were large. Poison bran bait, with Sevin as the toxicant, was recommended also. Sevin was used most commonly because of its safety factor compared to parathion, and possibly because of its effectiveness and price compared to malathion. The recommended amount was 1 lb. of actual carbaryl (2 lb. of 50% Sevin wettable powder or its equivalent using 85% powder) per acre applied by air in 8-10 gal. of water and by ground equipment in from 25-30 gal. of water.

[1]Obtained from questionnaires sent to Agricultural Representatives of Ontario.





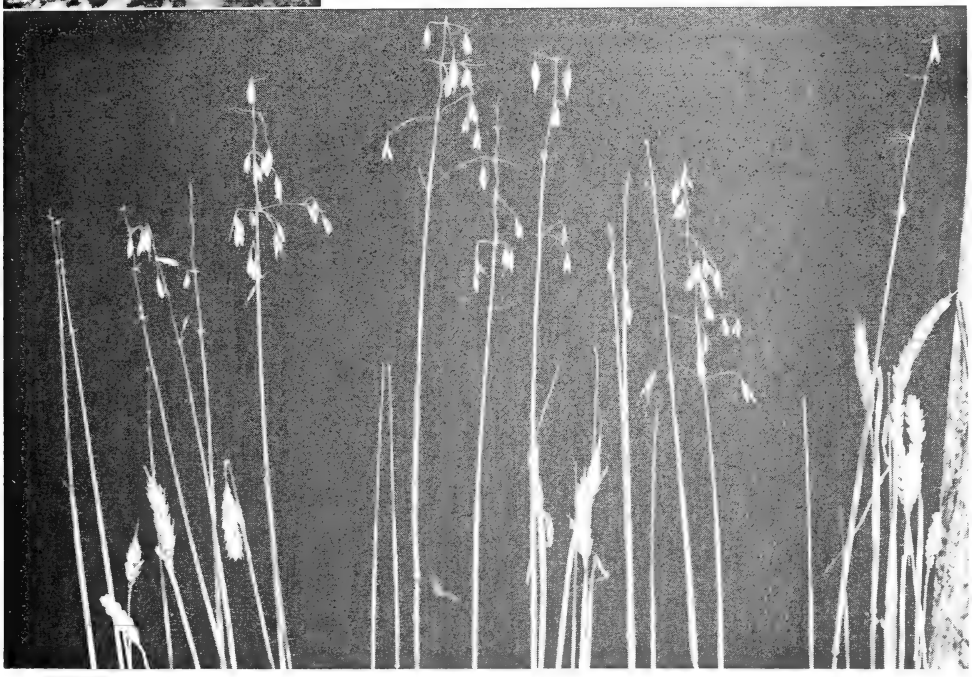


FIG. 1-3. The armyworm, *Pseudoletia unipuncta*. 1. Larvae. 2. Adult moth. 3. Armyworm injury to spring grain.

Endrin, some other cyclodiene insecticides, and DDT were applied in very limited areas and where livestock would not pasture or be fed the treated crop. Poison bran bait, using mostly Sevin, was applied as an insecticide on smaller fields and as a barrier between grain and corn fields. Parathion was applied only by a few growers who had orchard spraying equipment. Most of the aerial spraying was done by helicopter. Weed sprayers were used for ground application in most cases. Some Hi-Boy sprayers were used in corn.

Regardless of the method of application, Sevin was the most commonly used insecticide. It was generally reported to be effective. It was slow in action. Malathion was generally considered to be satisfactory although a few found it did not reduce armyworms as well. Poison bran bait, wherever used, was efficient. There was criticism concerning the application of endrin to a few fields because of the residual properties of this insecticide.

There have been some complaints from apiarists concerning bee poisoning by Sevin as a result of the armyworm sprays. This probably was a result of spray drift to clover and other crops where bees collect nectar. No bee yards were completely destroyed. The survey indicated that the ill effects on bees were very small, probably because bees do not gather nectar from oats, barley, and wheat.

Summary

1. In general, the control programme was effective. The availability of low toxicity insecticides, aeroplanes, and helicopters assisted greatly.

2. Some crops not attacked by the armyworms were treated, such as, tomatoes and sugar beets.

3. Corn fields with small populations or with armyworms only in the outside rows did not require treatment but some were sprayed nevertheless.

4. Particularly with oats, many growers did not examine their fields until the damage had been done. Treatments at that time served largely to protect adjacent susceptible crops.

5. Natural control was very evident by the end of July. It is not expected that there will be an outbreak in 1965 in areas where infestations were heavy this year.

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II. ENTOMOLOGICAL IMPRESSIONS

ENTOMOLOGY IN VENEZUELA

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The ravages of insect-borne diseases in the tropics are strikingly evident in central Venezuela, south of Maracay. Here one can find the remains of several large towns and cities, depopulated in the past by malaria, yellow fever and Chagas' disease. In recent years, phenomenal progress has been made in the supression of such diseases by controlling the insect vectors. The vector control groups of the Venezuelan Department of Health have now almost eliminated malaria and yellow fever with modern insecticides, but Chagas' disease is still present as a major public health problem.

My visits to Venezuela have been primarily concerned with *Rhodnius prolixus* Stål, the vector of Chagas' disease. Unfortunately, I have had little time to devote to other aspects of entomology in that country, but *Rhodnius* itself is enough of an enigma to demand one's full attention, especially since so little is known of its life history, dispersal, natural enemies and movements in its native habitat. The causal organism of Chagas's disease, *Trypanosoma cruzi* Chagas, is spread in the feces of the insect, which is discharged on the host's skin during a blood meal. The trypanosomes are readily transferred to the conjunctiva of the eyes or mucosa of the mouth or nose, and infection takes place. Reservoir animals for the disease include humans, armadillos, opossums, rats, mice, bats, dogs and squirrels. As no effective treatment of the disease has been discovered, measures to control its spread must be aimed at eliminating the insect vectors or the limitation of the reservoir animals.

Efforts to control *Rhodnius* by the use of insecticides have met with little success, since these insects spend most of their time deep in the cracks in the walls of native huts. Also, *Rhodnius* appears to be exceptionally resistant to DDT. In a cooperative study with Venezuelan entomologists, we have been exploring the possibility of applying the sterile male technique to the control of the insect, and one of the main questions to be answered in this connection is whether *Rhodnius* populations are static or whether the insect moves freely from hut to hut or from tree to tree. To answer this question, numbers of the adults tagged with Co^{60} have been followed after release. It appears that they do move, and a large experiment in an inhabited valley south of Valencia this winter will definitely settle the whole question. Experiments with laboratory populations have shown that males irradiated at doses which cause sterility soon lose their ability to mate, and at present we are concentrating on treatments (e.g. spot irradiation of testes) which will produce active males. Future releases of sterile males will be made in the valley mentioned above, from a field laboratory erected there recently.

Success in the control of *Rhodnius* will eliminate a great deal of suffering and early death in Venezuela, and the work now in progress at the Instituto Venozolano Investigaciones Cientificas near Caracas may lead to the eventual solution of the problem. Many of the other South American countries are interested in the progress at IVIC since Chagas' disease is prevalent throughout most of the continent.

(Accepted for publication: February 5, 1965)

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AN ENTOMOLOGIST'S IMPRESSIONS OF ICELAND[1]

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The traveller returning home from Iceland finds it difficult to avoid exaggeration in describing his experiences. Iceland is a land of sharp contrasts with its antagonistic marvels of frost and steam, of ice and fire, of gloom and colour, of darkness and light. In this respect, it is probably unequalled in all of Europe.

Iceland is a large island in the North Atlantic Ocean (between 63° 24' and 66° 32' North latitude) which lies just south of the Arctic Circle. The islands greatest distance from north to south is about 190 miles, and from west to east about 300 miles.

For the most part, Iceland is a mountainous country. The interior consists entirely of high plateaus and mountains (the highest mountain on the island reaches to 6,950 ft.) and is almost uninhabited. Most of the lowlands, scarcely exceeding seven per cent of the entire area, lie in the southwest and contain the greatest number of inhabitants. Vast areas of the highlands are covered by glaciers. The largest is Vatnajökull which covers an area of 3,140 sq. miles and is the largest glacier in Europe. In many parts of the country there are volcanoes of which about 30 are still active. The most recent land eruption occurred in 1961 from the volcano Askja. In November 1963, the eruption of a marine volcano formed the island Surtsey 13 miles south of the Westman Islands which lie just off the southwest coast of the mainland (Pálmadóttir, 1964).

Hot springs are found in all parts of the country. The most famous is Geysir, which has given its name to all such spouting springs the world over. In recent years villages have sprung up in hot-spring areas and the natural hot waters are used for heating houses. Greenhouses so heated are used for growing much of the islands supply of fresh vegetables and many fruits including bananas.

There are innumerable rivers in Iceland. Most of the larger rivers have their source in glaciers and are turbid and milky in colour. Many have large waterfalls such as Gullfoss in the south, and Godafoss and Dettifoss in the north. There are also a vast number of lakes but most of them are small.

[1]Summary of an invitation paper presented at the 101st annual meeting of the Entomological Society of Ontario, Guelph, Ontario, September 2-4, 1964.

Iceland received its name from the early Viking explorers because of the ice floes off its northern coast. Many people are under the misconception that Iceland is a very cold country, but Icelanders say that the coldest thing about the country is its name. Although the country is situated on the edge of the Arctic Circle, a wise Creator arranged a long time ago to have the warm Gulf Stream encircle it. As a result, Iceland has a relatively mild, oceanic climate. At Reykjavik the mean annual temperature is 39°F; the mean July temperature is 52°F, and the mean January temperature is about 30°F—considerably higher than the 12°F of Ottawa. The annual precipitation varies from 50 inches on the south coast to about 15 inches in the northeast.

With the variety of habitats that are present in Iceland and with its rather moderate climate, one might surmise that the island should be rather rich biologically. However, the vegetation of the country is of a northern European type that is quite uniform across the island. About 450 species of flowering plants and vascular cryptogams have been recorded (Clark, 1943). Birch woods occur in the warmer valleys but the trees rarely grow more than about 20 ft. high even in well protected areas. A few mountain-ash trees occur, some of which may reach 30 ft. in height. Reforestation is now being attempted in various parts of the country, particularly with cold-resistant species of conifers. About 20 species of willows are known but most of them are dwarfs. There are many attractive though small, wild flowers, and some of our common weeds such as yarrow and dandelion occur in Iceland. The grasses, as feed for livestock, are the most important plants.

The present land fauna of Iceland consists mostly of immigrants that have reached the island since the Pleistocene, when the island was completely covered by an ice cap except for a few small, isolated refugia, and those indigenous members who survived in these refugia (Clark, 1943; Lindroth, 1957; Larsson, 1959). The insects of Iceland are relatively few in species and numbers. Lindroth (1931) recorded 700 species in his comprehensive account of the insects of Iceland and their problems. Since then, revisionary and other studies have resulted in a number of changes, descriptions of new species and new faunal records. There are now approximately 800 species known whose affinities are with those of northern Europe or are widespread northern species. "The Nearctic element of the Icelandic insect fauna is less than one percent!" (Lindroth, 1957). Among Icelandic insects, the Diptera predominate with about 218 species (excluding the Ceratopogonidae and Chironomidae) (Nielsen, Ringdahl and Tuxen, 1954), followed by the Coleoptera with about 206 species (Larsson and Gigja, 1959), and the Hymenoptera with about 197 species (Petersen, 1956). Undoubtedly some of these numbers will increase slightly as the insect fauna becomes more fully studied.

Our trip to Iceland in June and July of 1962 was to study and collect black flies. As a result of our collections we now know of five species occurring on the island, *i.e., Prosimulium ursinum* (Edwards), *Simulium (Eusimulium) latipes* (Meigen), *S. (E.) latizonum* Rubtzov (reported by previous authors as *S. (E.) aureum* Fries), *S. (Psilozia) vittatum* Zetterstedt, and one species of *Simulium* which is probably undescribed. A full report on the black-fly fauna of Iceland will appear in due time.

Our general collecting, necessarily confined to selected habitats near rivers and streams, was less fruitful than we would have liked. Even so, our collection contained representatives of 22 of the 35 families of Diptera known to occur on the island, among which are several species new to science.

I was impressed favorably enough with Iceland, both in regard to the scenic marvels of the country and its people, and its entomological possibilities to want to return for a longer stay.

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AN ENTOMOLOGICAL ASSIGNMENT IN GHANA

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Ghana requested technical assistance from Canada in 1962 to meet the problem posed by the detection of cyclodiene resistance in mirids on cocoa. I had the pleasure of leading a research team which went to Ghana in January, 1963, to investigate the resistance problem and to develop alternative methods for the chemical control of these pests. In addition to myself, E. F. Bond of the former Entomology Laboratory at Guelph, Ontario, and G. Prins, of the Entomology Laboratory, Chatham, Ontario, were seconded from the Department of Agriculture to the External Aid Office for this assignment. Mr. J. N. Telford, who had recently completed post-graduate studies at the University of Western Ontario, was the fourth member of the team. The team was located at the Cocoa Research Institute, Ghana Academy of Sciences, which is at New Tafo in the Eastern Region. The Institute, which has served the industry for more than 25 years, has Entomology, Chemistry, Plant Breeding, Plant Physiology, Plant Pathology and Agronomy Divisions. Other agencies in Ghana are responsible for extension programs as well as for the study of insect pests on cocoa beans in storage awaiting shipment.

Cocoa provides about 60% of the national income of Ghana, one of the most rapidly developing, newly independent countries in Africa. Cocoa production is most seriously affected by the destruction of trees by two species of cocoa mirids and by swollen shoot, a virus disease transmitted by mealy bugs. The mirids, *Distantiella theobroma* (Dist.) and *Sahlbergella singularis* Hagl., were brought under control in 1955, when the efficacy of low-volume applications of lindane was demonstrated. By 1958, the Division of Agriculture had treated over one million acres of cocoa at a

dosage of 4 oz of lindane in 5 gal of water per acre. The responsibility for mirid control was turned over to the farmers in 1959 and portable mist blowers, hand sprayers and lindane were made available to them at heavily-subsidized prices. The Division of Agriculture recommended that farms should be treated for mirid control in June, July, November and December, a schedule related to the seasonal development of mirids from the beginning of the wet season in June to the onset of the cool, dry winds from the north in January. Lindane was to be applied initially in June and July at 4 oz in 5 gal of water per acre and thereafter, it was applied at 1 oz in 5 gal per acre to maintain control. The 12 Cocoa Stations, which were located throughout the cocoa growing area for field trials and agronomic studies, presumably were treated regularly for mirid control, and it was at the Pankese Station that lindane-resistant mirids were detected in July, 1961.

Several entomologists and authorities on insecticides visited the Institute in 1962 as consultants on the resistance problem. These included Dr. R. E. Galley, Shell Chemicals; Dr. A. W. A. Brown, University of Western Ontario; and Dr. J. Marshall, Research Station, C.D.A., Summerland, B.C. Dr. Brown showed that the problem was probably one of cyclodiene resistance and Dr. J. A. Dunn, the resident entomologist confirmed this by demonstrating that the resistance extended to aldrin, dieldrin, chlordane, heptachlor and thiodan. Dr. Marshall made valuable suggestions for the development of a substitute insecticide, and recommended that a research team should be assembled to study mirid control.

Our team established three projects, one to study the cyclodiene resistance, the second to assess candidate insecticides in the laboratory, and the third to conduct field trials with carbaryl and Sumithion (dimethyl - methylnitrophenylthiophosphate), two insecticides that had shown promise in earlier trials. The team was strengthened by the assignment to it of two recent graduates of Kwame Nkruma University of Science and Technology. We were assisted by Ghanaian technical officers, technicians and field assistants totalling about one hundred men.

Mr. Telford, who was responsible for the survey, established three teams to determine the distribution of cocoa mirids resistant to lindane and the cyclodiene insecticides. Samples of mirid populations were tested for their susceptibility and/or resistance by an impregnated-paper, continuous-exposure method, developed from the W.H.O. test for adult mosquitoes. Cyclodiene-resistant mirids were found to be concentrated in one large area and eight small pockets in the Ashanti and Eastern Regions. Low levels of resistant insects existed in other areas of the Ashanti and Eastern Regions. No cyclodiene-resistant mirids were detected in the Brong Ahafo and Volta Regions, two important cocoa-growing areas.

Mr. Prins assessed 28 insecticides in the laboratory against resistant and susceptible mirids. The insecticides were applied in a 5% olive oil in-acetone solvent by a Potter spraying tower. Dosage-mortality regression lines, as well as indices of effectiveness, i.e., LD_{50} for rats/LD_{50} for mirids X 1000, were calculated for all of the insecticides. Dimethrin, malathion, chlorothion and four experimental compounds were sufficiently effective to warrant assessment in the field. The median lethal dosage of carbaryl was seven times that of Sumithion.

Extensive field trials with carbaryl, applied as suspensions prepared from an 85% wettable powder, and Sumithion, applied as emulsions prepared from a 50% emulsifiable concentrate, were conducted from May to December, 1963, using about 100 two-acre plots of farmers' cocoa. The insecticides were applied by portable mistblowers. The field trials did not demonstrate the superior efficiency of carbaryl, at least in the formula-

tions tested. It was demonstrated that applications of a 0.625% carboxyl suspension (1 oz. active ingredient per gal) or a 0.625% Sumithion emulsion applied directly to the trees, would reduce a cocoa-mirid population by 95%.

Mr. Telford remained in Ghana until January, 1965, to continue the resistance survey. The balance of the team returned to Canada in January, 1964. Further laboratory assessments and field trials were conducted during 1964 by Institute staff. Meanwhile, the External Aid office has provided training in Canada for entomologists from the Institute and explored the availability of Canadian entomologists for service in Ghana. The Cocoa, Chocolate and Confectionery Alliance of the United Kingdom has expressed interest in the recruitment and assignment of an entomological team to the Institute to continue the assessment of new insecticides for the control of cocoa mirids.

This has described some aspects of one entomological problem facing the cocoa industry in Ghana. Swollen shoot disease is devastating large numbers of cocoa farms and the mealy-bug vectors of this disease need intensive study. In 1963 at least, the insect pests of agricultural crops other than cocoa, were the responsibility of one entomologist located at the Agricultural Research Institute at Kumasi. The Government is establishing a large number of state-owned farms for the production of food crops. The lack of entomologists to support this program is a critical situation.

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SOME IMPRESSIONS OF ENTOMOLOGY IN THE U.S.S.R.

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In the autumn of 1963 I spent three months in the Soviet Union under the auspices of the Exchange Agreement for Scientific Personnel between the Soviet Academy of Sciences and the National Research Council of Canada. My impressions of entomology are limited because I visited only Moscow and Leningrad and because most of my time was spent with nematologists.

Research on entomology is done in several Academies and many Institutes, though I did not find any Institute devoted solely to entomology as in Canada. The entomological effort did not seem as great as I would have expected for a country with a population twelve times greater than that of Canada, but there are estimated to be over 2,000 entomologists in the Soviet Union.

The taxonomic tradition is strong in Soviet entomology and finds its greatest expression at the Zoological Institute, Leningrad. Here some 30 or more taxonomists under Prof. Dr. A. A. Shtakel'berg have a long tradition of work and have made many contributions to the insect fauna of the Soviet Union. Though work follows the traditional taxonomic approach some interest was displayed in numerical taxonomy, and Prof. Dr. E. S. Smirnov at the University of Moscow has conducted several such studies.

The great range of latitudes and longitudes covered by the U.S.S.R. provides an excellent opportunity for zoogeographical studies. Many of them relate insect distribution to climate or soil type. For example, in the laboratory of Prof. Dr. M. S. Gilyarov of the Svertsov Institute of Animal Morphology, a study of soil type and insect fauna from samples along a longitude from the Arctic to subtropical regions is being completed.

Much active work is done on the effects of physical factors on diapause and life history. This stems from observed differences in populations of an insect at various latitudes. Temperature and light are tested on laboratory insects to explain differences in populations of, for example, insects from Leningrad, Kiev, and the Black Sea. Prof. Dr. A. S. Danilevskiy of the University of Leningrad has an interesting book on his studies, "Photoperiodism and Seasonal Growth of Insects". Similar work is pursued at other Institutes including the Laboratory of Experimental Entomology in Leningrad, formerly under the direction of the late Prof. Dr. D. M. Shteinberg who visited Canada in 1961. Cold temperature work is done in the Laboratory of Cosmos Biology of the Institute of Cytology in Leningrad.

Population ecology is active and I saw some interesting studies on competition between ant species by Dr. G. M. Dlusskiy, and parasitism of the Senn pest, *Eurygaster integriceps* Put., by Dr. G. A. Viktorov of the Svertsov Institute, Moscow. Prof. Dr. A. S. Monchadskiy of the Zoological Institute, Leningrad, described interesting predator-prey relations in the Chaoborinae. It was my impression that studies of population dynamics are not as extensive as in Canada, though its importance is appreciated and studies are in progress in some field areas.

Insect pathology is developed in several centres but my experiences were in Leningrad at the Laboratory of Micromethods under Prof. Dr. Fedorinchik at the All Union Institute of Plant Protection where viral, bacterial, fungal and nematode investigations are under way from both the theoretical and practical viewpoints.

Studies on biological control are actively pursued in the same Institute in the Laboratory of Biomethods under Dr. V. A. Shchepetil'nikova. The efficiency of native parasites is increased through the provision of food plants and this programme has attained the point of practical application. Biological control at the Zoological Institute is led by Prof. Dr. I. A. Rubtsov and by Dr. V. A. Zaslavskiy, present Director of the Laboratory of Experimental Entomology. Foreign exchange of biological control agents is carried out by the Central Plant Quarantine Institute, Moscow. Biological control of forest pests involves the use of Enterobacterin (*Bacillus thuringiensis* Berliner) and Dendrobacilin (*Bacillus dendrolimus* Talalaev) and mass rearing of *Dahlbominus*. Prof. Dr. A. I. Vorontzov of the All Union Institute of Forestry, Pushkino, is associated with some of this work. Enthusiasm for biological control and environmental manipulation is considerable and several committees are expanding existing and organizing new approaches. Late in 1964 a symposium was held at Novosibirsk and 85 papers were presented on biological control.

Physical control techniques are under study in the Laboratory of Biophysics under Dr. S. B. Andreev at the Institute of Plant Protection, Leningrad.

Chemical control is active and six laboratories of the Plant Protection Institute, Leningrad, check toxicities, recommend doses, and investigate new products as well as recommend treatments at the national level. Problems of toxic residues are recognized, but are considered less severe than in Canada, as state controls appear to be more strict; each collective farm usually has a trained insecticidal operator.

A most interesting aspect of entomology was the possibility of training graduate students at both the "Aspirant" (M.A.) level and the "Candidate" (Ph.D.) level in scientific Institutes. Degrees are granted by the respective Academies of the Institutes. The majority of higher degrees are taken at Institutes. University people are often present at the examinations. The system seems to produce narrower specialists than our own but does provide a wide national basis of training.

Soviet entomologists seem well informed on Canadian entomology through their admirable library systems, though there is a 6-18 month delay. Few entomologists have Canadian literature in their personal collections and would welcome an exchange of reprints.

Enthusiasm for work is high, and the pace of work much the same as our own. There is a higher proportion of women in entomology than in Canada. The presence of graduate students in the Institutes gives another dimension to the research programme.

Evolutionary theory and classical approaches receive more attention than here. My experience suggested that quantitative and experimental approaches are not emphasized as much as in Canadian entomology.

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III. SUBMITTED PAPERS

MONARCH BUTTERFLY *(DANAUS PLEXIPPUS)* MIGRATION STUDIES: AUTUMNAL MOVEMENT

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Introduction

For the past many years, and indeed long before we began our studies of the population movements of the monarch butterfly, most zoologists concerned with the study of the migration of insects were of the opinion that this particular species moved from north to south in late summer and fall, although the final destination of this autumnal movement was unknown. There were, however, those who believed that some members of a population did in fact remain in the breeding area in a state of hibernation. This belief may have been instigated by the writings of S. H. Scudder (1899) in which he states that: "Woodsmen sometimes, in cleaving open a tree, will discover a little colony of hibernating butterflies, as has been done in the case of the monarch." C. V. Riley (1877) had previously written that "the archippus butterfly hibernates within hollow trees and in other sheltered situations", and that such butterflies prefer to hibernate in the southerly timber regions until the following spring when a "small portion of these butterflies that have survived awake from their winter torpor and fly to the prairies, there to lay their eggs upon the milkweed." Regardless of such assertions, there were many who considered the flights of the monarch butterfly as being characteristic of a "migration". This lead J. Alston Moffat (1902) to write that there is "altogether insufficient direct evidence to warrant the assumption that the autumnal swarms migrate from the more northern parts of its summer range in America, to the south in order to winter there."

Thus the argument for and against a migration continued until as recently as 1951 when A. B. Klots states that "perhaps a few adults or pupae hibernate in the north."

When we commenced our studies in 1937, it was still an open question: Does the monarch butterfly migrate from its northern breeding grounds to overwintering grounds? And does it return again the following spring? These are the questions we set out to answer but, like a pandora's box, we opened a veritable treasure chest of unanswered problems one of which, the autumnal movement, is discussed in this paper.

Population Identification Methods

Although many entomologists now consider the monarch butterfly as a true migrant, most, if not all, consider it in the class of emigrants rather than remigrants (Urquhart, 1958). To obtain objective data on particular movements it was necessary for us to devise some form of population identification method. Geoffrey Beall (Beall, 1946; Beall and Williams, 1945) suggested that populations could be identified by means of a mathe-

matical index based on wing lengths and pointed out that it was quite unlikely that a banding method would prove feasible. C. A. Anderson, an amateur entomologist living in Texas, and a most enthusiastic investigator, attempted to identify populations by stamping a number on the wings, thus "branding" a particular individual of the population; then, in order to obtain recovery data, he informed numerous correspondents about his investigations and requested that such branded individuals be returned to him. Other investigators such as Brett (1936), following the method used by Anderson, employed various letters and combinations of letters and numbers in order to identify members of a particular population. In an attempt to inform the person capturing a branded specimen where to send it, some investigators stamped the abbreviated name of their institution, or the entire name of it when short, on the front wings. Roer (1960) devised a method of placing small circular labels constructed from aluminum on each of the front pair of wings.

In our early investigations we tested all of the above methods, with the exception of the latter, and in addition we investigated the feasibility of using various colour indicators. None of these methods, however, produced recovery data, except for a few local specimens for which the distances travelled were of little value in our studies.

It soon became apparent to us that the reason we were not obtaining recovery data was because no return instructions accompanied the marked specimen. We realized therefore that it was necessary to devise a system using a label, now referred to as an "alar tag", which would identify the individual of a population and the geographic population to which it belonged and at the same time would instruct the person capturing such a specimen to send it to our laboratory.

Over a period of four years, various sizes of alar tags and various tagging methods were investigated. Our early alar tags were glued to the plane surface of the front wing, usually the right front wing, using Canada balsam or clarite as the adhesive. Since the alar tags were small (9 x 12 mm) and were cut from a large sheet of printed stock, it was most difficult to apply the alar tag to the butterfly's wing without getting too much adhesive on the specimen. We also found that within a short period of time the adhesive became accidentally transferred to the box of unused alar tags as well as to one's fingers, regardless of how carefully we carried out the procedure. To overcome this difficulty, we arranged to have the block of alar tags (fifty to a single sheet) printed on gummed paper using a water soluble glue. Employing these gummed tags, we investigated the various areas of the wings to which the tag might be attached; we concluded that the simplest and most efficient area was the discal cell of the front wings—the right wing was decided upon since most people are right-handed. To apply the tag to this area it was bent in half and placed over the edge of the wing such that the gummed surface could be applied to the wing and the margins of the alar tag would lie within the discal cell.

Our returns, using the above method, were more encouraging but we still failed to obtain long distance returns. As a result of running a test sample of such tagged specimens, which were retained in our rearing cages, we found that the label would not adhere to the wing unless the scales were first removed from the area to which the alar tag was to be attached. The following year we removed the scales from the wing and as a result obtained longer flight records of up to forty miles.

It soon became obvious that a water soluble glue would not adhere to the smooth surface of the wing membrane once the glue had dried to its crystalline state. To overcome this difficulty, we made a small hole, using

a paper punch, through the discal cell and glued the label to itself through the hole. As a result of this innovation, recovery records were obtained for distances of over two hundred miles.

Still the alar tag did not remain attached to the wing for sufficiently long periods of time. Those associated with us in our research reported that during periods of wet weather, or following a period of high relative humidity, the tag dropped from the wing. This we found to be the case when carrying out a tagging program at Washington Park in the Monterey Peninsula of California during a period of light drizzle and fog.

Within recent years, a commercial preparation of a latex adhesive made it possible for us to obtain recoveries over much longer distances. We now use an alar tag of dull, lithocoated material with a 60 lb basis weight; the paper is 0.0035 inches in thickness and 0.005 with latex basis type adhesive; the label measures 8 x 13 mm which, when bent, fits into the discal cell such that the rounded free edges are not exposed as a result of lying on top of the Cu-M vein. We also found that by using the latex adhesive we did not need to coat the tag with a waterproof material since it remained attached to the wing even when the latter was submerged in water for periods in excess of 21 days.

Associate Organization

While carrying out much of the above experimentations, we had obtained the assistance of many individuals living in various parts of North America. It was necessary for us to obtain such assistance not only in order to tag as many specimens as possible during the migratory period but also to ascertain whether or not we were concerned with a single large peripherally diffuse population or individual sympatric or allopatric populations. These voluntary assistants were termed "cooperators". Later, since some of the cooperators obtained the assistance of local individuals, we changed the designation to "associate". Such associates work directly with our laboratory; local assistants, now termed cooperators, work directly with the associates. With this organization of volunteer assistants, we are able to handle reports from over 200 associates plus their respective cooperators. All material is processed and filed in our laboratory at Scarborough College, University of Toronto so that a careful check can be maintained as to the authenticity of direct recoveries or reports, particularly sight records or tagged specimens. The associates are kept informed of recent advancements in the studies through the medium of a "Newsletter" which is sent annually to each associate. Since the Newsletter is not a research publication we clearly state that the material must not be quoted in scientific literature. Those wishing to obtain more exact information for scientific research are asked to write to our laboratory.

Results

The data obtained over a period of many years of research were published by the University of Toronto Press (Urquhart, 1960). The autumnal flights, based on numerous release-recovery reports, take place between the breeding grounds in the north-eastern United States and Canada and the south-western United States and Mexico, with fringe populations existing as settled over-wintering colonies in one location on the Gulf Coast of Florida and as free-flying nomadic populations along the west coast of Florida, southern Alabama, Mississippi, Louisiana, and Texas.

Depending upon the geographic location of the release, the flight path terminates at various points along the Gulf Coast through Texas and into

Mexico, with occasional "strays" entering Florida. This flight path pattern applies to the north-eastern United States and Canada east of the Mississippi drainage and including Minnesota, Iowa, Missouri, Arkansas, Louisiana and south-east Texas.

Owing to the sparse human population in the foothill States and mountain States, recovery of tagged specimens has been most meagre. To this is added that monarch populations are also small in number throughout this area. From the few returns which we have received, however, it would appear that the autumnal flight in this area is likewise to the south and south-west.

Some of the results obtained for the past three years of our tagging program have been plotted as release-recovery lines on the accompanying map (Fig. 1). Only significant distances have been plotted.

An examination of the map plot indicates that under certain conditions of wind strength and direction, flight may be to the south-east over the Great Lakes. This is most obvious for release points on the east coast of Michigan, the southern point of Georgian Bay, and the central north shore of Lake Ontario. It will also be noted that flights across Lake Ontario with a trajectory to the south-east result in a release-recovery line crossing the northern portion of the Appalachian Highlands through northern New York and Pennsylvania. Flights from the Lake Huron and Georgian Bay regions have a trajectory to the central Appalachians and are deflected to the south-west, and hence do not cross to the Atlantic coastal region. This gives rise to two flight patterns, one west of the Appalachian Highlands and continuing to the south-west through the Mississippi Lowlands, and the other west of the Appalachians, following the coastal lowlands and eventually crossing through Georgia and Alabama to connect up with the Mississippi route. Migrants, deflected en route to the south-east, after having reached the coastal Atlantic lowlands together with those from breeding areas along the coastal lowlands, may reach northern and central Florida and with continued trajectory, arrive at the coastal area of the Gulf coast in the vicinity of St. Petersburg. These we have referred to as "strays".

It has been previously noted (Urquhart, 1960) that the release-recovery line may be a straight trajectory or, after deflection, it may represent the diameter of a circuitous route to the south-east.

Under relatively calm periods, or during periods of easterly or north-easterly winds, flight direction is to the south-west. Populations located north of the Great Lakes travel south or south-west, but on arriving at the north shores of the lakes the flight direction is to the south-west following the shore line. That such is the case is borne out by numerous recoveries, of short or long distances (flights of less than ten miles within the city limits of Toronto; longer flights such as Port Hope to Oakville; and Highland Creek to Leamington).

We may conclude that flight direction is the south or south-west with deflections caused by strong westerly winds.

Population Transfers

If, as assumed above, we are dealing with a single population with flight path variations related to the loci of departures, then if specimens from one area are transferred to remote areas the flight pattern should remain the same, namely to the south or south-west. (Such experiments are also significant with respect to displacement of flights by strong winds over the ocean and changed vernal return flights following the hibernal period).

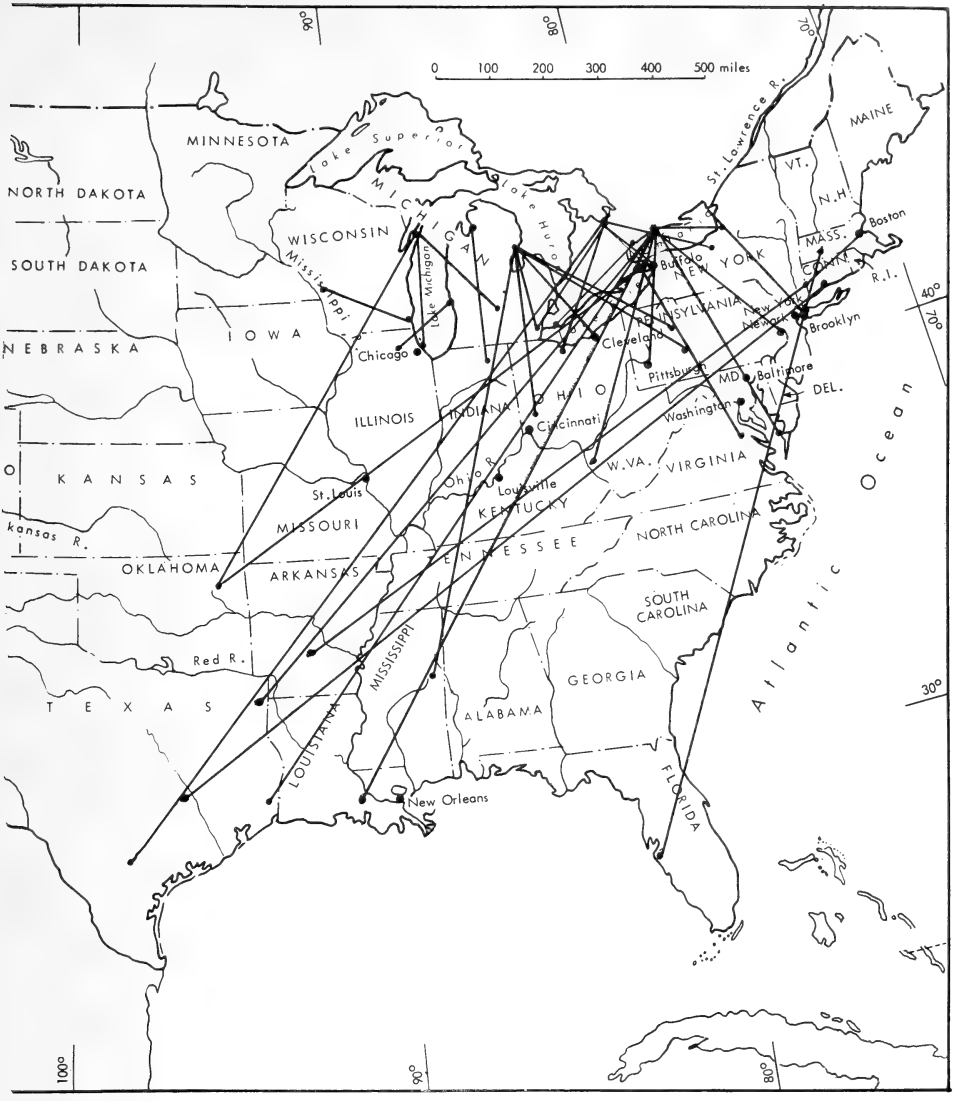

FIG. 1. Release-recovery lines for the eastern United States and Canada, selected from autumnal movement data.

In order to test the above, a system of population transfers was instigated during the summer of 1964. Five of our most active associates, and ourselves, captured specimens in home localities in Ontario and sent them by airmail, special delivery to other associates within the western zone of migration.

The specimens to be transferred were placed in small glassine envelopes ($2\frac{1}{2}$ x 4) the latter having a flap which when bent down, so as to enclose the specimen, allowed for a certain amount of shock resistance as the flap tended to return to its unfolded condition. This was important since it protected the specimen from crushing as one envelope was placed on top of another in the cardboard carton. The choice of glassine, or plastic,

envelopes was arrived at as a result of our laboratory experiments dealing with the effect of water loss in an atmosphere of low humidity. The cardboard carton measured 6 x 6½ x 4 inches and could accommodate as many as 200 specimens. The package was enclosed in strong packing paper and mailed by air to the recipient who liberated them on arrival.

Specimens from Ontario were mailed to the following points:

Gower Point, Gibsons, British Columbia
Lethbridge, Alberta
Denver, Colorado
Pearsall, Texas
Salt Lake City, Utah
Quemado, Texas
Tonopah, Arizona
Reno, Nevada
Rapid City, South Dakota

Of the specimens transferred to Gibsons, British Columbia, six of them were recaptured. Of these, one flew directly south to be recaptured on Sidney Island, off the coast of Victoria, B.C. having travelled across the Georgia Strait. Four specimens followed the shore line thus travelling in a south-south-easterly direction to be recaptured at West Vancouver. One specimen was recaptured at the point of release.

Of the specimens transferred to Denver, Colorado: One was recaptured at Denver south of the point of liberation; one at Englewood, south of Denver; and one at Golden, west of Denver.

One of the Salt Lake specimens was recaptured at Hunter, south of Salt Lake City.

Of the specimens liberated at Reno, Nevada: One was recaptured at Ventura, California, having travelled through the mountain area in a southerly direction; two at San Luis Obispo, California, having flown in a similar direction; and one at Bishop, California, a direction south-west of Reno.

There were no recaptures of specimens liberated from the other transfer points.

It would appear from the above data, that the flight direction remains the same when members of populations are transferred from one area to a remote area.

We may further conclude, with respect to directional flight of populations in the western flight area that: Flight direction in the northern coastal area tends to follow the coast line with a tendency to a south-westerly direction where islands in open water are present; populations in the mountainous regions, or foothills regions, travel to the south and south-west, the direction and final destination points being determined by mountain valleys and mountain passes; thus, the directional flight of populations from Reno, Nevada, is southerly or south-westerly being directed by the San Joaquin Valley and the coastal range to the south with final destination point west of Mount Pinas located north of Los Angeles. We believe, although without recovery data to substantiate such a belief, that populations entering the Sacramento Valley, north of the San Joaquin, reach their final destination points on the coastal areas in the vicinity of San Fransisco Bay; such populations, after remaining in this area for part of the winter move southward arriving in the Monterey area where permanent over-wintering sites are located.

The above conclusions would account for: The presence of large roosting populations in the San Fransisco Bay area which populations later move south to the Monterey Bay area and are perhaps limited in their southern flight by the low Santa Lucia Range; the active flight colonies south of Monterey to southern California are those reaching the coastal area in the vicinity of Mount Pinas near Los Angeles — these may move northward (based on sight records only) or continue to the south entering Baja, California, and the Gulf of California.

We are of the opinion tht colonies will eventually be located in the Imperial Valley area north-west of Baja, California and that such flight colonies will be found to extend down the coast of the Gulf of California joining the migrant easterly populations which we have been able to trace to central and southern Mexico. In order to obtain definitive data to fill in this part of the migration, it will be necessary not only to obtain the active cooperation of individuals in such areas but also to continue, on a much larger scale, our transfer experiments.

We also anticipate the recapture of such transferred specimens to ascertain whether or not they will follow the flight paths of western populations during the vernal movement.

Trans-Atlantic Flights

The monarch butterfly occurs in many geographical areas other than North America (Urquhart, 1960). It is our belief that such populations, where they have become established (e.g., Australia), and occurrences not established (e.g. British Isles), have been brought about by human agencies rather than by direct flights. This conclusion was proposed by Scudder and Gulik (1875). There are, however, many sight records on monarchs occurring at sea some hundreds of miles from land, as reported by Williams (1958) in his most comprehensive treatment of insect migration, and by Adkin (1924), Barrett (1893) and many others. Such records appear to be well documented and would seem to indicate a direct flight from North America to other distant islands and continents. Nevertheless, it is still an open question as to whether such butterflies occurred at sea as a result of direct flight or were carried this distance on board a trans-oceanic vessel.

If, as some believe, the monarch butterflies are capable of travelling from the North American continent to the British Isles, the following conditions might make such a feat possible:

(1) They might travel in an ENE direction from a latitude band of 30-45 deg to latitude band 45-60 deg;

(2) They might follow a straight line flight of approximately two thousand miles, without any divergences which would increase the distance, without stopping; or, if they came to rest on the surface of the ocean they would be able to remain for a period of time and still be able to become air-borne;

(3) The time taken to make such a flight might be curtailed if flight could continue day and night, still maintaining an ENE direction;

(4) The flight speed might be increased if the monarchs were assisted by strong westerly to south-westerly winds at low levels.

(5) At heights above 2000 ft they might be assisted in their flight by prevailing westerly winds.

We will consider each of these possibilities in the light of our recent experiments and investigations:

(1) As a result of our tagging program we have found that all release-recovery lines, when taken over an appreciable distance, indicate a south to

south-westerly route during the autumnal flight. Those that exhibit an easterly flight, over short distances, are to the south-east and never to the east or north-east. Specimens transferred from one part of the continent to another distant part still exhibit the southerly flight direction. Hence, even though the monarchs may be carried out over the ocean due to very strong off-shore winds, they would resume their southerly flight once they were beyond the effect of strong wind and hence would not continue in a direction which would carry them to the north or north-east.

(2) From our experiments (Urquhart, 1960) we have found that in the absence of water, when the specimens are freely exposed to atmospheric conditions, they died within a ten-day period. Hence the trip across the ocean would have to take place within a ten-day period (which brings in the possibility of night-flight discussed below) unless the monarchs could alight upon the surface of the water.

From our experiments on surface and complete immersion (Urquhart, 1960) it was found that the butterflies could remain, at least momentarily, on the surface of the water or, in the case of a turbulent sea, under its surface for a short period of time. In order to test the possibility of free flight after having come in contact with a free water surface the following series of experiments were carried out:

A large plastic dome (circumference, 6 ft; height 5 ft) was attached to a light metal frame such that it could be placed over a free water surface. Butterflies were placed in the dome during periods of maximum flight activity. When the specimens came to rest on the surface of the water the time was noted. The time was again noted when they flew from the surface of the water back to the walls of the dome and continued flight activity. When all specimens remained on the surface of the water for a period of time in excess of 30 min, the dome was removed so as to allow the wind to pass over the water surface and thus assist the specimens in taking off. Those that were unable to become air-borne were examined for water absorption which was accomplished by placing a drop of water on the wing; if the specimens had become waterlogged, the droplet spread out over the wing instead of maintaining its spherioidal shape as characteristic of such a drop placed on a dry wing surface. If the wing had become partly saturated, the droplet assumed a flattened elipsoid. Free surface water was removed, of course before applying the water droplet.

Other tests indicated that after 20 min in the water the wing had become water soaked. Such specimens were capable of short flights, of less than 20 ft, when they were removed from the water and tossed into the air—comparable to wave action with a formed crest. In gently swelling seas, however, it would not be possible for such individuals to elevate the wings from the water surface to allow air currents to carry the butterfly to a height necessary for sustained flight.

It is, however, possible for monarchs to survive for long periods of time when completely submerged. Two of our specimens that had become completely submerged for a period of 33 hr were still alive and one of them, when placed on the screen of the rearing cage, was capable of sustained flight after a drying period of 25 min.

It was observed that specimens resting upon the water surface elevated the abdomen so as to keep it out of the water which would allow for continued respiration through the adbdominal spiracles. When attempting to become air-borne, the wings were pressed down on the surface of the water thus levering the body up above the water surface. In the presence of a fairly brisk breeze, such as might be expected over the ocean surface,

this would assist in take off. However, after a period of 8 min, five of ten specimens were no longer able to raise the abdomen free from the water surface and attempts to do so caused the wing to sink below the surface; the weight of the water now on the upper surface of the wing tended to lever the body in the reverse direction thus totally submerging it. After a period of 45 min, five of the specimens were thus completely submerged. If the specimens were removed from the water surface and tossed into the air, it was found that three of them could take to wing and fly for a short distance, but seven of them were unable to do so and fell back into the water. After a period of 3 hr, none of the specimens was able to fly when tossed into the air.

It would appear that monarch butterflies are able to rest for short periods of time upon a free water surface but that, for periods in excess of 3 hr, flight would not be possible and that only short flights would be possible after periods in excess of 20 min. This would allow the monarchs to obtain free water and thus survive for periods in excess of ten days, providing that flight was continuous day and night.

(3) From observations made on caged specimens, it has been noted that flight continues sporadically during periods of light and ceases during periods of dark. Specimens liberated in an illuminated cage exhibited flight activity whereas those liberated in darkness came to rest and remained thus until the cage was illuminated.

Since we have no data on the possibility of nocturnal flights of free-flying individuals, we can only conclude, on the basis of cages specimens, that continuous 24-hr flights are improbable. In addition, based upon the abundant data that we now have from our tagging program, continuous north-easterly flights over long distances are unlikely, whether for a 24-hr period or not.

(4) The distribution and daily fluctuations of pressure systems over the ocean precludes any possibility of a continuous surface wind in one direction over a 2000-mile distance. It is therefore improbable that monarchs, carried out over the surface of the ocean, might be carried by strong and continuous south-westerly or westerly winds.

(5) It has been suggested that perhaps monarchs may fly at heights above the surface wind—heights of 2000 ft or more—and thus be carried over the ocean by the strong westerly upper winds. The presence of insects at varying heights has been reported upon by Glick (1939) and many others lending support to this possibility.

An examination of zonal westerly mean wind components for meridians from 10° W to 70° W longitude and at latitudes within the flight zone, we find that at 2000 ft or less the wind speed and direction is variable, with a westerly component of five knots at 2000 ft. At heights of 4000 ft, westerly wind speed increases to 10 knots and at heights of 6000 ft to 15 knots. At heights of 20,000 to 30,000 ft, wind speed shows a marked increase reaching 30 to 50 knots.

From our experiments (Urquhart, 1960) we have found that at temperatures below 13°C flight is impaired and controlled flight impossible at temperatures below 10°C with complete immobility at temperatures below 4°C.

From Newfoundland to S.W. Ireland, a distance of about 1600 naut. miles, the average wind components for September and the average temperatures are as follows:

Surface—15°C; variable
5,000 ft 9°C to 12°C; 12 knots
10,000 ft—11°C to 4°C; 18 knots

It is improbable that monarch butterflies reach heights where the wind component is of a sufficient magnitude to account for a passive transport over the ocean. If, due to strong vertical currents, such individuals were carried into the upper atmosphere, flight, from the point of view of temperature, would be so impaired as to cause such specimens to drop to lower levels where they would then be subjected to variable wind directions.

It is unlikely that upper winds play any part in the transporting of monarchs from North America to the British Isles.

Summary

A brief review of the population identification system in use is presented along with recent data of recoveries for the years 1961-1963. These data amplify previously published data bearing on the southerly autumnal movements of the monarch butterfly populations in North America. Evidence is presented for considering the population of North America as a single population with variations in density and with a common southerly directional migration characteristic. Transfer experiments are discussed and data presented to substantiate conclusions that the overwintering population distributions can be explained in terms of geographical obstructions, presence of valleys and the loci of departures. Data in support of mechanical transfer of monarch butterflies from North America to the British Isles are presented, and it is suggested that similar data would account for the distribution of monarch butterflies in other parts of the earth's surface remote from the Americas.

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STUDIES ON THE BEETLES *LEPTINILLUS VALIDUS* (HORN) AND *PLATYPSYLLUS CASTORIS* RITSEMA (COLEOPTERA: LEPTINIDAE) FROM BEAVER[1]

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Introduction

The species of the family Leptinidae are associated with the nests and fur of species of rodents and insectivores (Parks and Barnes, 1955). Although their host relationships have been described as accidental, phoretic, or ectoparasitic, few studies have attempted to evaluate the nature of these associations and to obtain information on the life histories of the six world species (Rüschkamp, 1914, 1921; Piechocki, 1959). The abundance of *Leptinillus validus* (Horn) and *Platypsyllus castoris* Ritsema on beaver (*Castor canadensis* Kuhl) and in beaver lodges in Algonquin Provincial Park, Ontario, provided an opportunity for studying the life histories of these insects and their association with the beaver. The investigation provided material for a study of the morphology of the various stages of development. All stages except the adult of *P. castoris* are described herein; the pupae were unknown previously and the larvae were incompletely known. An understanding of the life histories of these insects was obtained from field observations, supplemented by experimental studies in the laboratory. The findings lead to conclusions concerning their status as ectoparasites, and a hypothesis regarding the origin of the ectoparasitic habit in the Leptinidae is presented.

Leptinus validus was described by Horn (1872) from material collected in the Hudson Bay region. In 1882 he redescribed the species in greater detail, erected the genus *Leptinillus* for it, and provided a key for its separation from *Leptinus*. Jeannel (1922) compared *Leptinillus validus* with *Leptinus testaceus* Müller, the latter occurring on mice, shrews and

[1]The material in this paper constitutes part of a thesis submitted to the Department of Zoology, University of Toronto, for the degree of M.A.

moles. He considered the group as the sub-family Leptininae of the Silphidae, rather than as a separate family. The species is occasionally mentioned in papers dealing with the beaver (Bailey, 1923; Warren, 1927) and its parasites (Erikson, 1944; Lawrence and Graham, 1955). It has been recorded from several localities in North America, including Alaska (Riley, 1892), Wisconsin (Bailey, 1923), and Ontario (Judd, 1954), but no information on its biology was included in these reports. Parks and Barnes (1955), in a review of the family, presented additional locality records (Maine, British Columbia, Quebec and Minnesota). Their paper includes observations on the biology of the beetle, as well as illustrations of the head and abdomen of the larva. Clark (1961) recorded its occurrence in New Brunswick.

Platypsyllus castoris was described by Ritsema (1869a) on 15 September 1869 as a new species of flea. The host was recorded as *Castor fiber* L. from the Rotterdam Zoological Gardens, although later authors (Bugnion and du Buysson, 1924; Chobaut, 1899; Riley, 1889) stated that the host was *Castor canadensis*. According to Blöte (pers. comm. 1957), the types (two specimens on one pin labelled "Castor canad") are deposited in the Rijksmuseum van Natuurlijke Historie, Leiden, Holland.

Apparently unaware of Ritsema's description, Westwood (1869) published, on October 1, a brief description of *Platysypsyllus castorinus* which he had read to the Ashmolean Society of Oxford on November 9, the previous year. Westwood created a new order, Acreioptera, for his species. On November 15, 1869, Ritsema (1869b) pointed out that Westwood's species was the same as his *P. castoris,* but declined to accept Acreioptera. Later in the year, he suggested the name Platypsyllidae as a new flea family (Ritsema, 1870). Westwood (1874) presented another more detailed description of *P. castorinus,* acknowledged Ritsema's name, and explained that the similarity was a coincidence. The species (as *Platypsylla castoris*) was placed in the Coleoptera, family Platypsyllidae, by Leconte (1872), who considered that it had affinities with the Hydrophilidae and Leptinidae. Seidlitz (cited in Desneux, 1906) erected the tribe Platypsyllini in the Staphylinidae. Jeannel (1922), after comparing *Platypsyllus* with *Leptinus testaceus,* placed them in the sub-family Leptininae of the Silphidae. Recent classifications, notably those of Crowson (1955) and Hatch (1957), have included *P. castoris* in the Leptinidae, and this arrangement has been followed herein.

The larva of *P. castoris* was described by Horn (1888) and redescribed by Chobaut (1899) and Riley (1889, 1890a, 1892). Both the adult and larva were redescribed in more detail and illustrated by Bugnion and du Buysson (1924), Desneux (1906), and Jeannel (1922).

Occurrences in the palaearctic region on *Castor fiber* were recorded from France (Bonhoure, 1884), Germany (Friedrich, 1894), U.S.S.R. (Averin, 1929), Norway (Lindroth and Palm, cited by Jansson, 1940) and Sweden (Wirén, 1939; Jansson, 1940). Warren (1927) listed the North American localities where *P. castoris* had been collected. Reitter (1884), after comparing specimens from the European and American beaver, concluded that the beetles from both continents were conspecific.

Materials and Methods

Field research was carried out in Algonquin Provincial Park, Ontario in 1956 and 1957. Fifty-five beaver lodges were opened temporarily at different times of the year; the earth in the top and sides of the lodge and the material of the nest (a mass of chips and vegetation forming the floor of the lodge) were examined for various stages of *L. validus* and *P. castoris.*

All specimens of *L. validus* used in subsequent experiments were obtained in this way. Adults and larvae of *P. castoris* were obtained by combing the fur of forty-five living and dead beaver. Fine combs having about thirty teeth to the inch were used. Most satisfactory combs had teeth at least 15 mm in length and 0.25 mm-0.35 mm in width.

Young beaver, 3-6 months old obtained from Algonquin Park, were used in the laboratory in preference to older animals. They were maintained separately in pens with a lining of brick and galvanized iron and an asphalt flooring. Each pen was provided with a tub of galvanized iron containing water. An artificial lodge, which served both as a den for the beaver and as a suitable habitat for the beetles, was situated at one end of and above the tub of water.

The essential feature of the artificial lodge was the presence of a vertical wall of earth and peat enclosed in heavy galvanized wire screening (one-inch mesh) in contact with the platform on which the beaver rested and with its base in water to provide a moisture gradient in the earth. In the lodge design finally adopted, this earthen wall formed the back of a cubic enclosure (Fig. 1-2). The floor, roof and two sides of the enclosure were made of wood (faced with galvanized sheet iron to prevent its destruction by the beaver), while the front was a curtain of burlap sacking.

Adults of *L. validus* could not be retained satisfactorily in this construction, and in 1957 were kept in damp earth and peatmoss in a porcelain container (approximately two feet in diameter and one foot high). The upper edges of this container were curved inwardly to prevent the adults from climbing out. Humidity was kept relatively high by watering the earth frequently and by covering the container with nylon cloth. The adults were fed by placing a beaver in the container for a few hours. When the beaver was removed, the adults were combed out of the fur and returned to the container. The temperature of the room in which the beaver and the container were kept was usually maintained between 50 and 60°F.

Adults, when fed *in vitro,* were kept in Erlenmeyer flasks and screw-cap vials and provided with a substrate of either damp earth or absorbent paper. Larvae fed experimentally on various materials were maintained in stender dishes on moist absorbent paper. The beaver skin to be used in experimental feeding was coated on the flesh side with a concentrated solution of aureomycin and deep-frozen immediately after removal from the animal. When needed, inch-square pieces were cut off and the hair was clipped short. These pieces of skin were replaced with fresh samples after two or three days use. Mature larvae were provided with moist earth for pupation.

Adults of both species were marked by tearing small portions from the posterior margins of the elytra. Living adults of *P. castoris* were sexed and examined for gonadal development by observing the genital structures with transmitted light at 50X magnification. The individual to be examined was held between two microscope slides; the weight of the top slide was sufficient to prevent movement without damaging the insect. Adults of *L. validus,* anaesthetized with carbon dioxide, were sexed without magnification by differences in the shape of the elytra. Gonadal development of *L. validus* adults could be determined only by dissection.

Larvae and adults of both species were fixed and stored in 70% alcohol. Illustrations were prepared from such material and from specimens that had been treated with cold 10% KOH for 24-28 hr and cleared in glycerin. Eggs and pupae were fixed and stored in 10% formalin. Illustrations of the latter were made from living material.

Description of the Stages of *L. validus*

Adult (Fig. 16, 17)

Uniform reddish-brown. Head and body broad, dorso-ventrally compressed. Dorsal surface, antennae, palpi, and most of ventral surface densely clothed with short setae; legs clothed with slightly longer setae in addition to a few longer tibial and tarsal setae. Head prognathous, semicircular, rounded anteriorly, with narrow, crescent-shaped labrum; posterior edge truncate dorsally, with tubular postero-ventral extension fitting into notch in prothorax. Antenna composed of eleven segments; basal segment twice as long and somewhat wider than any subsequent segments; segments two to seven filiform, eight to ten somewhat moniliform, last segment fusiform. On each posterior corner of head just below lateral edge is a circular (about 70 μ in diameter), convex, transparent area of cuticle, which Horn (1882) called the eye. Externally this structure shows no evidence of facets, although it is similar in appearance and position to the eyes of the Amblyopinini (Staphylinidae) (Seevers, 1955), and may be a vestigial compound eye. Ocelli absent. Mandible flat, subcircular (Fig. 13), apex produced medially into a slender, weak, bifid process; median edge fringed with a submarginal row of fine setae. Maxilla well developed; tip of lacinia triangular (Fig. 14), bearing a patch of stout, hooked setae surrounded with finer, straight setae (Fig. 15); galea terminating with a dense brush of fine curved setae; palpus four-segmented. Mentum broad, flat, each posterior angle produced into a long, sharp-pointed projection. Prothorax broad, shield-shaped, notched ventrally to receive head. Prosternum produced posteriorly to form a long, narrow, spear-shaped flap, fringed with setae extending ventral to the globose, anterior coxae, and bearing at its distal end a tuft of long, strong setae. Mesosternum similarly developed but smaller, and armed with shorter setae; metasternum without posterior process. Elytra broad, flat, firmly attached to one another along their median edges; those of female broader than those of male. Wing reduced to a minute peg (0.4 mm long) near postero-lateral corner of metapleuron. Mid- and hind coxae flattened. Tibiae with stout lateral and terminal spines. All tarsi with five segments; fore and mid-tarsi with numerous fine setae ventrally, hind tarsi with spurs. Abdomen with eight visible segments dorsally and six visible segments ventrally, barely or not at all projecting beyond elytra in female, one to two segments projecting in male, particularly in mature males.

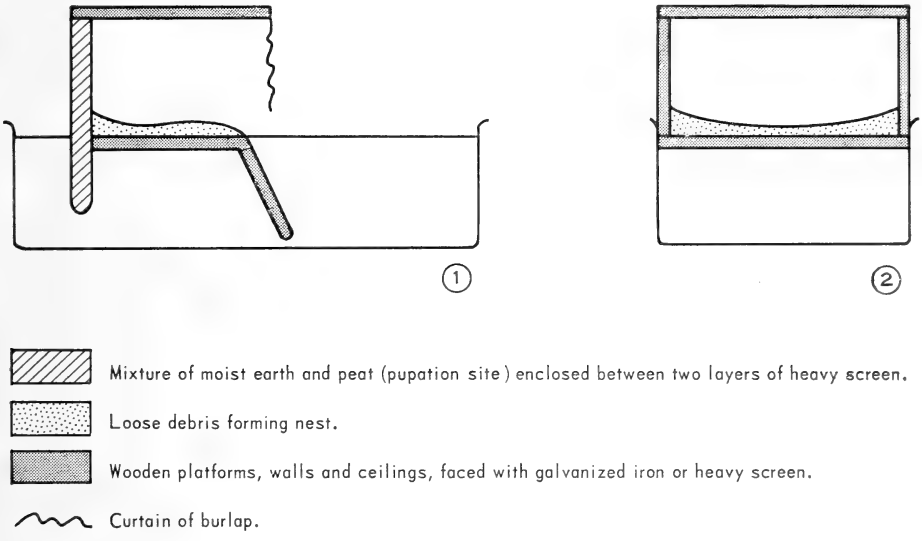
External genitalia of male similar to those of *Leptinus testaceus* as illustrated by Sharp and Muir (1912). Internal genitalia consisting of four testes, four pairs of long, coiled accessory glands arising, together with two long vasa deferentia, from anterior end of ejaculatory duct; each vas deferens terminating in two short vasa efferentia, each bearing one spherical testis. The spermatheca of the female is not sclerotized.

Pupa (Fig. 18-20)

Length approximately 5 mm, white, somewhat translucent. Dorsal surface of the head, pro- and mesonotum and abdomen with sparsely distributed short, fine yellowish spines each arising from a small tubercle. A small outgrowth apparent in dorsal view beneath each elytron (Fig. 18-R) represents the rudimentary second pair of wings. A pair of simple spiracles present laterally on dorsal surface of first and second abdominal segments.

Larva

The number of larval instars of *L. validus* was determined from a frequency distribution of measurements of the widths of the head capsules of a series of 182 larvae (all the preserved specimens then available). These measurements fell into three distinct groups indicating three instars (Fig. 3). This was confirmed by rearing experiments described in the next section. The mean head width for 100 first instar larvae was 0.45 mm, for 34 second instar larvae was 0.62 mm, and for 48 third instar larvae was 0.81 mm. The mean head width of the second and third instars increased over the previous instar by a factor of approximately 1.3, and thus the



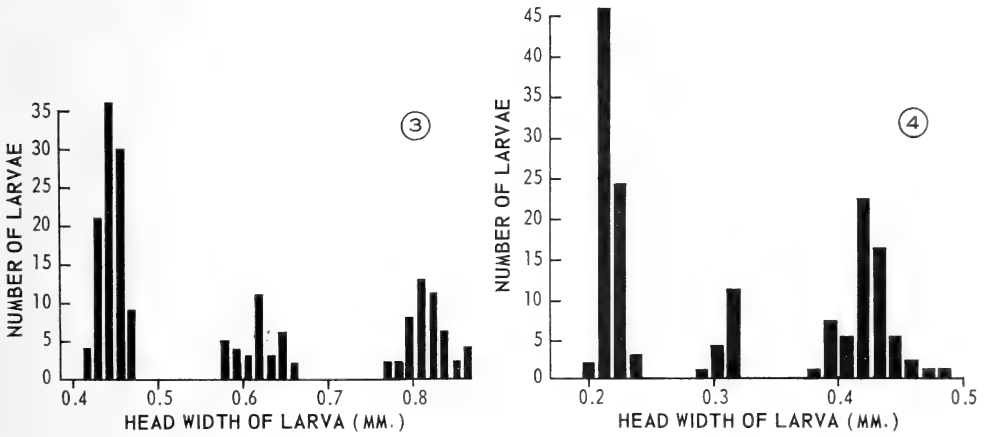
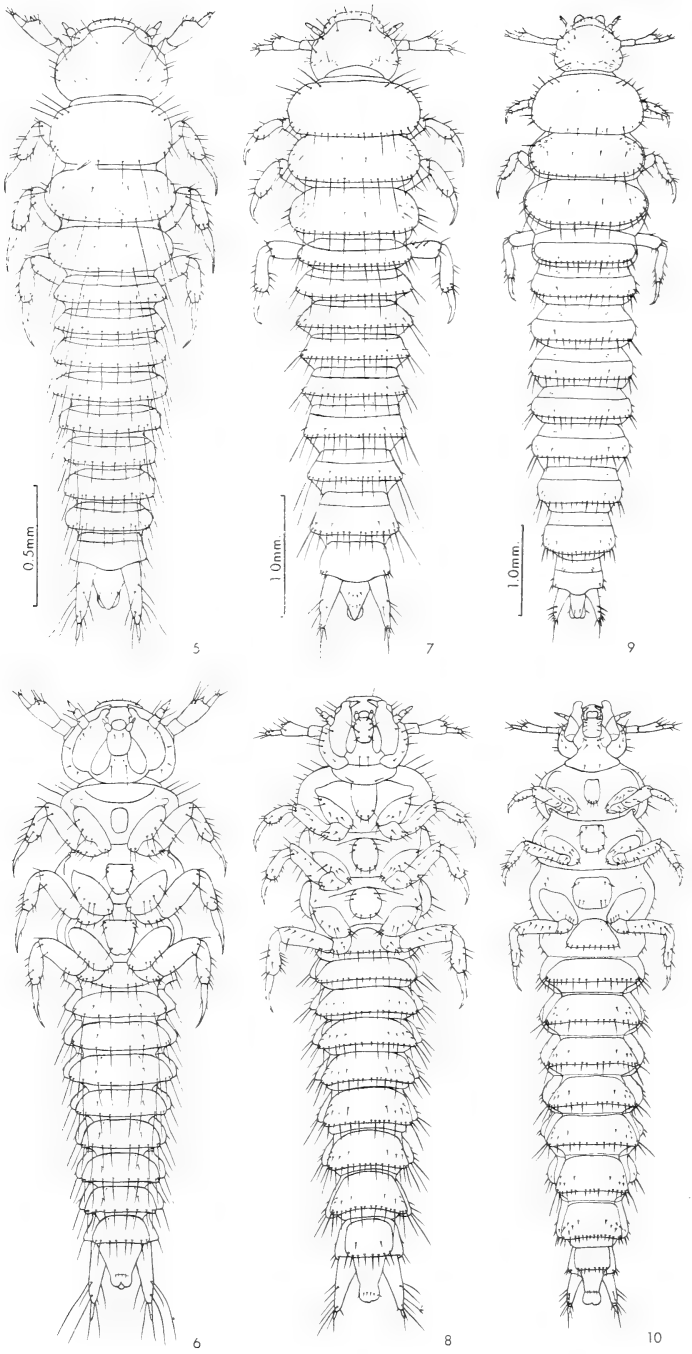


FIG. 1. Diagram of longitudinal section through artificial beaver lodge suspended from rim of galvanized tub containing water.

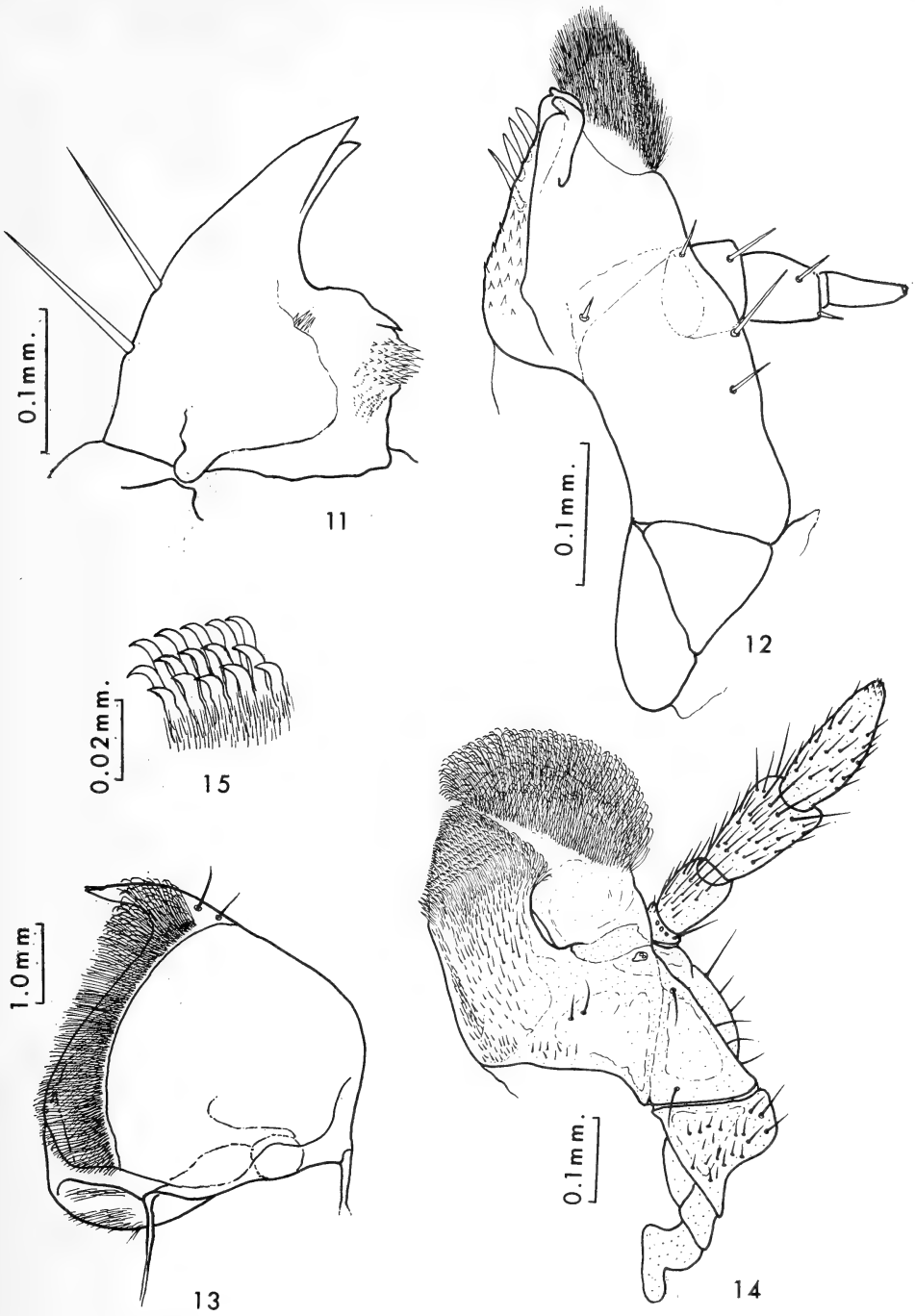
FIG. 2. Cross-section of same.

FIG. 3. Histogram of head widths of 182 larvae of *L. validus*, showing three instars.

FIG. 4. Histogram of head widths of 151 larvae of *P. castoris*.



FIGS. 5-10. Larvae of *L. validus*. 5. Dorsal view of first instar. 6. Ventral view of first instar. 7. Dorsal view of second instar. 8. Ventral view of second instar. 9. Dorsal view of third instar. 10. Ventral view of third instar.



FIGS. 11-15. Mouthparts of *L. validus*. 11. Ventral view of right mandible of third instar larva. 12. Ventral view of left maxilla of third instar larva. 13. Ventral view of left mandible of adult. 14. Ventral view of left maxilla of adult. 15. Enlarged ventral view of portion of distal end of lacinia of adult, showing rows of recurved spines.

growth of the head conforms to Dyar's rule (cited in Imms, 1957). The only figures of the larva are by Parks and Barnes (1955) and appear to represent the third instar.

The dorsal and ventral aspects of the three instars are illustrated in Fig. 5-10 to show changes in the relative proportions between various parts of the body as the larva matures. Thus, Fig. 5, 7, 9 show that the width of the head is greatest in proportion to the body in the first instar and least in the third, while the antennae and legs become longer and narrower in successive stages. The setae, particularly on the abdomen, become more numerous with each moult but do not increase appreciably in length. In

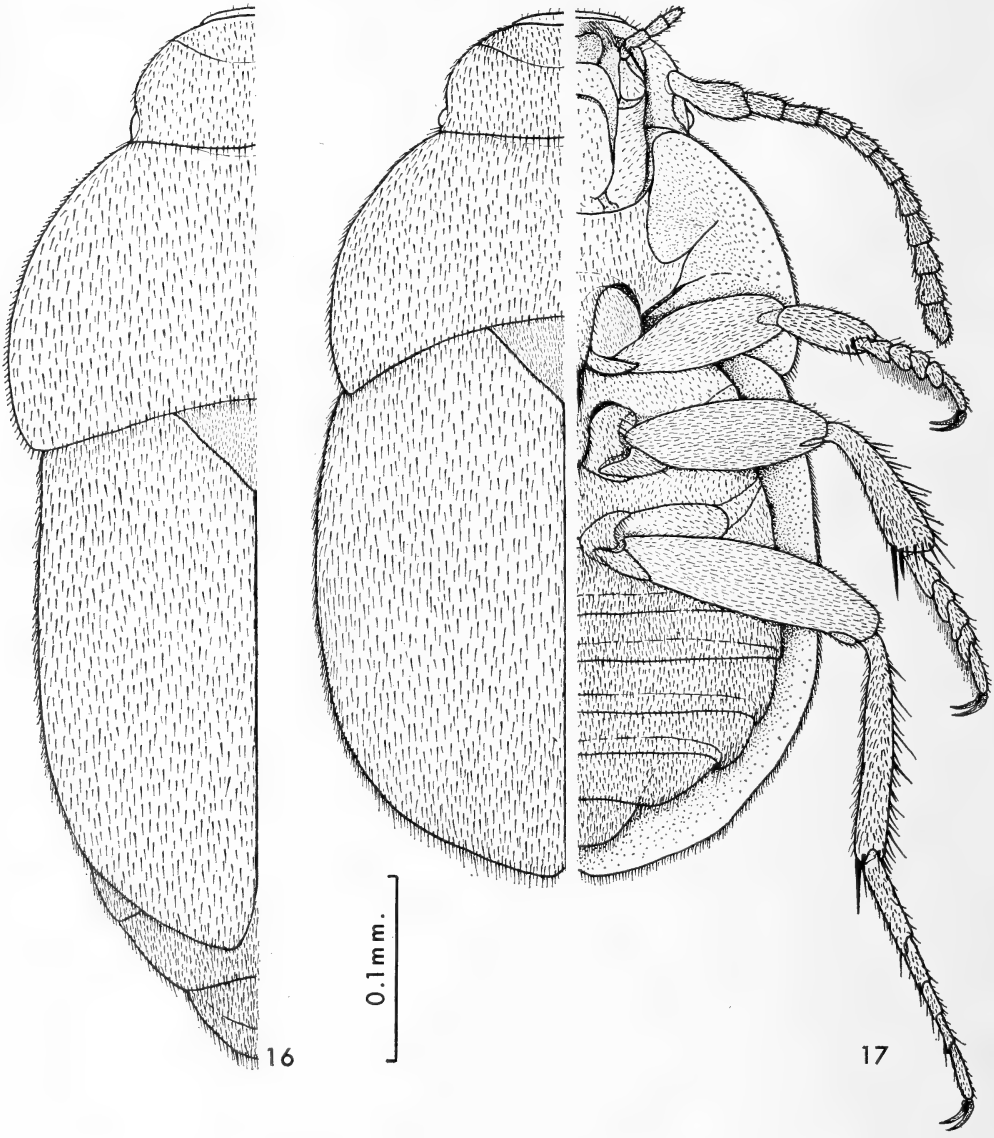
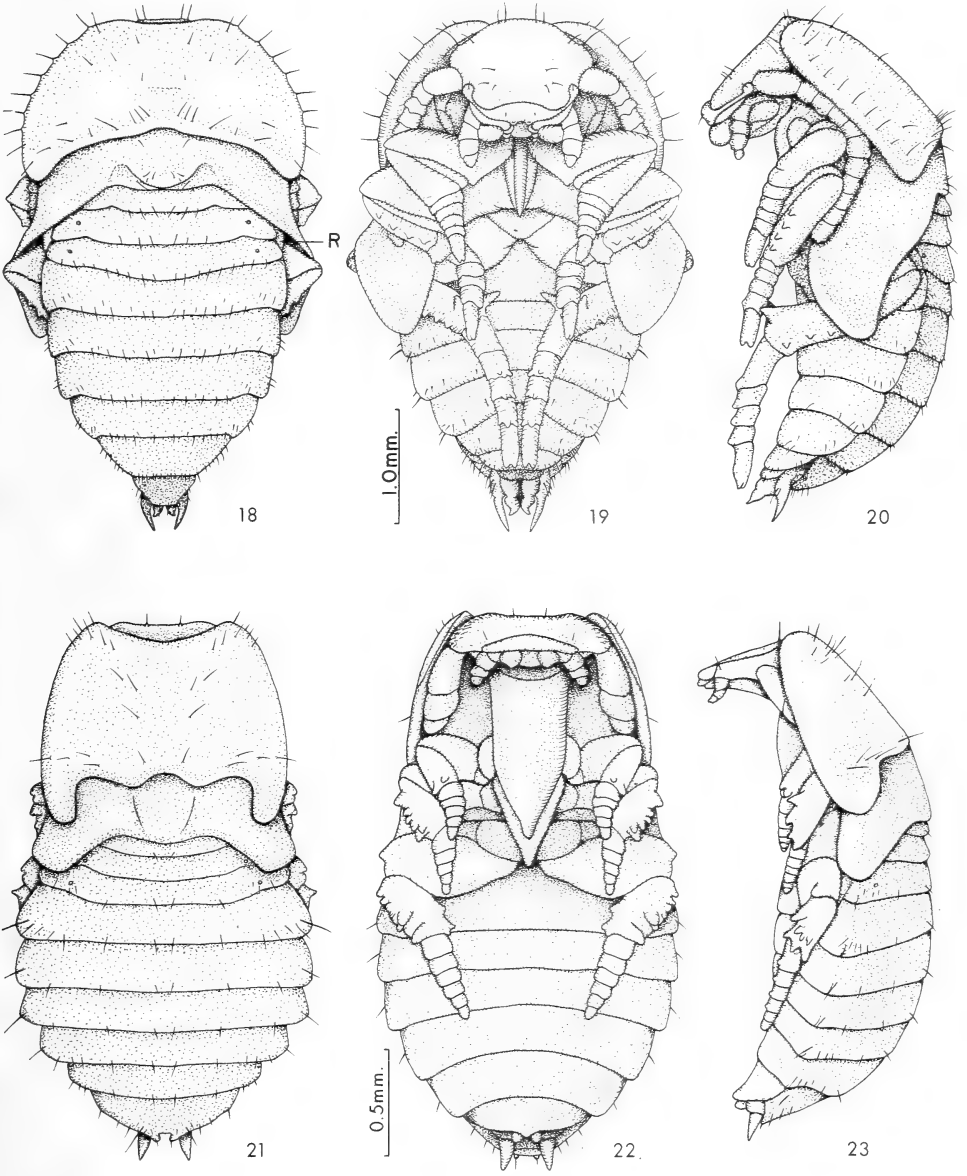


FIG. 16. Dorsal view of left half of adult male of *L. validus*.
FIG. 17. Dorsal view (left) and ventral view (right) of adult female of *L. validus*.

proportion to the body therefore, they become much shorter. The arrangement of the setae may vary on the tergites and sternites of the first nine abdominal segments and some specimens show slight asymmetry. The pattern of setae of the head capsule, antennae, legs, thoracic sternites and urogomphi is more uniform in the three instars even though individual variation occurs within an instar.



FIGS. 18-20. Pupae of *L. validus*. 18. Dorsal view (R-rudimentary methathoracic wing). 19. Ventral view. 20. Lateral view of left side.

FIGS. 21-23. Pupae of *P. castoris*. 21. Dorsal view. 22. Ventral view. 23. Lateral view of left side.

Third Instar (Fig 9, 10)

Colour white to pale yellowish-brown. Head nearly circular above, with slight postero-lateral angles; head width three-fifths that of pronotum; setae on dorsal surface confined to marginal region; eyes absent. Antenna three-segmented, slender, greatest width approximately one-sixth of length, situated on a lateral prominence at side of head; length approximately two-thirds width of head; first segment short, cylindrical, without setae; second segment longest, with an anteriorly directed enlargement bearing a small conical projection and three large setae; terminal segment small, cylindrical, bearing four small, subterminal setae and a terminal group of minute setae. Labrum with row of short setae on anterior margin. Mandible (Fig. 11) with a vestigial retinaculum and molar area; lateral edge bearing two stout setae; apex bifid, strongly sclerotized. Maxilla (Fig. 12) well developed; lacinia somewhat spoon-shaped, bearing two fixed, blunt teeth at distal end and more proximally a row of four stout setae borne along dorsal edge; median surface of stipes with 15-20 minute spines; galea paddle-shaped, concave ventrally, with a dense fringe of long hair-like setae along entire edge and with similar setae scattered over dorsal and ventral surfaces; maxillary palpus three-segmented; length approximately equal to maximum width of maxilla. Labium small, ligulae simple, without spines; palpus small, two-segmented. Pro-, meso- and metanotum each with a border of short and long setae on lateral and posterior margins; central portion with two to four small setae (Fig. 9). Prosternum small, with two pairs of small setae on posterior margin; meso- and metasternum (Fig. 10) larger, each with four pairs of setae. Antero-ventral corner of mesothorax bearing a spiracle. Legs long, slender, with similar setal pattern on all three pairs; coxa conical, with row of four to five prominent spines on anterior surface; femur and tibia cylindrical, each with numerous setae; tarsungulus long, slender, bearing two small setae at the midpoint. Abdomen with ten segments, tapering uniformly from thorax to last segment; tergites one to eight, each with a posterior marginal row of 20-26 large and small setae arranged more or less alternately (Fig. 9) but frequently showing slight asymmetry; disc of tergites one to eight bare except for one (on anterior segments) to three (on posterior segments) pairs of small lateral setae; setae on tergite nine restricted to four on each of the lateral corners; sternite one subtriangular, with posterior marginal row of approximately ten to fourteen subequal setae; sternites two to eight similar to corresponding tergites, except that number of setae varies from 14 to 22 and setae in each row are more uniform in length; sternite nine with posterior marginal row of eight to ten setae. Segment ten small, tubular, bearing a subterminal row of four small setae on dorsal and on ventral surfaces. One pair of spiracles on each of abdominal segments one to eight, situated ventral to postero-lateral corners of tergites. Urogomphus two-segmented; length of distal segment less than one-quarter the length of proximal segment; distal segment bearing a stout, terminal seta; proximal segment with about seven stout, lateral setae.

Second Instar (Fig. 7, 8)

The arrangement of setae of second instar similar to that of third instar. Proportions intermediate between first and third instars, but more closely resembling the latter.

First Instar (Fig. 5, 6)

In external morphology similar to third instar except as follows. Head proportionally large, almost as wide as pronotum, with six to eight pairs

of slender setae on dorsum. Antenna stout, greatest width approximately one-quarter or more of length. Thorax and abdomen with fewer setae, symmetrically placed. Pronotum with three pairs of setae in antero-lateral corners and a posterior marginal row of five pairs of setae. Meso- and metanotum each with a postero-lateral marginal row of seven pairs of setae and a submarginal row of two pairs of setae. Abdominal tergites one to eight similar, with posterior marginal row of five pairs in addition to a submarginal row of two pairs of smaller setae; an additional lateral pair of small setae present on tergites four to seven; tergite nine with two pairs in postero- lateral corners. Prosternum without setae; meso- and metasternum each with three pairs of lateral setae. Abdominal sternite one with two to three pairs, sternites two to eight each with five pairs, and sternite nine with four pairs of posterior marginal setae; sternites two to eight each with a single pair of smaller submarginal setae. Setae on legs and urogomphi similar in arrangement to those of third instar.

Life History of *L. validus*

The life history of *L. validus* was determined from observations made in the field and from a study of beetles kept *in vitro* and with beaver maintained in artificial lodges. The stages (larvae, pupae, and adults, but no eggs) of *L. validus* found in the 55 lodges examined in Algonquin Park at different times of the year, and their approximate abundance, are recorded in Table I.

In October only first instar larvae were present, in January all three instars were encountered, while in March last instar larvae were predominant. In March 1957 all the larvae recovered were in the last instar, and most were recovered from the earth in the top of the lodge rather than from the nest.

Larvae of this species were found only during the winter months, except for a single instance in which 14 small larvae were found in June

TABLE I. Occurrence of stages of *L. validus* in beaver lodges throughout the year in Algonquin Park, Ontario.

				No. lodges examined	
Date	Larvae	Pupae	Adults	Beetles present	Beetles absent
Oct/55	—	—	—	0	1
March/56	xxx	—	—	2	0
May/56	—	—	—	0	5
June 1-10/56	14*	xx	—	3 (1)	4
June 11-20/56	—	xx	xx	4 (1)	7
June 21-30/56	—	—	xx	1 (1)	1
July-Sept/56	—	—	xxx	14	4
Oct/56	xxx	—	xx	6 (4)	2 (1)
Jan/57	xx	—	—	1 (1)	0
March/57	xxx	—	—	2 (2)	3
June/57	—	—	xxx	5	1

*—This lodge had been opened previously in March 1956 and left open. It is probable that beaver did not occupy it after this time.

x—Small numbers present (under 25).

xx—Approximately 100-500 of this stage present.

xxx—Numerous individuals present. (1000 or more).

Numbers in brackets indicate the number of lodges which had been examined on a previous occasion.

1956 in a lodge that had been opened previously in March 1956 and left open. Probably the beaver did not occupy the lodge during this period.

Pupae were recovered in June in the earth in the top of the lodge. Lodges were not examined in April and early May; pupae may have been present during these months. Each pupa was found within a spherical chamber in the earth, located two to six inches below the outside surface.

The adults emerged at approximately the same time in early June in 1956. The soft cuticle on all the adults recovered from three other lodges at approximately this time also indicated recent emergence. From late June to September, only adults were encountered in the lodges. During this time, they clustered on twigs and grass hanging from the ceilings of the lodges; sometimes more than 1000 beetles per lodge were present. During this period their gonads remained undeveloped. In October 1956 the beetles were in the nest, their gonads were mature, and numerous small larvae were present in one of the lodges. In the remaining three lodges, however, the beetles, still with immature gonads, were clustered on the ceiling. It was assumed, because of the beetles' need for food described below, that beaver had not been present in these three lodges during the summer.

The abundance of larvae and adults of *L. validus* on living and dead beaver trapped in Algonquin Park at various times is summarized in Table II. A comparison of these data with those in Table I shows that adults and larvae of *L. validus* were present on the beaver in the fur at the same time of the year as in the lodges.

TABLE II. Number of *L. validus* and *P. castoris* recovered from beaver trapped throughout the year in Algonquin Park, Ontario.

	L. validus		*P. castoris*		No. beaver examined	
Date	Larvae	Adults	Larvae	Adults	Beetles present	Beetles absent
Feb/56	x	x	—	x	4	0
June/56	—	1	12	64	6	2
July/56	—	1	8	13	2	4
Aug/56					0	2
Sept/56	—	6	26	68	14	3
Jan/57	x	x	—	x	3	1
July-Sept/57	—	—	—	7	2	2

x—denotes the presence of this stage, numbers not determined.

Observations and Experiments in the Laboratory

Uninfested beaver, maintained in the laboratory, built nests in the artificial lodges described above. By infesting these nests, lodges, and beaver, with adults and larvae of *L. validus*, it was possible to confirm and extend field observations concerning their life history. Thus the association between the beetles and their host was studied throughout the year and provided the information that follows.

Food, Feeding and Development of the Larva

To obtain information on the food of the larvae, first instar larvae were given continuous access to a young beaver, or were fed *in vitro*, using various materials as food. The first instar larvae used in these feeding experiments were obtained from an artificial lodge approximately 25 days after the beaver in it had died; presumably these larvae had no access to a beaver.

Over 100 previously unfed larvae were placed with a young beaver in an artificial lodge that was kept in a room between 55 and 65°F. Many of these larvae reached the last instar in 16-25 days, but were not yet fully grown. One fully grown larva and more than 20 pupae were recovered from the earth in the top of the artificial lodge after an additional 15 days. It was concluded that larvae would attain full growth in the presence of a beaver.

To determine whether beaver skin alone would sustain larval growth, an additional 100 unfed first instar larvae were reared in stender dishes on pieces of skin from which most of the hair had been removed. Larvae of all three instars, when offered pieces of fresh beaver skin *in vitro,* would feed readily around the edges of and on the surface of the skin. In the feeding process, the maxillae were extended, applied to the skin and brought together. The material thus scraped off was passed into the mouth by the mandibles. When offered skin on which the underfur was still present, the larvae entered the fur, and appeared to feed in a vertical position with the head and thorax buried in the fur.

During these tests, the larvae were kept at 55°F for 20 hours each day, and at 75°F for the remaining four hours. This alternation of daily temperatures was adopted because larvae fed most readily at 75°F, while survival was better at 55°F.

Nearly all of these larvae died shortly after the beginning of the experiment from an unknown cause (one or two dark spots appeared within the affected larvae several days before their death), but two larvae reached the second instar in 25-26 days, and the third instar in 6-10 additional days. Neither of them, however, formed prepupae.

Another group of 15 first instar larvae was also kept in stender dishes on the same diet under the same temperature conditions. They reached the second instar in 6-10 days. However, these larvae had been taken from an artificial lodge that housed a beaver, and presumably the larvae had access to food previously. Each of these larvae moulted into the third instar in 8-10 days, but died before becoming prepupae.

A third group of ten second instar larvae obtained from an artificial lodge were kept in stender dishes as above. They reached the third instar in 2-9 days, and formed prepupae in 33-41 days. These prepupae died before pupating.

The foregoing data indicate that development *in vitro* of the first instar required 25-26 days, of the second 6-10 days and of the third 33-41 days; a total of 61-77 days for the growth under the conditions specified. This period is twice as long as that (approximately 25-35 days) required for full growth of those larvae that had continuous access to beaver. Too few larvae were reared successfully *in vitro* on beaver skin to permit critical comparison, but the results indicated that beaver skin, separated from the host, will sustain limited growth allowing the larva to pass through one complete stadium.

Larvae of *L. validus* were also given access to various other materials (blood, insect body fluids and tissues, muskrat skin, and decayed vegetation) which might be encountered within a beaver lodge, to see if these would enable them to survive and grow. Over 100 larvae of all three instars were fed mouse blood daily, until they died. Beef, beaver and human blood were also tried, and although each was eaten by the larvae, these materials were difficult to obtain and were not tested satisfactorily. Twenty-five first instar larvae were fed crushed larvae of *Tenebrio, Attagenus* and *Leptinillus* daily (each type every third day). The body fluids of these

larvae, provided they were fresh, were readily consumed. Ten second instar larvae were provided every other day with pieces of muskrat skin (which had been treated similarly to the beaver skin mentioned above). This material was eaten in the same manner as was the beaver skin, although not as readily. Hundreds of larvae of all three instars were kept at room temperature and at 40°F in wet decayed moss, earth and peat taken from beaver lodges in Algonquin Park.

None of the larvae that was offered blood, crushed larvae, muskrat skin, or decayed vegetation either moulted or showed other signs of growth. Most of the larvae died in two weeks or less; those fed muskrat skin and kept at room temperature survived up to a month and those at 40°F somewhat longer. Evidently, larvae cannot survive on a diet of mouse blood alone (many of them became trapped in this material); the blood of other species and the diets of crushed larvae and muskrat skin require further testing.

Effects of Temperature on Fully Grown Larvae, Prepupae and Pupae

Larvae, in all stages of development, were recovered from the nests of beaver lodges in January and March in Algonquin Park. In March, most of the last instar larvae were apparently fully grown. They were found in the earth in the top of the lodge. No pupae were found until June, however, and adult emergence apparently took place during a few days in early June. These observations suggest that continuous development may be inhibited by low temperature.

Studies were made in the laboratory to determine if such inhibition occurred, whether the larva, prepupa, or pupa was affected, and what temperature would permit resumption of development. Fully grown, active, third instar larvae were obtained from the earth in the top of a beaver lodge in Algonquin Park in late March and held at temperatures ranging from 32 to 60°F until further development took place (Table III).

TABLE III. Duration of prepupal and pupal stages of *L. validus* at various temperatures.

Temp °F.	No. of days in each stadium		
	Third instar larva	Prepupa	Pupa
32-35	215 + (20)	—	—
40	20-25 (10)	15-20 (10)	50-60 (10)
50-60	2- 5 (20)	8-11 (10)	14-24 (30)
75			5- 8 (6)

Numbers in brackets indicate the number of individuals, in some cases combined from several groups of larvae.

Fifty of these third instar larvae were kept near freezing (32-35°F). As long as this temperature was maintained, the larvae continued to move about slowly in the earth in the dish, but failed to become prepupae. To determine if some of these larvae were capable of pupation after prolonged exposure, three groups of ten were removed to higher temperatures after one, two and three month intervals (in April, May and June of 1957). These pupated and emerged as adults. The remaining 20 larvae were left at 32-35°F and five of these survived for nine months, yet did not become prepupae. It appears, therefore, that larvae, after completing their growth,

and migrating to the earth in the top of the lodge, remain in the earth as larvae until the temperature of the earth becomes warm enough for development to be resumed. The temperatures recorded within the chambers and adjacent earth of beaver lodges in January 1957 in Algonquin Park were 28-30°F, which would inhibit pupation.

Two groups of 10 and 20 third instar larvae (respectively) from the same source were maintained at 40°F and at 50-60°F, to determine the effect of temperature on prepupation. Larvae kept at 40°F formed pupal chambers and became prepupae within 20-25 days. Apparently, the thermal threshold for development is between 35 and 40°F.

On the basis of these observations, larvae can be expected to burrow into the earth to pupate if the temperature is above 40°F but are unlikely to do so below this temperature. This process (and the subsequent formation of the pupal chamber) has been observed *in vitro* in one instance when larvae were placed in a glass dish containing earth at room temperature. The larva burrowed into packed earth (adjacent to the glass), initiating and enlarging a spherical chamber by dorso-ventral, lateral and twisting movements. The diameter of the chamber was a little less than the length of the larva. No additional substance lining the inner walls of the chamber could be detected. After the chamber had been completed (in about two days) the larva assumed the arched form of the prepupa.

The remainder of the fully grown larvae, described in the previous section, were allowed to complete their development to provide information on the duration of the prepupal and pupal stages. The duration of the prepupal stage is here defined as the time from the formation of the prepupa (when the third instar larva assumes an arched position and becomes inactive) until the third larval skin is moulted and the pupa appears. To follow the development, larvae were given only a small amount of earth in which to pupate, and each was relocated at regular intervals for observation, until the prepupa had been formed. At 32-35°F, as already stated, prepupae were not formed. Development at higher temperatures is summarized in Table III. At about 40°F the pupae moved little, even when disturbed, but at higher temperatures they actively rotated their abdomens. At approximately 75°F development was rapid (5-8 days), but many pupae did not become completely free of the larval skin and most died before completing development. The six adults that did emerge failed to expand their elytra successfully and four of these had other deformities of the head and abdomen.

Food and Feeding Habits of the Adult

The stomachs of adults that had been denied solid food since their emergence, and of those that had been taken from beaver or beaver lodges and then starved for a month or more, contained only a brownish fluid. These adults when hidden in a container of earth in the laboratory or in the nest of a beaver lodge, were quickly activated and brought to the surface by blowing on that surface, or by moving the hand or a stick through the medium. The adults ran actively over the surface for several minutes, and appeared to move toward the source of the disturbance.

When starved adults were introduced into the fur of a beaver for a few hours and then dissected, the stomachs were packed with small, dull, whitish particles, which resembled particles of skin. When these fed adults were kept alive for a day *in vitro*, and then dissected, the particles in the stomach had a shiny, flaky appearance, presumably having been modified by digestion.

On the second day after feeding, dissections revealed that the remaining solid material of the meal had passed out of the stomach into the hind-gut. This material was egested almost completely on the third or fourth day after feeding, but a few particles usually remained in the hind-gut. These remaining particles had a characteristic appearance and their presence indicated that the beetle had previously fed. Occasionally adults fed on loose particles of beaver dandruff that were offered to them *in vitro*.

It was suspected that the fatty substances in the dandruff were attractive to the beetles. Therefore, a small quantity of fresh dandruff removed from beaver was soaked in ether. The ether was evaporated and the extract and the extracted dandruff particles were each offered to adults *in vitro*. The extract was eagerly eaten but the extracted particles no longer possessed any recognizable attractiveness. This suggested that the ether-soluble portion contains the substances necessary for food recognition. It was also noted that the extracted dandruff resembled, in its shiny, flaky apearance, the partially digested particles seen in the adult gut two or three days after feeding in the fur of a beaver.

Feeding of adults was observed to determine the manner in which the mouthparts were used. On large pieces of skin the maxillae were extended, applied to the medium and retracted, in a "grazing movement". This movement apparently drew the rows of hooked spines on the ventral surface of the lacinia (Fig. 15) over the surface of the skin, scraping material from it. Smaller particles were picked up by the maxillae and passed into the mouth by the mandibles. The mandibles protrude only slightly, if at all, beyond the labrum; their use in picking up material was not observed. Occasionally, a particle was passed back and forth several times in and out of the mouth.

Attempts were made to determine whether adults would feed on substances other than dandruff. Beef, mouse, beaver, and human blood were readily accepted *in vitro*. Beaver faeces, crushed mealworm larvae (*Tenebrio*), and decayed vegetation were not eaten. Occasionally, beetles would apply their mouthparts to the surface of the faeces, but the mouthparts were not moved; presumably they were merely taking moisture.

During the study, over 100 adults (a sample of ten from each lodge opened, as well as all those obtained from beaver (Table II) were dissected. Particles resembling dandruff were the only solid material present. The guts of some of the adults from a few of the beaver that had been wounded when trapped contained a pale red fluid, presumed to be blood, although this was not demonstrated. The mouthparts of the adults of *L. validus* seem unadapted for causing more than superficial abrasions, however, and it is unlikely that blood is normally available to them.

Relation Between Food and Gonadal Development in the Adult

After it was established that food was taken by the adults, it seemed important to determine whether feeding was necessary for attainment of sexual maturity.

At the time of emergence, the adults of *L. validus* are sexually immature, and the gonads are too small to be located readily among the fat bodies. In the summer of 1956, ten adults were kept in vials on moist paper without food. These adults lived for more than four months without developing mature gonads, suggesting that some food is necessary for gonadal development. To determine what food is necessary, and whether beaver dandruff is sufficient, over 2000 adults were used in various feeding experiments.

Gonadal development in males was determined by measuring the diameter of the testes. Testes with an average diameter of over 0.55 mm were considered mature (the greatest diameter recorded was 0.68 mm). Females were considered mature when their ovarioles containd fully developed eggs.

An initial experiment was carried out on 29 October 1956 using 575 adults that had been obtained from a beaver lodge in Algonquin Park the week previously. A sample of ten of each sex indicated that no gonadal development had taken place (average diameter of the testes was 0.36 mm and average length of the egg tubes, which did not contain eggs was 0.28 mm).

Five hundred of these unfed adults were placed in an artificial lodge in the laboratory with a young, uninfested beaver. One month later, numerous small first instar larvae appeared in the artificial lodge indicating that the experimental population of adults had undergone gonadal development and that eggs had been deposited. The controls (55 adults) were kept in moist earth and peat but had no access to a beaver. Most of the controls were dead and none had shown any increase in gonadal development by the time larvae had appeared among the experimental group. These results point strongly to the necessity of food (of beaver origin) for gonadal development.

The following summer, this type of experiment was repeated in an attempt to show that food of beaver origin was required for gonadal development to the exclusion of other substances which might be present and used as food, also to determine approximately how many feedings would be required to obtain full development. The adults used in this test were a group of 1400 that were collected on 9 July 1957. Their previous history was unknown, but examination of a sample of ten of each sex showed that the gonads were undeveloped (testes averaged 0.25-0.28 mm in diameter, and the egg tubes of the female measured 0.20-0.35 mm in length with no evidence of developing eggs). Three hundred of these adults were maintained in moist earth and peat in a large porcelain container, into which a young beaver was admitted for a few hours at intervals of one to three weeks. After each exposure (the first was made on 15 July 1957), the adults were combed from the fur and restored to the porcelain container, and five beetles were dissected to determine if feeding had taken place. Initially, the beaver was placed with the beetles once a week, but not all of the adults in the sample were fully fed.

It was concluded that not all the adults fed every week, so that after the seventh week, the exposures were made every 16 days for 20 weeks. When exposed in this way, all the adults in the sample had fed, and it was assumed that the remaining adults had fed also.

Although the males showed considerable testis development towards the end of this period, no appreciable development was noticed in the females and therefore for the remainder of the experiment (7 weeks) exposures were made weekly.

Altogether, this experimental group received 24 feedings totalling 200 hours exposure to a beaver. After the fourteenth feeding (and after approximately 130 hours) the measurements of the testes of a sample of five males exceeded 0.55 mm; in one individual they approached 0.65 mm. Each sample dissected after subsequent feedings also showed mature testes, indicating that the males had reached maturity. No adults were alive a week after the twenty-fourth feeding (more than eight months

after the initial feeding). None of the females developed viable eggs, although average lengths of the egg tubes increased three to four times during the course of the experiment.

The remaining 1100 adults were set up in five groups on 16 July 1957. They were maintained in large Erlenmeyer flasks on various substrates. One group of 200 (sexes equally divided) was maintained in earth and peat, and a quantity of hair and dandruff that had been combed from a beaver at least a week previously was added to the flask at weekly intervals. This was done to simulate conditions of available food that might be present in an abandoned lodge. On 20 September, after nearly all of them had died, five males and five females were dissected. Gonadal dvelopment had not progressed beyond that shown by the original sample. In all but three of these, the hind-gut contained a few dandruff particles suggesting that the adults will eat dandruff after it has been removed from the host, but either the quality is poor, or the quantity is insufficient for gonodal development. A second group of 200 was maintained in earth and peat alone. All were dead by 20 September, before any dissections were made.

A third group of 200 was kept in washed sand and provided, every second day, with fresh beaver faeces. Occasionally adults would apply their mouthparts to the surface of this material, apparently taking moisture, but no attempts to feed (i.e., to use the maxillae) were observed. A fourth group of 400 adults were kept in washed sand, receiving no food. From each of these two groups, a sample of five of each sex was dissected on 20 September, but no gonadal development had taken place.

The foregoing four groups were kept at room temperature as was the experimental group between feedings. To determine if a higher temperature alone would induce gonadal development, a fifth group of 100 adults, kept in washed sand without additional food, was placed for a few hours a day in an incubator at approximately 90°F for a total of 41 hours between 16 July and 27 August. These daily exposures to high temperature were discontinued after 27 August because most of the beetles had died. On 20 September, only four males and one female were alive, and dissection showed that the gonads were smaller than in the sample measured on 16 July.

When it became apparent (in late November 1957) that the males of the experimental group exposed to the beaver were approaching full sexual development, all adults in the control groups that still remained alive were dissected. None of these showed any gonadal development. These observations lead to the conclusion that skin products, both loose (dandruff) and attached (epidermis) from the fur and skin of a live beaver, form the chief item of diet of the adults and that the gonads, at least in the male, and probably also in the female, will develop to maturity following a diet of this material alone and will not develop in the absence of food. They also indicate that epidermal material, to be effective as food, must be procured from the fur of a living host. Possibly some other, yet undetected, material is available to them which may also facilitate gonadal development.

Suitability of Muskrat as a Host for L. validus

Fourteen muskrats (*Ondatra zibethica* (L.)) from Algonquin Park were examined in 1956 and 1957. Two of these (in September 1956) were infested with two and six adults, respectively, of *L. validus*. To determine if adults would survive in the fur of this animal, 50 starved beetles were introduced into the fur of a muskrat that apparently did not harbour *L. validus*. Only two adults were recovered the following day. The stomach

of one of these was partially filled with dandruff particles. Presumably a muskrat entering a beaver lodge containing adults of *L. validus* may become infested and the adults may feed on the dandruff particles present in the fur. However, further investigation of the relationship between *L. validus* and muskrat is necessary before conclusions can be drawn.

Observations on Mating

Copulation was only observed among adults that were sexually mature. Even males, in which the testes were probably fully developed, did not attempt to mate with females that were sexually immature. Among groups of adults fed experimentally on beaver in which the males became mature before the females, copulation apparently did not take place until the ovarioles of the females (judged from a sample of five) contained well-developed ova. Mating pairs were observed both in the fur of the host and in the lodge.

Description of the Stages of *P. castoris*

Adult

The adult has been described and figured by many authors, notably Westwood (1874), Desneux (1906), and Bugnion and du Buysson (1924), and it is unnecessary to redescribe it here. The adult of *P. castoris* cannot be mistaken for any other known species. Several features concerning the mouthparts, however, require clarification, particularly with respect to feeding habits.

The structure of the maxillae is shown in detail by Westwood and Desneux *(loc. cit)*. The importance of the hooked setae, on the ventral surface of the distal portion of the galea, should be emphasized in reference to feeding (Fig. 33, 34).

Westwood (1874) found no trace of mandibles. Leconte (1872) described them as three-segmented structures, and Horn (1882) supposed that they were present only in some individuals. Desneaux was the first to describe them accurately, as thin, rudimentary plates lying dorsal to the maxillae. In the present study, several dissections of both sexes revealed their presence and confirmed Desneaux's description. Their structure (Fig. 35) is unlike that of the mandibles of the adult of *L. validus,* however, and strongly suggests degeneration and probable loss of function.

The external genitalia of the male, described and illustrated by Sharp and Muir (1912), are smaller but otherwise similar to those of *L. validus.* The internal genitalia, as in *L. validus,* consist of two pairs of spherical testes and four pairs of long, slender, coiled accessory glands, all arising near the distal ends of the vasa deferentia. The spermatheca of the female is sausage-shaped and sclerotized.

Pupa (Fig. 21-23)

Length 2.5-3.0 mm, white, somewhat translucent. Dorsal surface with short, fine, yellowish spines distributed as in Fig. 21. Profile of head is distinctive (Fig. 23). Antennae apparently three-segmented. Eyes lacking. Prosternum broad. Elytra small, quadrate.

Larva

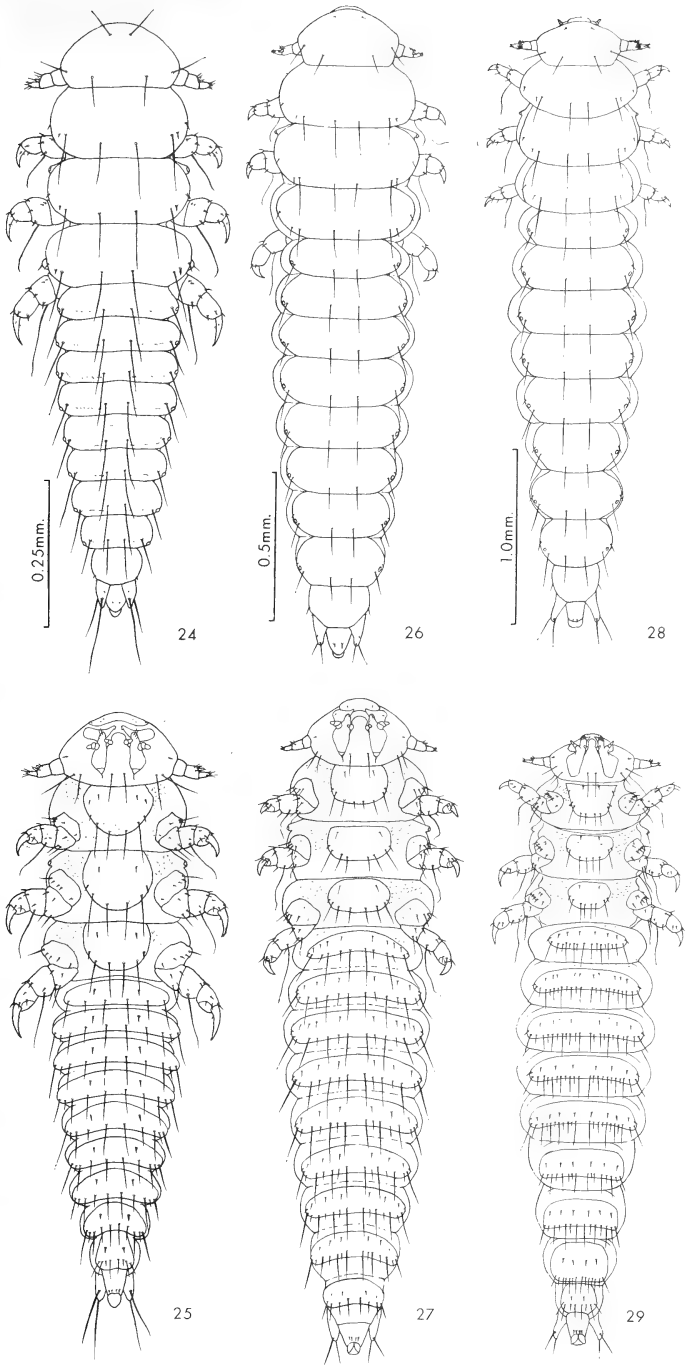
Measurements of the head widths of 151 larvae of all sizes (Fig. 4) indicate that the larva of *P. castoris* passes through three stages. The larva of this species has been described and figured by several authors (Chobaut, 1899; Desneux, 1906; Horn, 1888; Riley, 1889, 1890a), but the instar in each case was not indicated.

Changes in proportion between various parts of the body, similar to those discussed for the three instars of *L. validus*, are evident in this species. The head is proportionately smaller in successive instars, while the legs and antennae become longer and narrower, the second instar shows intermediate conditions, although resembling the third instar more closely. The arrangement of the setae is more constant among instars and among individuals of the same instar in this species, particularly those of the thoracic tergites, head, urogomphi and ninth abdominal segment. All of the setae, except the pair on the anterior region of the dorsum of the head, and the terminal pair on the urogomphi, double their length from the first to the third instars.

The mandibles have been described by Böving and Craighead (1930) as having the apex bent away from the sagittal plane, and the larva of *P. castoris* was separated from other species in their paper on this character. A study of over 150 whole, unmounted larvae of all three instars indicated that the apex of the mandible is hooked but that it is bent ventrally (away from the coronal plane of the larva) and cannot be observed from the dorsal or ventral aspect unless the specimen is flattened, which causes the mandibles to rotate slightly out of position. In a lateral view of the head of the second instar of *P. castoris* (Fig. 30), the ventrally curved apex of the mandible is apparent. The possible significance of this structure will be discussed below in connection with feeding.

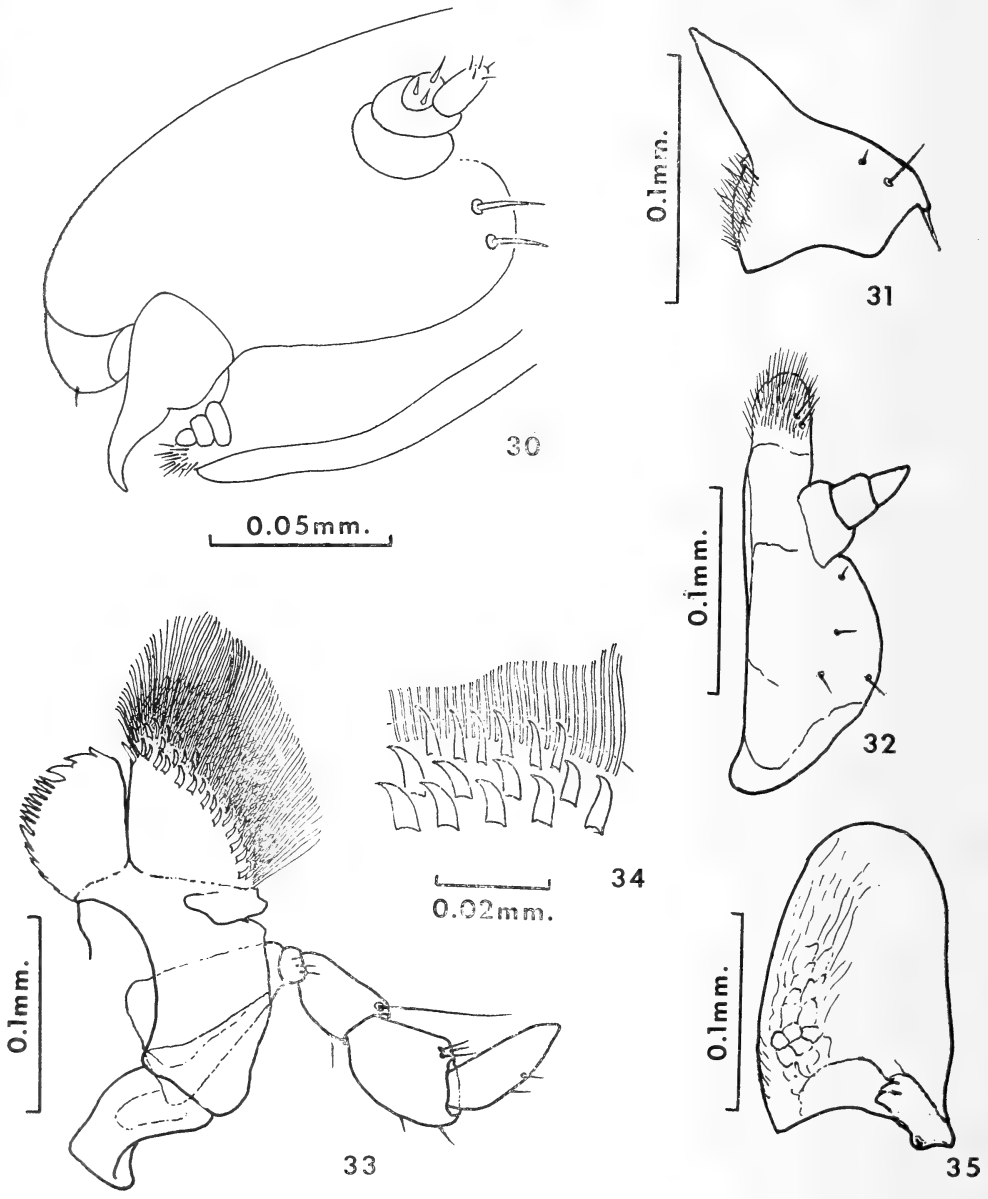
Third Instar (Fig. 28, 29)

Length 3-4 mm. Colour white or nearly so. Head rounded apically, truncate posteriorly; above with two pairs of setae near posterior margin, one smaller pair at anterior margin; below with one lateral pair and one median pair of postero-lateral setae. Antenna three-segmented, stout, short, cylindrical; segments approximately equal in length; second segment bearing three small, conical projections and four short setae distally; distal segment one third or less width of proximal segment, bearing four minute setae distally. Labrum with a pair of small setae on ventral surface. Mandible with a fringe of setae on molar area, retinaculum not evident (Fig. 31); distal half heavily sclerotized, stout, conical; tip of mandible decurved ventrally. Galea of maxilla with dense brush of setae distally (Fig. 32); maxillary palpus short, stout, three-segmented. Labium simple, without spines; palpus small, two-segmented. Posterior margin of pro-, meso-, and metanotum each with one large median pair and a large and two small lateral pairs of setae. Pro-, meso-, and metasternum trapezoidal, each with one small anterior pair, one small lateral pair, and four pairs of posterior marginal setae. Antero-ventral corner of mesothorax with a spiracle at end of a short papilla. Legs relatively short and stout, longer and more slender than in preceding instars; each with similar pattern of setae; coxa with an oblique row of five large setae; trochanter distally with a pair of setae,median seta long and fine, arising from postero-ventral corner; femur with an even longer, frequently curled, ribbon-like seta arising from posterior margin of ventral surface; tarsungulus apparently lacking setae. Tergites one to eight each with a spiracle below postero-lateral margin, each with one median and one lateral pair of long setae (absent on tergite one) antero-lateral to spiracle; tergite nine with only a small lateral pair of setae. Abdominal sternites one to eight each with a transverse central row of three to six pairs of small setae, usually asymmetrically arranged, and a posterior marginal row of six to eight pairs of long setae interspersed with short setae, frequently asymmetrical; a small median seta (not shown in Fig. 29) often present; sternite nine



FIGS. 24-29. Larvae of *P. castoris*. 24. Dorsal view of first instar. 25. Ventral view of first instar. 26. Dorsal view of second instar. 27. Ventral view of second instar. 28. Dorsal view of third instar. 29. Ventral view of third instar.

with only two setae in central row, four pairs in posterior marginal row. Segment ten with two pairs of small subterminal setae on both dorsal and ventral surfaces. Urogomphus one-segmented, bearing two long terminal setae.



FIGS. 30-35. Mouthparts of *P. castoris*. 30. Lateral view of left side of head of second instar larva. 31. Ventral view of left mandible of third instar larva. 32. Ventral view of left maxilla of third instar larva. 33. Ventral view of left maxilla of adult. 34. Enlarged ventral view of distal edge of galea of adult. 35. Ventral view of left mandible of adult.

Second Instar (Fig. 26, 27)

Length 1.8-2.5 mm. Not differing appreciably from third instar except in size and as follows. Decurved tip of mandible proportionally large, not heavily sclerotized (Fig. 30). Galea of maxilla with fewer shorter setae distally. Abdominal sternites with 6-12 small setae in discal row, usually not symmetrically arranged (Fig. 27), and with seven or eight pairs of posterior marginal setae, more or less symmetrical, alternating long and short; this row frequently with a small, submedian seta (not shown in Fig. 27).

First Instar (Fig. 24, 25)

Length 0.7-1.0 mm. Similar to third instar except as follows. Head proportionally larger (Fig. 24), more rounded anteriorly. Decurved tip of mandible more prominent, proportionally larger, not heavily sclerotized. Galea of maxilla with fewer, shorter setae. Legs proportionally shorter, stouter. Thoracic sternites large, sub-circular; each lacking one pair of large setae from posterior marginal row. Abdominal tergites two to eight lacking pair of short setae antero-lateral to spiracles; tergites one to eight each with small crenulate ridge between the large median and lateral setae on each side. Abdominal sternites one to eight with single pair of small discal setae and with three (on sternite one) or five (on sternites two to eight) pairs of setae in posterior marginal row.

Life History of *P. castoris*

Field Observations

A search for the stages of *P. castoris* was made concurrent with the field observations on *L. validus*. In 1956 and 1957, 55 beaver lodges and 45 beaver were examined in Algonquin Park. The data, in Table II, indicate that adults of *P. castoris* occur in the fur of over 60% of beaver throughout the year and that larvae were present on them at least during the summer, from June to September (and until December on a beaver kept in captivity). Except for a newly emerged adult found in the nest of a lodge in early October 1955, specimens of *P. castoris* were not found in beaver lodges in Algonquin Park.

Oviposition and Egg Development

Horn (1888) stated that the eggs of *P. castoris* are laid on the skin of the host, but gave no further details. Riley (1890b) did not believe that the objects described by Horn were eggs of *P. castoris,* although he gave no reason for this view. He described eggs that were taken from the oviduct of a female of *P. castoris* as being flattened on two sides. He suggested that their structure indicated that they might be either fastened to the skin, or inserted under the scales of the skin.

No eggs of *P. castoris* were found in the fur or on the skin of beaver during this study, although the skins of several recently deceased animals, known to harbour adults of *P. castoris,* were searched for eggs with the aid of a dissecting microscope.

Eggs were readily obtained *in vitro,* however, from gravid females that had been removed recently from the fur of the host. In an effort to determine whether eggs, oviposited on paper *in vitro* would develop when placed on the skin of the host, 13 recently deposited eggs were transferred to a small area of skin on the top of the head of a young beaver. After four days, only one egg was recovered. It had not collapsed, but its contents had become dry and hard.

A single egg of *P. castoris* was located in the nest of a young beaver known to harbour gravid females. On another occasion, a gravid female was found beneath a beaver that was resting on a wooden platform. In an effort to determine whether gravid females would leave the host to oviposit in the nesting material and then return to the host, a young beaver, known to be carrying gravid females, was placed on top of about fifty short sticks (that had been previously soaked in boiling water to destroy anything already present) in an earthenware container. After six hours, the beaver was removed and the sticks examined for eggs. Eleven eggs, which later hatched, were located in crevices at the ends of three of the sticks. No female beetles remained in the bottom of the container. This evidence indicates that the gravid female of *P. castoris* leaves the host to oviposit in the lodge, returning to the fur of the host after oviposition has been completed.

Over 200 eggs were laid on paper by 21 females *in vitro* between May and November 1957. All of the females that oviposited *in vitro* had been recently removed from the fur of the host, usually less than one and not more than two days previously. The number of eggs produced at one time, including a few relict eggs in the oviduct, by a single female varied from 10 to 26. When ovipositing on paper, the head was lowered and the posterior half of the abdomen bent downward at right angles to the body. The egg was slowly extruded on the paper, and after about one minute was free. The egg was soft, opaque, and white with a viscid coating, to which the fibres of the paper became attached. The following day this coating was no longer adhesive, the shell was firmer, pale yellowish brown, and somewhat translucent. Ten eggs from one female averaged 0.40 mm (0.38-0.42) in length and 0.26 mm (0.23-0.29) in width. This is similar to the measurements of eggs obtained by Riley (1890b). The majority were ellipsoidal in long axis and circular in cross-section.

Egg Development

At 70-75°F a small whitish mass, about half the diameter of the egg, was discernible within the egg on the third day; on the fourth day, the embryo could be seen curled about the yolk mass. The embryo rapidly enlarged, filling the cavity within the shell, and hatching occurred on the fifth to sixth day. Development of ten eggs at an average temperature of 57°F (45-64°F) required 31-33 days.

The hatching process of over fifty eggs that had developed at room temperature (70-75°F) was observed. Hatching could be readily induced by gently prodding the surface of the shell with a probe. Before hatching, the larva was coiled dorso-ventrally with the posterior segments folded beneath the head. The mandibles were clearly visible through the shell, and by moving the head backwards, the larva brought the mandibles in contact with the shell and after three or four short nodding movements, the shell was torn and the head and anterior half of the thorax were extruded. The antennae and legs were free and the larva crawled rapidly out of the open end of the shell, assisted by peristaltic movements of the body. The process required only 10-15 seconds. When the head was extruded from the shell, small bubbles of air passed down the oesophagus forming a single larger bubble in the midgut region. As soon as the larva was free of the shell, it ran about without difficulty for five to ten seconds becoming motionless for a minute or two while continuing to swallow air, and then resumed activity. The large bubble in the midgut became smaller, and disappeared five to ten minutes after hatching.

Food and Feeding Habits of the Larva

Only first instar larvae (probably newly hatched) and fully grown larvae were recovered from the artificial lodges; larvae intermediate between these could only be obtained by combing them from the fur. These observations indicated that the larvae of *P. castoris* spent all of their time, between hatching and completion of growth, in the fur of the host, and that feeding evidently took place there also. All attempts to feed larvae *in vitro,* on beaver skin, blood, and body fluids of crushed *Tenebrio* larvae, were unsuccessful. Larvae were observed making what were interpreted as feeding movements, however, on the surface of the skin of a recently deceased beaver. The larvae attacked both unbroken skin and around the edges of scabby areas, and at times seemed to be trying to force their way under the scabs by vigorous serpentine movements. The antennae moved rapidly during the procedure. This behaviour differed from that associated with intake of fluid, when the body and antennae were kept motionless.

Lesions on the Skin of the Host

The skin of the back, particularly in the region of the shoulders and spine of three beaver (under one year old) that were harbouring several hundred larvae of *P. castoris,* was covered with many small, exuding lesions, resembling abrasions. Some of the lesions were fresh, and the capillaries were exposed. Others were encrusted with dried, serous exudates. There was no evidence of active purulence. Two of the beaver died (on 15 July 1956 and 15 November 1956—apparently from an unrelated cause) at the time that these lesions were present. The skin, after removal, showed small dark spots on the flesh side, corresponding to the lesions on the outside, and the sites of some of the larger lesions were rather dry and hard, as if infiltrated with scar tissue. The third animal remained alive for more than a year after the lesions were first noticed. The lesions disappeared as the number of larvae decreased, only to reappear the following July, when the animal again was supporting numerous larvae of *P. castoris.* Since the presence of several hundred larvae and the lesions were coincident (neither lesions nor such large numbers of larvae were found on any of the other beaver that were examined during the study), it was suspected that lesions were a result of the feeding activities of numerous larvae. These three infested beaver were often examined, and many adults and larvae were found repeatedly in the neighborhood of the lesions. The sharply-pointed mandibles (Fig. 30) of the larvae appear capable of initiating a lesion. Probably, once the surface of the skin has been broken, the larvae continue their feeding activities, thus enlarging the lesions and preventing healing.

Food of the Larva

The stomach contents of most of the larvae that were dissected contained droplets, apparently of a fatty nature, as they dissolved readily in xylene and stained with Sudan III. Presumably these came from fatty secretions of the skin. In addition, the stomachs of most of the larvae contained a mass of small whitish particles that were presumably skin particles similar in appearance to, but smaller than, those obtained from the stomachs of adults and larvae of *L. validus.* Piechocki (1959) also noted these particles and concluded that they were of epidermal origin.

Prepupal and Pupal Stages

Observation of larvae on captive beaver in artificial lodges indicated that larvae, when fully grown, leave the host and, if the temperature is not too low, climb into the earth in the top of the lodge where they form a

chamber and become prepupae. The pupal chamber is similar to, although smaller than, that of *L. validus*. Its diameter is a little less than the length of the larva, and the inner walls are smooth.

The prepupal stage is characterized by the dorso-ventrally arched, fully grown larva which has lost the ability to use its legs. Six prepupae, kept at 54F (51-56°F) with a few extreme temperatures between 48-60°F formed viable pupae in 9-10 days.

Although pupae were never recovered from beaver lodges in Algonquin Park, 14 were found in the earth in the side of an artificial lodge, in which the volume of earth was sufficiently small to enable the entire contents to be examined. None was located in the loose nesting material on the floor, nor recovered from the fur of any of the beaver examined. It seems likely that the normal pupation site is in the earthen roof of the lodge.

The duration of the pupal stage for seven pupae *in vitro* at 50-56°F was 17-22 days. At approximately 60°F, the combined time of development of both prepupal and pupal stages for five individuals was 11-12 days.

Survival of Larvae at Low Temperatures

Lawrence, Hays and Graham (1961) found larvae of *P. castoris* throughout the year in the upper peninsula of Michigan, although Janzen (1963) did not find larvae during winter or spring at Hastings, Minn. No larvae of *P. castoris* were recovered from eight beaver examined in Algonquin Park in February 1956 and January 1957, and larvae were apparently not present on three beaver kept in the laboratory during these months. To determine whether fully grown larvae of *P. castoris* would form prepupae and pupate when subjected to a low temperature, six larvae (considered to be fully grown because they were recovered from the earth of an artificial lodge), were maintained in earth at 32-35°F, beginning on 15 August 1957. Nine days later, all but one were dead, but the remaining larva lived until the middle of October (two months) without becoming a prepupa. As a control, six larvae from the same source were maintained in earth at an average temperature of about 52°F. All of these pupated and emerged as adults, suggesting that larvae of *P. castoris,* when subjected to freezing temperatures, were unable to develop further.

Behaviour of the Adult

As noted previously, the pupal stage is passed in the earth in the lodge. Pale, newly-emerged adults, which *in vitro* do not darken completely for at least a week after emergence, were frequently found in all parts of artificial lodges from which beaver had been removed from one to two weeks previously. Only one adult, that appeared to have emerged recently, was recovered from a lodge in Algonquin Park. In another instance, three older adults, all females, were recovered from artificial lodges. One of these females was gravid, the second contained one relict egg, and the third contained no eggs, but its spermatheca contained sperm and the oviducts were enlarged suggesting that it had just oviposited. This evidence supports the view that newly emerged adults after reaching the fur of the host remain there for the remainder of their life, except when they return temporarily to the nest to oviposit.

As is the case for *L. validus,* the adults of *P. castoris,* when removed from the host, are strongly attracted to the human breath and will attempt to climb anything they contact. In the fur, the adults move rapidly, using a shuffling movement of the second and third pairs of legs. The backwardly projecting spines on the tibiae of these legs are used to gain purchase on the hair, while the tarsi and tarsal claws seem to play a minor role. The forelegs are used in a forward and backward movement, using the tarsal

claws (which are curved in contrast to the relatively straight claws of the second and third legs) for catching the hairs. The adults have little difficulty in moving about on paper and can climb on rough surfaces, but seem incapable of walking on a glass-like surface; usually they turn upside down and cannot right themselves.

When on the host, the adults are able to remain within the underfur, which always remains dry, even though the outer layer of the fur may be wet. Perhaps the assumption that the fur of the beaver becomes wet to the skin prompted Jeannel (1922) to describe the modifications of the adult of *P. castoris* for swimming. Adults of *P. castoris* float when placed in water and are killed by immersion.

Food of the Adult

Adults were frequently observed applying their mouthparts to wet surfaces, apparently taking water. No activity that could be interpreted as feeding movements were observed, however.

No adults *in vitro* lived for more than three weeks and none developed mature gonads, whereas their life span on the host was much longer (as shown below) where, supposedly, some food must be taken.

The gut of one male adult contained a red fluid which appeared to be blood, but this was not determined conclusively. The stomachs of all other adults dissected contained either a colourless liquid, or a few to many pale, yellow droplets, similar to those found in the guts of most of the larvae examined. These droplets dissolved readily in xylene and stained with Sudan III. No solid material, such as skin debris, was recognized although Janzen (1963) found particles which he interpreted as loose epidermis. The stomachs of adults that had been kept on paper *in vitro* without food for a week or more contained only a colourless fluid. The fatty droplets, usually present in the stomachs of adults recently removed from a beaver are thought to be oily skin secretions. When lesions were present as a result of larval feeding, adults were also prevalent in their vicinity and may also take some of the exudates from these lesions.

Food in Relation to Development of the Gonads

At emergence, the gonads are undeveloped. To determine approximately how much time was required for the development of mature gonads, adults, which had emerged *in vitro,* were placed in the fur of a young beaver which was apparently free of *P. castoris.* Fourteen adults, marked by tearing a small portion from the distal edge of the left elytron, were placed on this beaver on 18 September 1957 and 11 more, marked on the right elytron, six days later. On 23 October 1957 seven marked males and two marked females were recovered. Each of the females laid 20 eggs *in vitro* during the hour after removal from the beaver and the males examined by transmitted light all appeared to have mature testes. These adults were all returned to the host the same day. Evidently, gonadal development may take place in 36 days or less.

On 29 November 1957 a marked female was recovered in gravid condition a second time (the torn pattern of the elytron matched a sketch made of one of the females that oviposited on 23 October). This female laid 26 eggs *in vitro* and was returned to the beaver but was not recovered again. This constitutes the only evidence for more than one gonotrophic cycle.

Adults kept *in vitro* for two weeks after emergence showed no inclination to mate. Mating was observed, however, on two occasions prior to oviposition. Pairing was attempted *in vitro* but was only successful in a small mass of loose fur.

Discussion

This study has shown that both larvae and adults of *L. validus* derive food from the epidermis of beaver, and that other substances, often available in the lodge, apparently fail to support growth of the larva or reproductive development in the adult. Of the foods tested, the fresh epidermis of beaver was a preferred substance readily available to them under natural conditions in inhabited lodges. In addition, their morphological modifications such as the flattened form of the body, the reduced eyes, and their almost complete association with beaver and their lodges indicate an ectoparasitic status.

Evidence obtained in this study has also shown that *P. castoris* is closely associated with its host, and that contact with the external environment occurs in the egg and pupal stages, and only briefly in the larval and adult stages. The morphological modifications of the adult for existence as an ectoparasite are pronounced and include loss of the eyes, shortening of the antennae, flattening of the body, reduction of the wings, and presence of a ctenidium. The available evidence suggests an even closer relationship to the host than that shown by *L. validus*.

Significantly, the other members of the Leptinidae are also associated with other species of rodents and insectivores. However, *Leptinus testaceus*, in addition to its most common association with small mammals, has sometimes been found in the nests of wasps and bumble bees and has been taken under litter, apparently not associated with a host (Jeannel, 1922; Paulian, 1943; Reid, 1942; Rüschkamp, 1921). Both the larva and adult of this species are similar to the corresponding stages of *L. validus*, and future work may show that *L. testaceus* and other species of *Leptinus* also feed on epidermal tissue of small mammals, as has been suggested by Jeannel (1922) and Rüschkamp (1914, 1921). The latter author noted the capacity of the adult of *L. testaceus* to survive for long periods without food which would account for their occasional appearance unassociated with a mammalian host. This capacity has already been noted for the adults of *L. validus*.

Another small group of beetles, the tribe Amblyopinini of the Staphylinidae, has been taken in the fur of rodents and marsupials in South America (Seevers, 1944, 1955). The habits of members of this group seem to be analogous to those of the Leptinidae, but they appear to be specialized staphylinids and their similarity to leptinids is probably convergent.

The origin of the leptinids, including their ectoparasitic habit, may possibly be traced to the Catopinae (Anisotomidae), a group of small beetles that have been recovered from carrion, and from the burrows of several species of mammals in Europe and North America (Jeannel, 1936; Hatch, 1933). Jeannel (1936) suggests that these Catopinae are commensal, feeding on debris accumulated by the mammal and perhaps also on its excrement. Benton and Wilcox (1955) review older records of the association of *Catops* with nests of mice and shrews, and with owl pellets and record the presence of *Catops* on recently trapped mice. Many adults and several larvae of *Catops* sp. were found during the present study feeding on faeces of marten, *Martes americana* (Turton), in Algonquin Park. These larvae strongly resemble those of *L. validus* (except that the urogomphi are longer and annulated). An adult male reared from these larvae was dissected and, although the accessory glands were not found, the two pairs of testes present were arranged like those of *L. validus* and *P. castoris*. Crowson (1955) revealed the common presence of antennal pits in the

adults of Anisotomidae and Leptinidae, which have not been found in other Coleoptera. These similarities indicate a close relationship between the two groups and suggest a way in which coprophagous or saprophagous forms associated with carrion, excrement or the nests of mammals can give rise to ectoparasitic forms, dependent on the skin products of mammals.

Summary

1. The egg, larva and pupa of *Leptinillus validus* (Horn) and *Platypsyllus castoris* Ritsema and the adult of *L. validus* are described and illustrated.

2. *L. validus* is univoltine, the adults emerging in early summer in Algonquin Provincial Park, Ontario. After repeated experimental feedings on epidermal material of beaver, the gonads of the male became mature. In nature, gonads of both sexes were usually mature in late summer.

3. Larvae of *L. validus,* hatching from eggs laid in the beaver lodge, spend part of the winter in the nest on the floor of the lodge, periodically entering the fur of the host to feed on epidermal material. When fully grown, larvae climb to the top of the lodge, pupating in the earth there when the temperature becomes suitable (averaging between 35 and 40°F in the laboratory).

4. The eggs of *P. castoris* are laid in the beaver lodge, and pupae are formed in the earth at the top of the lodge. When not seeking an oviposition or pupation site, or a host, larvae and adults appear to live continually in the fur of the beaver. Food appears to consist of the skin products of the host.

5. Larvae of *P. castoris,* when present in hundreds on one host, appear capable, as a result of their feeding, of inflicting superficial abrasions on the host's skin. The adult of this species and all the stages of *L. validus,* however, seem harmless to the host.

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THE DISTRIBUTION OF TIGER BEETLES IN ONTARIO
(Coleoptera: Cicindelidae)

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Introduction

The publication of *The Cicindelidae of Canada* (Wallis, 1961) was a great step toward a more complete understanding of the taxonomy and distribution of this family in North America. Although this book includes numerous Ontario records, several species are not as well represented as one might wish. In the distribution of *Cicindela hirticollis,* for example, there is a "gap" between Point Pelee and Lake Nipigon, while, in fact, this species is actually quite common along the shore of the Great Lakes.

My wife, Anne, and I have collected tiger beetles in this region for some time (Graves, 1963). In order to compare Ontario distributions with those known from Michigan, we made several collecting trips through parts of the province. In addition, the following have kindly provided Ontario records: Patricia Vaurie, American Museum of Natural History, New York, N.Y. (AMNH) ; H. S. Dybas, Chicago Natural History Museum, Chicago, Ill. (CNHM) ; Henry Dietrich, Cornell University, Ithaca, N.Y. (CU) ; D. M. Davies, McMaster University, Hamilton, Ont. (McM) ; J. F. Lawrence, Museum of Comparative Zoology, Cambridge, Mass. (MCZ) ; O. L. Cartwright, United States National Museum, Washington, D. C. (USNM) ; W. W. Judd, University of Western Ontario, London (UWO).

Ronald L. Huber generously provided the Minnesota records for *C. longilabris* and *C. scutellaris* from his unpublished manuscript on the Cicindelidae of Minnesota. Wisconsin localities for *C. scutellaris* were provided by Robert Tetrault, University of Wisconsin, Madison and Walter R. Suter, Carthage College, Kenosha, Wisconsin. These data are used in the map (Fig. 1). I greatly appreciate the cooperation of these individuals who took time from their busy schedules to search out Ontario records.

Since Wallis included records of the Canadian National Collection and the Royal Ontario Museum, only the specimens of *C. hirticollis* (in which I am studying variation) were borrowed from these institutions and no new CNC record was found for this species.

C. hirticollis was studied from all the institutions mentioned except the MCZ. Other records were sent by the curators. Dr. Davies sent the McMaster specimens to me for determination. The UWO specimens were determined by Dr. Mont A. Cazier. Records from the author's collection are indicated by "RCG".

The distribution of the Cicindelidae in Ontario is of considerable interest. Several forest regions span the province, from deciduous forest in the south to arctic tundra along Hudson Bay (for details see Munroe, 1956). Few species of *Cicindela* can survive the rigorous conditions of the north. None are truly arctic insects (Downes, 1962, 1964, 1965). The adults are heliophilic, most remain inactive on cloudy days. No species have evolved the necessary cold hardiness and cold adaptation to exist in arctic situations. It seems remarkable that *C. repanda* and *C. tranquebarica,* both widespread species distributed as far south as Texas, and *C. limbalis* are able to survive along Hudson and James Bays. The "boreal" species, *C. longilabris,* is found under similar conditions, but its distribution is restricted chiefly to Canada, northern U.S. and south at high altitudes.

Thirteen species are recorded from southern Ontario, only three of which (see above), plus *C. longilabris,* survive in Patricia Subdistrict, and only one *(C. repanda)* is recorded from a tundra locality.

It is difficult to pinpoint factors responsible for limiting the distribution of *Cicindela.* Several species oviposit only in certain types of soil, under certain conditions of moisture, etc. (Shelford, 1909). At the northern distributional boundaries, we may expect isolated "islands" of acceptable conditions surrounded by large areas in which the species cannot exist. Therefore, we may expect "outliers" from the main body of the species. This appears to be the case with several Ontario species.

Notes and Records

The following is a list of Ontario species of tiger beetles with notes and records. Wallis' records are not repeated here unless of special interest. "Additional records" (not included in Wallis) are given. Counties and districts are printed in upper case type.

Cicindela repanda Dejean, 1825

This is one of the most ubiquitous of North American *Cicindela* and is common throughout the province, particularly in moist sandy situations. Wallis lists it from Point Pelee to Cape Henrietta Maria (PATRICIA), a tundra situation. Far northern records also include Attawapiskat (PATRICIA, mouth Attawapiskat R. at James Bay), listed by Wallis but not included on his map, p. 19, and Moose Factory (COCHRANE). *C. repanda,* doubtless, is found in every county and district of Ontario and there is no point in listing additional records. This common species was seen to fall prey to dragonflies on the shore of Lake Superior (Graves, 1962).

Cicindela duodecimguttata Dejean, 1825

This species is found throughout most of the province but generally on a much darker substrate than its more common relative, *C. repanda*. Either it cannot survive as far north as *C. repanda* or it has simply not been collected as well. The northern records listed by Wallis include Favourable Lake (Lat. 53° N. near the Manitoba border, PATRICIA), Ogoki (confluence Ogoki and Albany rivers on the PATRICIA-COCHRANE boundary) and Kapuskasing (COCHRANE). This species is restricted to moist situations near water. The *Cicindela maritima* group (or *repanda* group, if one prefers) is represented in Ontario by *C. repanda, duodecimguttata,* and *hirticollis*. The ecological requirements of these closely related species are subtle and not well understood. At Middlebrun Bay, Sibley Prov. Pk. (THUNDER BAY) all three species are common on the beach (RCG). But this is not often the case: usually the environment is preferential to one or the other. Additional records: KENT: Chatham (UWO); MIDDLESEX: MacGillivray Twp. (UWO), Thorndale (UWO); SIMCOE: Bradford (UWO); SUDBURY: Coniston (MCZ); THUNDER BAY: Shuniah Prov. Pk. (shore of L. Superior) (RCG).

Cicindela hirticollis Say, 1817

In Ontario this species is restricted to the sandy shores of the Great Lakes and other very large lakes (*e.g.,* Lake Nipigon). Rare individuals from inland situations probably are stragglers and do not represent breeding populations. These wanderers are responsible for spreading the species along isolated beaches where conditions are favourable. Due to the isolated nature of these populations, gene-flow is restricted and variation is pronounced. Some Ontario populations (*e.g.,* Pancake Bay) are almost immaculate (*i.e.,* lack the white elytral markings) while others (*e.g.,* Sauble Falls are about 2/3 maculated. No immaculate individuals are illustrated by Wallis but will be included in a forthcoming publication by Graves, concerning variation in this species. Additional records: ALGOMA: Batchawana Bay (RCG), Pancake Bay (RCG); BRUCE: Southampton (CNC), Sauble Beach (RCG); KENT: Rondeau Prov. Pk. (RCG); LAMBTON: Aux Sable River Cut (sand dunes) (RCG); MIDDLESEX: MacGillivray Twp. ("Northwest corner of Middlesex Co., probably from along banks Aux Sable River at a point about 6 miles from L. Huron near Port Franks"—W. W. Judd) (UWO); THUNDER BAY: Sibley Prov. Pk. (RCG); WELLAND: Empire Beach (near Crystal Beach) (CU).

Cicindela sexguttata sexguttata Fabricius, 1775

C. sexguttata is of particular interest in Ontario because of the two apparently different populations. *C. sexguttata sexguttata* is a common resident of deciduous forests in southern Ontario (south of the Precambrian Shield) and much of eastern United States. In addition to these southern Ontario specimens, Wallis cites records from Sudbury (SUDBURY) and Hymers (the only Hymers I can locate on my map is in THUNDER BAY about 20 miles west of Fort William; however, this locality is not shown on his map, p. 31). There is also a single specimen from Timmins (COCHRANE) in the McMaster collection; it does not appear different from *C. s. sexguttata* individuals from the south. Normally one thinks of this species as characteristic of the deciduous forests, especially in spring when adults are numerous, running along woodland paths and sunning on fallen logs. If the three previously mentioned records are correct, at least several populations must be found in the more northern forest

regions. More collecting may indicate the presence or absence of intergrades with *C. sexguttata denikei* Brown, 1934. It is not yet clear whether *C. denikei* is a subspecies of *C. sexguttata* or a sibling species, and more specimens from northern Ontario would be very helpful. Additional records: BRANT: Brantford (McM); HASTINGS (USNM); LAMBTON: Ipperwash (UWO); SIMCOE: Bradford (UWO); WATERLOO: Kitchener (McM); WENTWORTH: Hamilton (AMNH, McM), Troy (McM), YORK: Toronto (McM, USNM).

Cicindela sexguttata denikei Brown, 1934

No additional records have been located to add to those of Wallis, all of which are from KENORA around Lake of the Woods, and adjacent Manitoba. See discussion above under *C. sexguttata sexguttata.*

Cicindela patruela Dejean, 1825

No additional records, however, this species should be sought in localities other than the one at Constance Bay. W. J. Brown's description of the habitat (Wallis, p. 33) is identical with the typical habitat in Michigan. While uncommon in Michigan, *C. patruela* has been found in scattered localities throughout the state (Graves, 1963) and it is difficult to believe that the population at Constance Bay can be far isolated from similar populations in other parts of the province.

Cicindela scutellaris lecontei Haldeman, 1835

Common in dry, sandy areas south of the Precambrian Shield, which, in Ontario, appears to represent the northern boundary of its distribution (see map, fig. 1). Note that this species is almost completely allopatric with *C. longilabris (q. v.).* Additional records: CARLETON: Ottawa (AMNH); HASTINGS (AMNH); LAMBTON: Pinery Prov. Pk. (RCG); MIDDLESEX: MacGillivray Twp. (UWO), Strathroy (UWO).

Cicindela formosa generosa Dejean, 1831

This large *Cicindela* is found in sandy areas among sparse vegetation. It is common in the sand dunes of Pinery Provincial Park. Wallis lists it from Normandale and Walsingham (NORFOLK) and Fisher Glen (which I can't locate but appears to be in ELGIN on Wallis' map, p. 37). Additional records: ESSEX: Pelee Island (CU); LAMBTON: Pinery Prov. Pk. (RCG) where it is associated with *C. scutellaris lecontei;* LEEDS: Tar Island (in Thosuand Islands of St. Lawrence R.) (McM); MIDDLESEX: MacGillivray Twp. (UWO); NIPISSING: North Bay (CU); NORFOLK: Turkey Point (CU), SIMCOE; Camp Borden (UWO). The Pelee Island record is a new southern locality for this species in Canada, although it was to be expected. North Bay is a new northern record for the subspecies in Canada and corresponds with the northern record for Michigan (ALGER: Grand Marais, RCG). Like *C. purpurea, punctulata, scutellaris* and *lepida,* this species seems unable to survive in the far north.

Cicindela limbalis Klug, 1834

This colourful beetle might be found in every county and district in the province. It is not found in breeding populations except where the habitat is right (steep, clay banks that are either bare or sparsely covered with vegetation). Individual stragglers may be collected in other situations, illustrating the manner in which the species disperses. The steep, eroded clay banks along the north shore of Lake Erie are an ideal habitat for this stenokous species. Wallis cites Smoky Falls (50° N. on the Mattagami

River, COCHRANE) as the northern record but since it seldom is collected, it may be expected even farther north. Port Alma is a new southern locality for Canada. Additional records WENTWORTH: Dundas (McM); KENT: 5 miles west of Port Alma (RCG). There is a specimen in the USNM labelled "Charlton, Canada". This may be the Charlton in TIMISKAMING.

Cicindela purpurea Olivier, 1709

Apparently this species does not get as far north as its close relative, *C. limbalis*. Wallis lists Sudbury (not shown on his map, p. 44) and this stands as a northern record for Ontario. I have few additional records as follows: MIDDLESEX: Thorndale (UWO); MUSKOKA: Bala (McM); SIMCOE: Bradford (UWO); YORK: Toronto (MCZ). At the USNM there is a specimen labelled "Irondale, Canada" which may be the Irondale in HALIBURTON.

Cicindela longilabris Say, 1824

This is the only member of the Cicindelidae which attains the southern boundary of its distribution in Ontario. For this and other reasons it is of particular interest. Wallis does not list any localities for *C. longilabris* but from his map (p. 47) none appear to be south of MUSKOKA. *C. longilabris* is cited as a species with a "boreal range" by Munroe (1956). However it is not a good example of a "boreal species" because its distribution is not restricted to the spruce-fir forest. In Ontario, *C. longilabris* extends southward roughly to the southern boundary of the Precambrian Shield. It is common in both the Boreal Forest (spruce-fir) and the Hemlock-White Pine-Northern Hardwoods Region of Braun (1950).

The distribution map (Fig. 1) indicates that *Cicindela longilabris* and *C. scutellaris* are largely allopatric with a relatively narrow area of overlap. The close correspondence of the southern boundary of *C. longilabris* with the northern border of *C. scutellaris* poses an interesting question. Are the same ecologic factors limiting both species, yet acting as the southern limit for the former and the northern limit for *C. scutellaris?*

The nature of these factors is not clear at present. The southernmost area records for *C. longilabris* may perhaps be regarded as stragglers. These, from Huron and Iosco counties, Michigan, are both represented by single specimens collected in 1905 and 1937 respectively. No breeding populations have been discovered in these parts of the state since. The presence of *C. longilabris* on at least three Great Lakes islands (Garden, Beaver, and Isle Royale) indicates that the species is capable of crossing considerable distances over water. *C. longilabris* is usually found in sandy, forested areas especially around jack pines and other conifers. In the Great Lakes region its southern boundary corresponds roughly with that of red pine (*Pinus resinosa,*) jack pine (*P. banksiana*), white spruce (*Picea glauca*), black spruce (*P. mariana*), and balsam fir (*Abies balsamifera*) as nearly as can be determined from small scale distribution maps (U.S.D.A., 1949).

The northern boundaries of *C. scutellaris* in this area are roughly similar to hackberry (*Celtis occidentalis*) and eastern cottonwood (*Populus deltoides*). I do not imply that there is any direct relationship between these plant species and the predatory tiger beetles. However, there may be a similar combination of factors, such as soil, climate, etc., which are responsible for limiting these species to essentially comparable distributions in the Great Lakes region. Since both *Cicindela* and many plant species are especially responsive to soil type, this may well be an important factor.

Yet both *C. longilabris* and *scutellaris* are associated with poor, sandy soils so that other factors must be involved. Perhaps the presence of conifers is in some way necessary for the existence of *C. longilabris* but it is difficult to see how this could have any effect. Further collecting, especially in Ontario and Wisconsin, will be very helpful.

Ontario records: ALGOMA: Agawa Bay (Univ. Mich.), Pancake Bay (RCG); CARLETON: Ottawa (MCZ); KENORA: Borups (CU), Ingolf (CU); MUSKOKA: Hunstville (CU); NIPISSING: Bear Island in Lake Temagami (AMNH), Lake Opeongo in Algonquin Park (McM); PARRY SOUND: "Orville" (Orrville?, CU); RAINY RIVER: Gold Rock (MCZ); RENFREW: Chalk River (UWO), Petawawa Forest Reserve (UWO); SUDBURY: Sudbury (CU); THUNDER BAY: "Nepagon" (USNM), Sibley Prov. Pk. (along sandy road with *C. tranquebarica,* RCG).

Cicindela tranquebarica Herbst, 1806

This species may be expected in all counties and districts. Wallis lists Attawapiskat but does not show this locality on his map, p. 58. When added to the map, this northern record (PATRICIA: mouth of Attawapiskat R. across from Akimiski Island) gives a different appearance to the Canadian distribution of this species. Nor does his map show Smoky Falls (over 50° N. on the Mattagami R., COCHRANE) although listed in the text. Additional records: ALGOMA: Thessalon (CU), CHIPPEWA River Falls near Batchawana (RCG); KENORA: Borups (CU); MIDDLESEX: Thorndale (UWO), MacGillivray Twp. (UWO); NIPISSING: Lake Opeongo, Algonquin Park (McM), North Bay (MCZ); PARRY SOUND: Parry Sound (gravel pit, RCG); RENFREW: Chalk River (UWO); SUDBURY. Coniston (CNHM, MCZ), Nairn Center (sandy areas in company with *C. repanda,* RCG); THUNDER BAY: Sibley Prov. Pk. (sandy road with *C. longilabris,* RCG); WATERLOO: Kitchener (McM); WELLINGTON: Guelph (UWO); WENTWORTH: Hamilton (CNHM).

Cicindela punctulata Olivier, 1790

Common in southern parts of the province. Additional records: BRANT: Brantford (McM); BRUCE: Sauble Falls (RCG); KENT: Chatham (UWO); LAMBTON. Port Lambton (UWO); WENTWORTH: Hamilton (McM); YORK: Toronto (MCZ, USNM).

Cicindela lepida Dejean, 1831

I could locate no additional records to add to those of Wallis (DURHAM: Leskard, Port Hope). Certainly this species should be sought in sandy areas in other parts of southern Ontario. In Michigan it is found as far north as Empire (LEELANAU) and should be expected throughout peninsular Ontario. It is apparently very susceptible to modern insecticides (as are most, if not all, species of *Cicindela*) and seems scarcer every year. Since it is not common to begin with, *C. lepida* may now be extinct in portions of its original distribution.

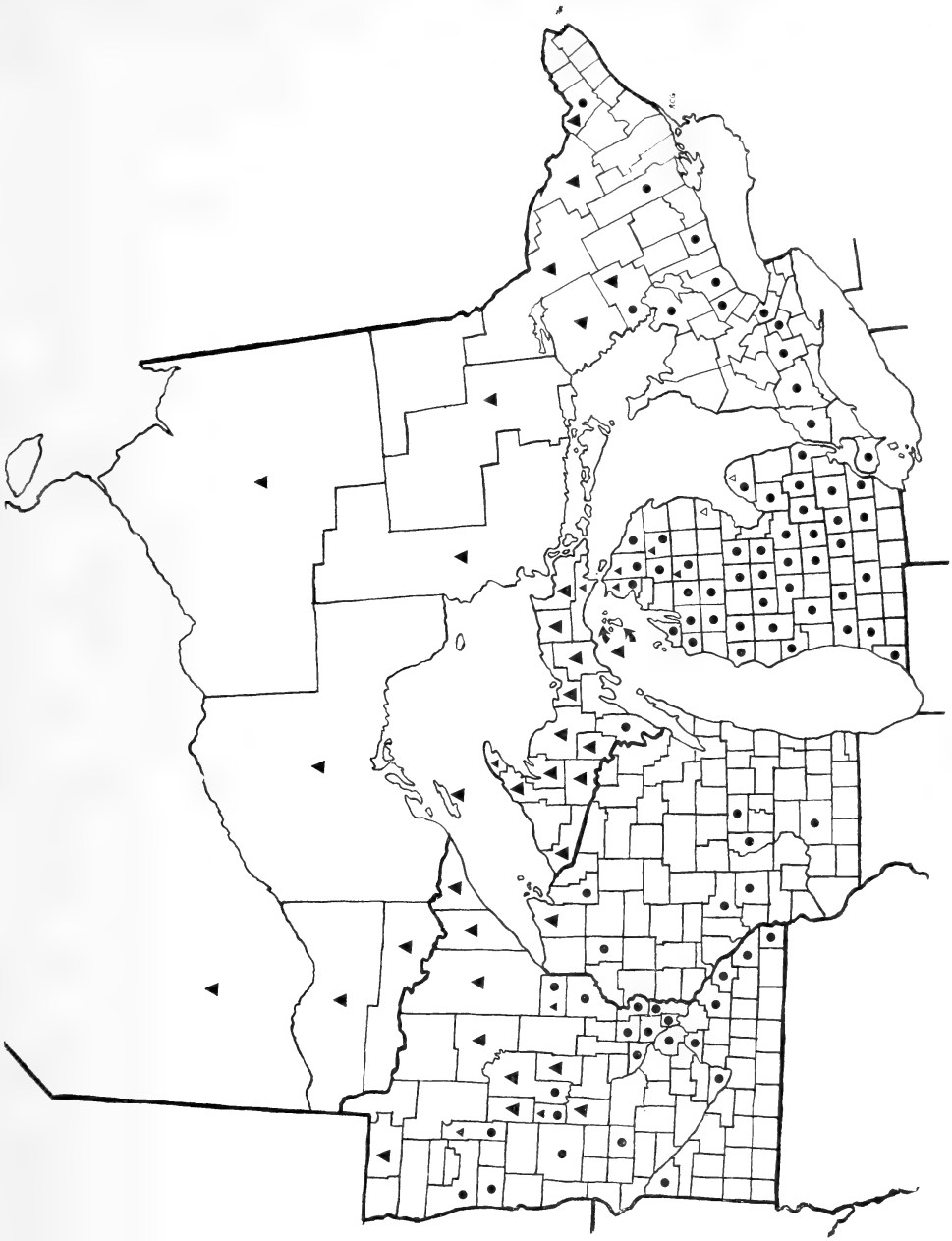

FIG. 1. Map of Ontario, Minnesota, Wisconsin and Michigan showing the distribution of *C.longilabris* and *C. scutellaris lecontei* by counties and districts. Solid triangles: *C. longilabris*. Open triangles: *C. longilabris* in Huron and Iosco Cos., Michigan (see text). Dots: *C. scutellaris lecontei*.

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THE INSECT ECOLOGY OF OLD-FIELD RED PINE PLANTATIONS IN CENTRAL ONTARIO. I. DESCRIPTION OF THE STUDY AREA[1]

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Introduction

Over 25,000,000 trees are planted in Ontario annually, many in pure stands on abandoned, sub-marginal farm land. In most cases, the soils have been badly depleted by cropping, grazing, and burning prior to tree planting. These artificially induced ecological successions present many problems of which insect and disease outbreaks are among the most important. In some cases, these factors, coupled with soil deficiencies, are believed to be the cause of early breakdown in the stands.

The cause of the insect and disease epidemics is usually considered a result of the concentrated food supply in pure stands of even age. However, many other factors may be involved, related to the seemingly inherent instability of simple population systems. Elton (1958) has shown that there is considerable evidence to support the belief that "the balance of relatively simple communities of plants and animals is more easily upset than that of richer ones; that is, more subject to destructive oscillations in populations, especially of animals, and more vulnerable to invasions."

Much research has been done on individual problems related to the control of specific insects or diseases, but relatively little work of a broad ecological nature has been carried out. There is urgent need for research on the distribution of the various taxonomic groups of plants and animals

[1]Contribution No. 1048, Forest Entomology and Pathology Branch, Canada Department of Forestry, Ottawa.

from the time of tree planting until a relatively stable forest is established, followed by extensive study of these groups as functional units throughout the development of the stand.

Although many workers have recognized the need for the synecological approach, it has been avoided because of the danger of becoming lost among the myriad of taxonomic and ecological complexities. The author readily concurs with this view in relation to natural mixed forest, but is convinced that the ecological simplicity of the old-field, forest monoculture offers a vastly different prospect. The author believes that the synecological approach to the latter situation is not only practical, but essential to a better understanding of our problems in plantation management.

Research was begun in 1959 on old-field red pine (*Pinus resinosa* Ait.) plantations along broad ecological lines to determine the changes in insect populations during the transition from old field to forest; the relations of the insect populations at each stage to the vegetational, climatic, and soil conditions; the inter-relations of the various insect groups at different stages; and the effects of plantation management on insect populations.

This paper presents some of the results of a preliminary survey of certain red pine plantations from 1 to 33 years of age. It consists of a description of the physical and historical features of the area, and of the general ecological organization of the red pine community. It is intended to provide an introduction and background for future reports of more specialized faunal studies.

The study area is located in the red pine plantations of Kirkwood Township, about 5 miles north of the town of Thessalon, on the North Channel of Lake Huron. The author gladly acknowledges the assistance of the staff of the Forest Insect Laboratory in Sault Ste. Marie, Ontario, and the Kirkwood Forest Management Unit of the Ontario Department of Lands and Forests.

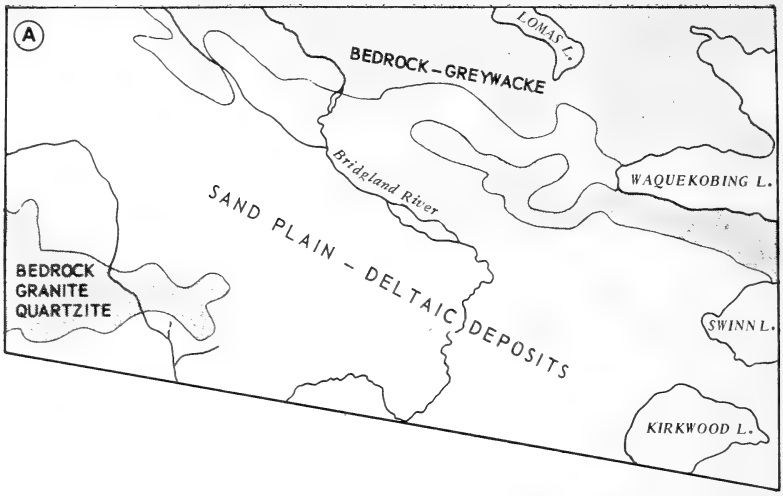
Physical and Historical Features, Kirkwood Township

The physical characteristics of the Kirkwood region have been discussed in detail by Pierpoint (1962). Low, broken outcrops of precambrian greywacke occur on the northwestern boundary, and an outcrop of granite and quartzite bedrock projects into the southwestern corner of the Township (Fig. 1A). Where soils occur on these rocky ridges, they consist of stony glacial tills. Although usually shallow, they may, in some cases, be quite deep and contain up to 60% fine sand and silt.

The remainder of the Township consists of a large sand plain derived from a delta in a post-glacial lake. The soils are predominantly deep coarse to medium sands, largely stone-free, and overdrained. The topography of the sand plain is flat to gently undulating, with occasional terrace-like formations or long channels. The Township is drained by the Bridgland River and its tributaries.

Kirkwood Township is in the Sault Ste. Marie-North Bay-Temiskaming Climatic Region (Chapman, 1953). The growing season begins about April 26 and ends about October 17, with an average length of 175 days. The winter temperatures are modified by the effects of Lake Huron, with a January isotherm of 15°F. The mean July temperature is 66°F. The mean annual precipitation is 30 inches, with an average snowfall of 75 inches. The rainfall from April to September averages 18 inches.

An unusually good record of the original forest cover is provided by the survey notes of Bolger (1877). Except for two small, burned areas (Fig. 1B), most of the sand plain was covered with a mature or over-mature


A
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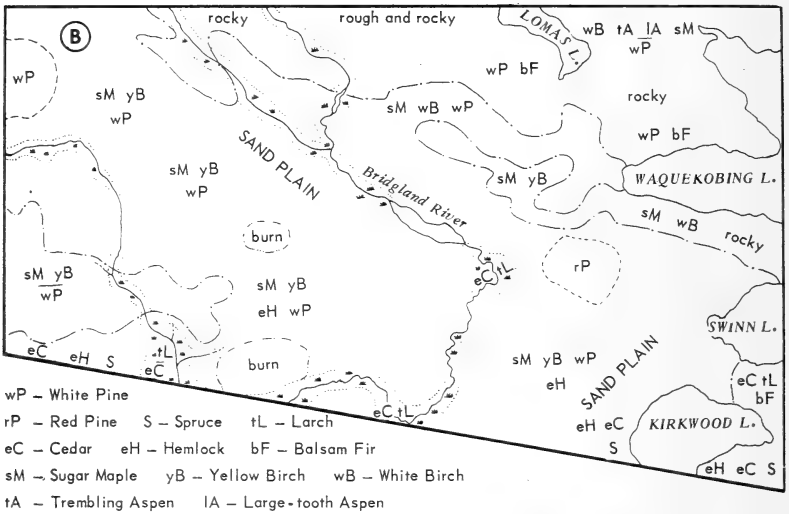
LOMAS L.
Bridgland River
WAQUEKOBING L.
SAND PLAIN – DELTAIC DEPOSITS
BEDROCK
GRANITE
QUARTZITE
SWINN L.
KIRKWOOD L.


B
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Bridgland River
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WAQUEKOBING L.
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SAND PLAIN
eC tL
bF
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S
KIRKWOOD L.
eH eC S
wP – White Pine
rP – Red Pine S – Spruce tL – Larch
eC – Cedar eH – Hemlock bF – Balsam Fir
sM – Sugar Maple yB – Yellow Birch wB – White Birch
tA – Trembling Aspen lA – Large-tooth Aspen

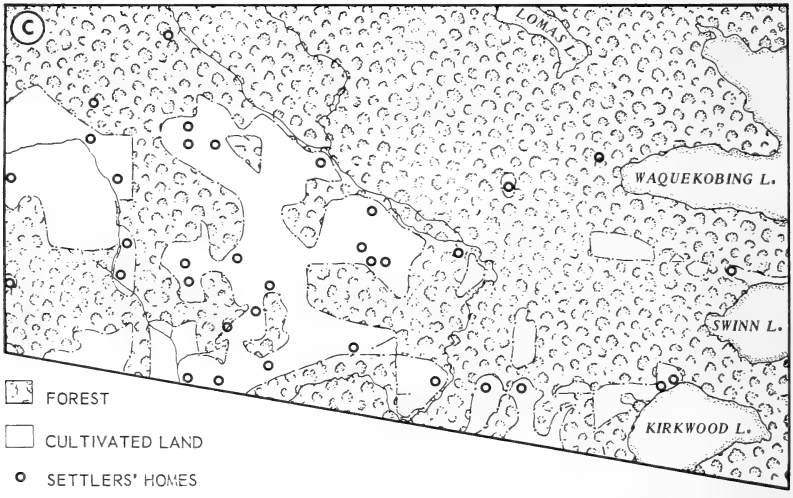
C
LOMAS L.
WAQUEKOBING L.
SWINN L.
KIRKWOOD L.
FOREST
CULTIVATED LAND
SETTLERS' HOMES

FIG. 1. Kirkwood Township, Ontario, showing:

A—Surface geology (after Pierpoint, 1962),

B—Original forest cover (after Bolger, 1877),

C—Cleared land and settlers homes 1880-1910.

forest. White pine, *Pinus strobus* L., usually occurred sparsely in stands predominantly stocked with sugar maple, *Acer saccharum* Marsh., and yellow birch, *Betula allegheniensis* Britt. Recent stump measurements indicate that south and west of the Bridgland River there were about 15 pine stems per acre, with the age of trees averaging over 300 years. East of the river, there were over 100 stems per acre, and they averaged slightly over 100 years of age[2].

The moister sands on the Township's southern border supported hemlock, *Tsuga canadensis* (L.) Carr, eastern white cedar, *Thuja occidentalis* L., and spruce, probably both *Picea glauca* (Moench) Voss., and *P. mariana* (Mill.) BSP. The rocky ridges along the northern boundary supported scattered white pine, balsam fir, *Abies balsamea* (L.) Mill., white birch, *B. papyrifera* Marsh., sugar maple, and aspen, probably both *Populus tremuloides* Michx., and *P. grandidentata* Michx. Cedar, tamarack, *Larix laricinia* (DuRoi) K. Koch, and alder, *Alnus* sp., were found along the waterways.

Although the Township was not surveyed until 1877, the first timber-cutting license was sold in 1872. Square timber was taken out until about 1880, and sawlogs until 1908. The timber license was surrendered to the crown in 1917.

Settlers from Bruce and Huron counties of Ontario moved into Kirkwood Township shortly after 1880 (Fig. 10). They settled on the sand plains, worked in the lumber camps in winter, and cleared and farmed the land during the summer. Cash crops consisted mostly of hay, oats, and potatoes for the lumber camps. Agricultural practices were primitive, soil exhaustion was rapid, and by 1900 most of the farms were abandoned. During the next 30 years, farmers from many miles around used the Township for pasture, and hundreds of cattle and horses grazed there throughout the summer. The land was burned repeatedly, often several times in a season, in a vain effort to improve the grass.

The broken country along the northern and southwestern boundaries was never cultivated and escaped most of the grazing and fire, and much of the original vegetation survived. However, the sand plains were reduced to barren fields supporting a thin cover of grasses, weeds, mosses, and lichens, growing between charred white pine stumps. Burning and grazing ceased by 1930, and although scattered stands of aspen and white birch appeared during the following 25 years, much of the old field remained virtually unchanged.

Reforestation began in Kirkwood in 1928, and pure stands of red, white, and Scots pine, *P. sylvestris* L., and white spruce were planted until 1931. The programme was resumed in 1938, and has continued until the present. Although most of the older stands were established in the open on old fields, in recent years considerable numbers of white pine, red pine, and spruce have been underplanted in natural birch and aspen stands. The Township consists of about 11,300 acres (land area), and over 5,000 acres have been reforested.

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[2]Personal communication from J. E. MacDonald, Forest Insect Laboratory, Sault Ste. Marie, Ontario.

The Red Pine Community

Stand Descriptions

Stands utilized for permanent plots were located on the north-central part of the sand plain. Four adjacent old fields were planted with red pine in 1929, 1939, 1950, and 1960. All the plantations were on level ground, thus minimizing local climatic differences, and the soil was uniform throughout the area.

Trees and Tree Growth — Red Pine

The 1960 stand was planted with 3-year-old red pine seedlings in May 1960, by a tractor-drawn slit-planter. A 4 by 7-ft spacing was used, and the trees averaged 7.5 inches in height in August 1960. The trees in the 1950 stand were spring-planted in furrows by machine. They were spaced 7 by 7 ft and in August 1960 they averaged 8 ft 7 inches high and 1.3 inches dbh. The crowns covered about 38 per cent of the ground.

The 1939 stand was spring-planted at a 6- by 8-ft spacing. In 1960, the trees averaged 26 ft 7 inches high and 5.1 inches dbh, and the crowns were completely closed. The 1929 stand was planted by hand in ploughed furrows in the spring. The trees were originally spaced 7.5 by 8 ft apart, but in 1956 an alternate-row thinning was done, and at the time of survey the residual trees were spaced at 8 by 15 ft. In August 1960, the trees averaged 42.1 ft in height, and 7.3 inches dbh. The crowns covered about 64% of the ground.

Five-acre blocks were selected in each stand, and were divided into 10 one-half acre plots marked with permanent corner stakes. Tree size was relatively uniform in each of the 4 stands, and a 2 per cent sample was considered adequate for growth measurements. Every tenth tree in 2 one-half-acre plots in each stand was measured in 1960 and remeasured in 1962. Heights were determined directly in the younger stands, and with an Abney level in the older stands. Diameter-breast-height was measured with a diameter tape, and crown cover by measuring the greatest crown radius at the 4 compass points. Survival counts were made on 40% of the trees by examining 4 one-half-acre plots. Ten-year intercepts were used to determine annual height growth in the 3 older stands, and annual diameter growth was calculated from increment borings from living trees, and ring measurements on stumps of felled trees.

Table I shows that 13% of the trees in the 1960 stand died during the first 3 years. Observations indicated that most of the mortality in the older stands also occurred in the establishment period.

During the period from August 1960 until August 1962, the trees in the 1950 stand increased in height at the rate of 1.5 ft per year. Annual diameter increment averaged 0.5 inch, and basal area increased 7.4 ft^2 per acre per year. The 1939 stand, with an additional 241 trees per acre and crown closure complete, averaged 1.4 ft annual height growth, but only 0.1-inch diameter growth and an increase of 5.3 ft^2 in basal area per acre per year. The 1929 stand, with its density reduced to about one-half that of the 1950 stand and one-third that of the 1939 stand and as a result of the thinning operation in 1956, showed height growth equal to that of the 1950 stand, and an annual diameter increment half that of the 1950 stand, but two and one half times as great as the 1939 stand. Annual increase in basal area averaged 6.8 ft^2 per acre (Table I).

In general, height growth in red pine plantations appears related most strongly to site quality, particularly soils and soil moisture, whereas diameter increment is strongly influenced by stand density (Horton and Bedell, 1960; Buckman, 1962).

TABLE I. Growth measurements of four red pine plantations in Kirkwood Township, Ontario in 1960-1962

Year planted	No. trees per acre		Average dbh (inches)		Basal area sq ft/acre		Average height (ft)		Crown cover per cent		Survival per cent	
	1960	1962	1960	1962	1960	1962	1960	1962	1960	1962	1960	1962
1960	1,582	1,285	—	—	—	—	0.8	1.3	—	—	90	77
1950	740	740	1.3	2.3	6.6	21.4	8.7	11.7	38	75	81	81
1939	981	981	5.1	5.3	139.3	150.0	26.7	29.1	100	100	84	84
1929	332[a]	332	7.3	7.8	96.6	110.2	42.1	45.1	64	77	77	77

[a]Residual stand after 50% thinning 1956-57.

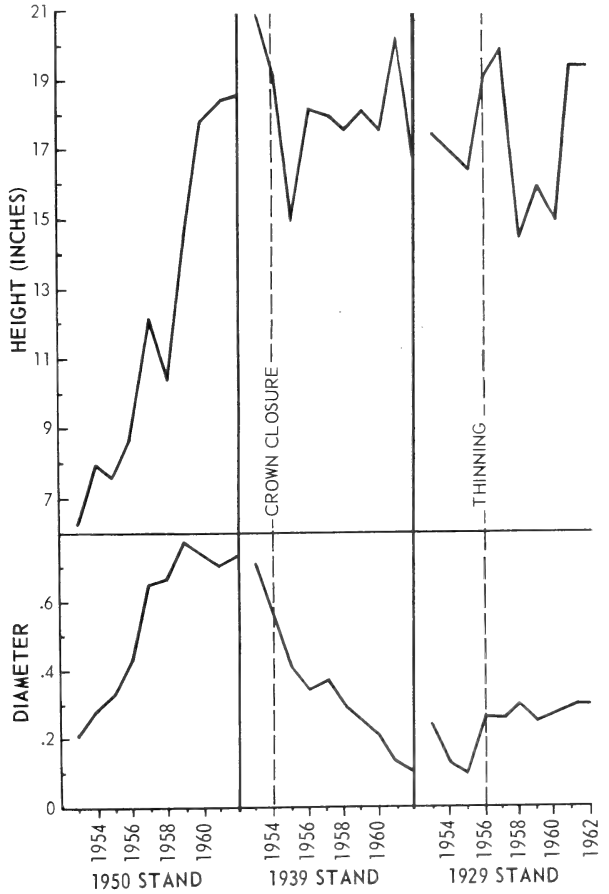

FIG. 2. Growth of 3 red pine stands in Kirkwood Township, Ontario, from 1953 to 1962.

By combining the 10-year intercepts, consisting of growth measurements from 1953 to 1962, of the 3 older red pine stands, an approximate 30-year growth curve for red pine on this soil type in Kirkwood Township results (Fig. 2). Rapid height growth and diameter increment occurs during the first 10 to 12 years until crown closure approaches. Following closure annual height growth tends to level off, although fluctuating from year to year probably as a result of water supply and other seasonal variables. Annual diameter increment, however, shows a steady decline until the stand is thinned. The thinning operation appears to have a favourable effect on diameter growth, but no pronounced effect on height growth.

Natural Vegetation — Herbs, Shrubs, and Trees

Ten permanent quadrats of each of 4 sizes were established at the plot corners to record changes in the natural vegetation. The quadrats were placed in a nested fashion, and the dimensions used were as follows:

3.3 x 3.3 ft—herbaceous vegetation

6.6 x 6.6 ft—shrubs, seedlings, and transgressives (trees from 1 to 10 ft in height)

TABLE II. Coverage (C) and Frequency (F) of the herbaceous plants in four red pine plantations, Kirkwood Township, Ontario, 1960.

	Stands							
	1960		1950		1939		1929	
SPECIES	C	F	C	F	C	F	C	F
Fragaria virginiana Duchesne	1.7	100	0.7	60	—	—	0.5	30
Danthonia spicata (L.) Beauv.	2.8	90	4.1	100	—	—	0.2	20
Hieracium aurantiacum L.	1.4	90	1.6	100	0.1	10	0.9	60
Convolvulus spithamaeus L.	1.1	90	1.1	90	—	—	0.7	50
Polytrichum piliferum Hedw.	2.0	80	1.1	80	0.1	10	—	—
Cladonia cristatella Tuck.	1.0	80	0.6	60	—	—	0.1	10
Rumex acetosella L.	0.7	70	0.1	10	—	—	—	—
Poa pratensis L.	0.6	30	0.1	10	—	—	—	—
Hypericum perforatum L.	0.3	30	0.7	70	—	—	0.1	10
Solidago sp.	0.3	30	0.3	30	—	—	—	—
Antennaria plantaginifolia (L.) Hook	0.3	30	0.6	60	—	—	0.2	20
Pteridium aquilinum (L.) Kuhn	0.2	20	—	—	—	—	0.4	30
Apocynum androsaemifolium L.	0.2	20	—	—	0.1	10	—	—
Panicum depauperatum Muhl.	0.2	10	0.2	20	—	—	—	—
Polytrichum juniperinum Hedw.	—	—	0.2	20	0.5	40	0.6	30
Antennaria neodioica Greene	0.1	10	0.1	10	—	—	0.1	10
Melampyrum lineare Desr.	0.1	10	—	—	—	—	0.1	10
Achillea millefolium L.	—	—	0.3	30	—	—	0.2	20
Polytrichum juniperinum Hedw.	—	—	.02	20	0.5	40	0.6	30
Cladonia sylvatica (L.) Hoffm.	—	—	0.2	20	—	—	0.1	10
Spiranthes sp.	—	—	0.1	10	—	—	—	—
Hieracium sp.	—	—	0.1	10	—	—	—	—
Pyrola elliptica Nutt.	—	—	—	—	0.4	40	0.1	10
Gramineae	—	—	—	—	0.2	20	2.5	60
Pleurozium schreberi (Brid.) Mitt.	—	—	—	—	0.2	20	0.5	30
Polytrichum ohioense Ren. & Gard.	—	—	—	—	0.2	10	0.2	10
Lycopodium sp.	—	—	—	—	0.1	10	—	—
Maianthemum canadense Desf.	—	—	—	—	—	—	0.2	20
Viola conspersa Reich.	—	—	—	—	—	—	0.2	20
Anaphalis margaritacea (L.) Gray	—	—	—	—	—	—	0.1	10

13.2 x 13.2 ft—trees over 10 ft in height and up to 10 inches dbh

26.4 x 26.4 ft—trees over 10 inches dbh

The herbaceous plants were listed and their coverage was recorded on the 1 to 5 percentage scale of Braun-Blanquet (1932). Shrubs, seedlings, transgressives, and trees were listed and counted, and their density rather than coverage was recorded. The presence of all species on the quadrats was represented as percentage frequency.

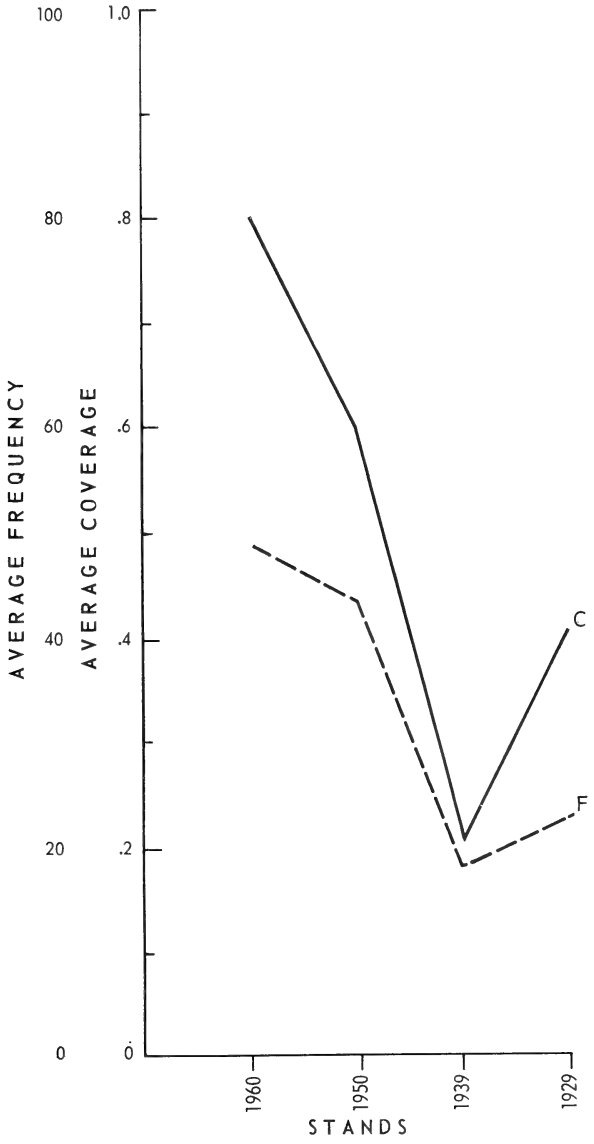

FIG. 3. Frequency and coverage of herbaceous plants in 4 red pine stands, Kirkwood Township, Ontario.

Sixteen species of herbaceous plants occurred in the 1960 stand in 1960, and of these, 7 species made up the bulk of the vegetation (Table II). They were mostly weed species typical of old fields with sour, impoverished soils. Essentially the same species complex appeared in the 1950 stand, but their total coverage and frequency was reduced (Fig. 3). The reduction in numbers and distribution of *Fragaria virginiana, Rumex acetosella,* and *Cladonia cristatella,* and the increase in *Hypericum perforatum, Antennaria plantaginifolia,* and the appearance of *Polytrichum juniperinum* and *Cladonia sylvatica* may reflect the changing mesoclimate following tree growth.

With crown closure, the number of species in the 1939 stand was reduced to 9, and their distribution was largely restricted to small stand openings resulting from tree mortality. The appearance of *Polytrichum juniperinum, P. ohioense, Pleurozium schreberi, Lycopodium* sp., and *Pyrola elliptica* indicated a movement from old field to woodland conditions.

Following the thinning of the 1929 stand in 1956, many of the old-field species reappeared, and the woodland species common to the 1939 stand remained, thus providing a larger species complex than in any of the 3 younger stands. Coverage and frequency was fairly low (Fig. 3), but appeared to be increasing slowly.

Shrubs and trees were of little ecological importance in the 1960 and 1939 stands, but *Rubus idaeus* and *R. allegheniensis* were fairly numerous and widespread in the 1950 stand (Table III). The appearance of small numbers of shrubs, seedlings, and trees in the 1929 stand marked the beginning of a trend toward a mixed forest type.

Soils

The soil was uniform throughout the 4 stands, consisting of a deep, deltaic, stonefree, coarse to medium sand. Pierpoint (1962) classed the soil as Petawawa type, but pointed out that there is considerable variation in the Petawawa sands. Although some are typical of very low base deposits and strongly granitic in composition, the Kirkwood sands often contain a large proportion of dark minerals, particularly greywacke, and their high cation exchange capacity (about 10 meq/100 g) suggests an origin other than granitic. However, since there is no evidence to suggest that these variations in mineral composition cause significant differences in soil profiles or vegetation production, Pierpoint refrained from placing the Kirkwood sands in another landtype.

Pierpoint (1962) stated: "dry sites predominate on the Petawawa land type . . . the typical site characterized by moisture regime 0 (Hills, 1954). On the relatively flat deltaic areas, the local climate is fairly extreme. Hot, dry atmospheric conditions by day are followed by cold, dry nights. Frost is common and can be a severe hazard to tree seedlings."

Typical profile descriptions by stands are summarized as follows: (The pH was determined colorimetrically, the texture by Wilde's rapid field method, and the organic matter by Wilde's colorimetric method (Wilde and Voigt, 1955).)

1960 STAND:

Ap—0 to 7 inches—dark brown medium to coarse sand, 10% silt and clay; pH 5.8; 4.5% organic matter; scattered fragments of carbon; roots restricted to this layer.

B—7 to 27 inches—light brown medium to coarse sand, 5% silt and clay; pH 5.8-6.2; 1.5% organic matter; some iron streaks and discontinuous hardpan.

C—22+ inches—reddish-brown, coarse sand, no silt or clay; pH 6.2; no organic matter.

1950 STAND:

Ap—0 to 6 inches—dark brown medium to coarse sand, 7% silt and clay; pH 5.4; 4.0% organic matter; scattered fragments of carbon; most roots restricted to this layer.

B—6 to 22 inches—light brown medium to coarse sand, 5% silt and clay; pH 5.6; 1.5% organic matter.

C—22+ inches—redish-brown, coarse sand, no silt or clay; pH 6.2; no organic matter.

1939 STAND:

L—1 to 1½ inches—red pine needles

F—½ inch—matted needle material

H—

A_2—Trace only of greyish-brown sand

B_2—0 to 8 inches—dark brown medium to coarse sand, 7% silt and clay; pH 5.3; 4% organic matter; roots mostly in this layer.

B_3—8 to 26 inches—medium brown medium to coarse sand, 3% silt and clay; pH 5.8; 1.5% organic matter; some root penetration.

C—26 + inches—reddish-brown, coarse sand, no silt or clay; pH 5.8; no organic matter.

1929 STAND:

L—½ to 1 inch—red pine needles

F—¾ inch—matted needle material

H—Trace

A_2—0 to 3 inches—greyish-brown sand

B_2—3 to 13 inches—dark brown, medium to coarse sand, 8% silt and clay; pH 5.2; 4% organic matter; roots mostly in this layer.

B_3—13 to 30 inches—medium brown, medium to coarse sand, 1% silt and clay; pH 5.4; 2% organic matter; some root penetration.

C—30 + inches—reddish-brown, coarse sand, no silt or clay; pH 5.8; no organic matter; some root penetration.

TABLE III. Density (D) and Frequency (F) of Shrubs, Seedlings, and Trees (other than red pine) in four red pine plantations, Kirkwood Township, Ontario, 1960.

	Stands							
	1960		1950		1939		1929	
SPECIES	D	F	D	F	D	F	D	F
SHRUBS								
Rubus idaeus L., var. *strigosus* Michx.	0.4	10	4.2	40	2.4	10	0.5	40
Rubus allegheniensis Porter	1.1	10	2.3	30	—	—	—	—
Vaccinium angustifolium Ait.	—	—	—	—	—	—	0.1	10
Diervilla lonicera Mill.	—	—	—	—	—	—	0.5	20
Corylus cornuta Marsh.	—	—	—	—	—	—	0.3	10
Salix sp.	—	—	—	—	—	—	0.1	10
SEEDLINGS								
Acer rubrum L.	—	—	—	—	—	—	0.8	30
Pinus strobus L.	—	—	—	—	—	—	0.1	10
TRANSGRESSIVES								
Populus tremuloides Michx.	—	—	—	—	—	—	0.7	20
Populus grandidentata Michx.	0.7	20	—	—	—	—	—	—
Prunus pensylvanica L. & F.	1.1	10	—	—	—	—	—	—
TREES (under 10 inches dbh)								
Populus tremuloides Michx.	—	—	—	—	—	—	0.3	20
Populus grandidentata Michx.	—	—	—	—	—	—	0.2	10
Prunus pensylvanica L. & F.	—	—	—	—	—	—	0.1	10

Community Development

During the transition from old field to forest, red pine plantations in Kirkwood Township pass through 4 readily distinguishable stages from the standpoint of their ecological characteristics:

1. The old-field stage—1 to 5 years
2. The transition stage—6 to 14 years
3. The monoculture stage—15 to 25 years
4. The young-forest stage—26 years and over.

These stages are brought about by the increasingly greater influence of the red pine trees on the site, and they are characterized by a steadily multiplying complexity in the vertical stratification of the community, both above and below ground (Fig. 4).

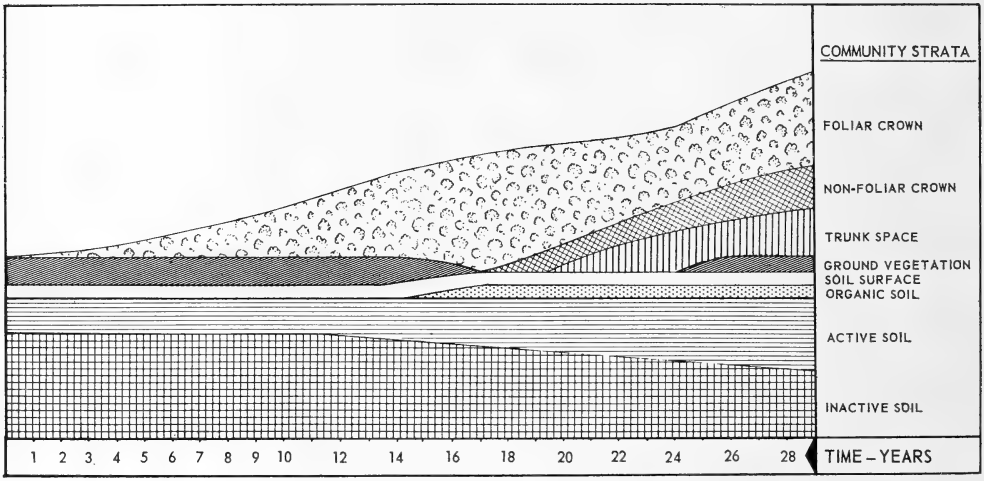

FIG. 4. Diagram of community development in old-field red pine plantations, Kirkwood Township, Ontario.

Although these changes are initiated by the vegetation, and the vegetation during any one stage may be used as an indicator of that stage, the transition involves the entire ecological community. As development proceeds, changes in stand climate, soil, fauna, and flora play such important and interdependent roles that it is often difficult to identify any one primary cause of a certain effect.

In the old-field stage, the trees are not an influential part of the community, and the ecological conditions remain essentially those of an old field. Although the trees form an important part of the vegetation, they are not in a dominant position, and their effects on the mesoclimate, soil, fauna, and flora of the area are negligible. On the other hand, the trees are strongly affected by the other elements of the community. Their roots are restricted to a narrow feeding zone (the old plow-layer) near the soil surface, and they are subject to severe competition from old-field plants for water and nutrients. This problem is often intensified by planting methods; hand planting usually spreads the roots in one plane only, and the moving machine planter bunches the roots together and trails them in one direction.

The climate is typical of the open, differing from that of the older stands in many ways, the most important of which may be: a more even distribution of rainfall at the soil surface, but lacking the litter layer, a more rapid percolation downward through the coarse soil, and a higher evaporation rate due to the exposure to wind and sun; greater temperature extremes during the growing season (Geiger, 1957); and since the snow usually comes in Kirkwood before hard-freezing temperatures, the soil in the open is subjected to shallower freezing (Table IV) than that of the older stands where the canopies of the trees tend to keep the snow off the ground for longer periods.

Water is probably the most important factor limiting plant growth on the Kirkwood sands. Although there is sufficient total rainfall in most years, its distribution throughout the growing season is erratic (Fig. 5),

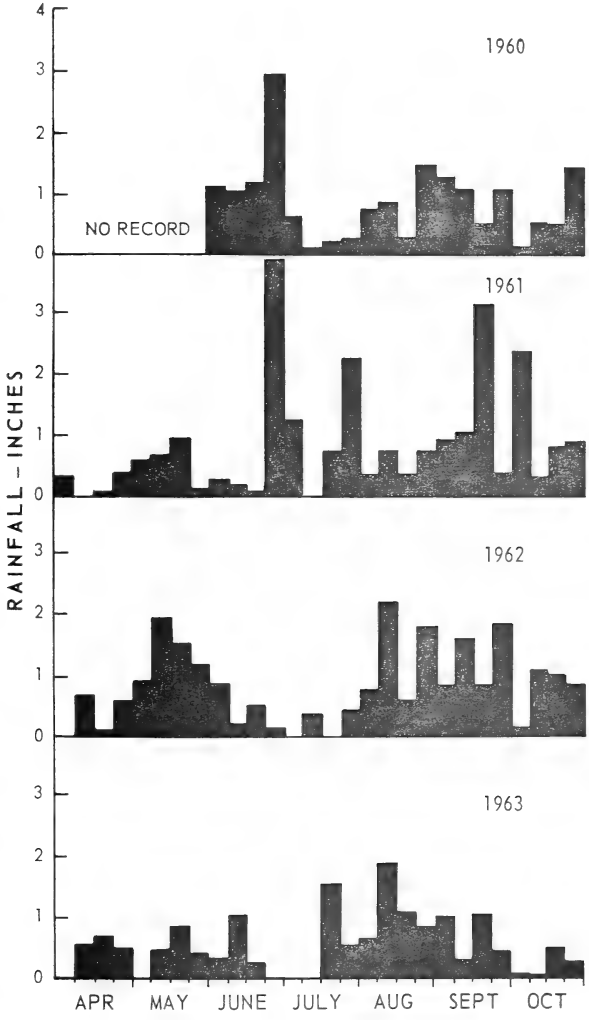

FIG. 5. Weekly rainfall from April to October, 1960 to 1963, Kirkwood Township, Ontario.

and even a week without rain, particularly in spring and early summer, has noticeable effects on the vegetation. As a result, the groundcover of the 1960 stand is very poor (Fig. 6), with patches of bare soil not uncommon.

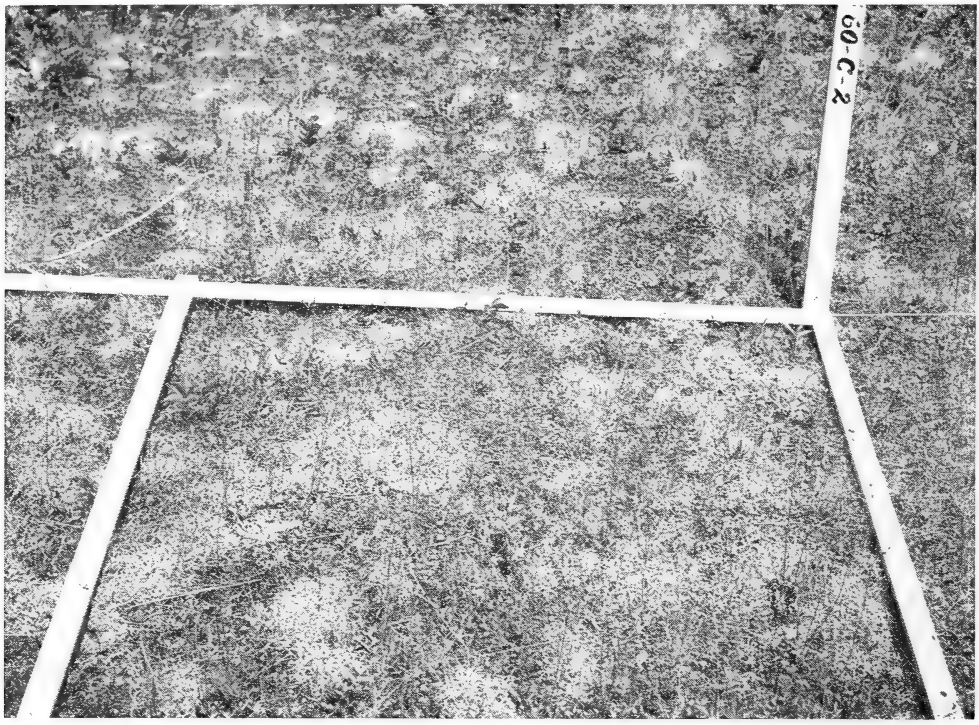

FIG. 6. Ground cover, 1960 stand, Kirkwood Township, Ontario, 1962.

The transitional stage begins when the crowns of the trees become large enough to exert appreciable effects on the climate of the stand. Probably the first measurable effect is decreased wind velocity, and this occurs after the trees have been growing on the site for 3 to 5 years.

As the trees increase in size, their foliage intercepts larger amounts of rainfall, and some of this may be lost to the soil by evaporation (Kittredge, 1948). Sunlight is still able to penetrate to the soil surface, and evaporation there remains at a high level as well. Since litter has accumulated only directly under the trees during this stage, and since the ground vegetation has been reduced percolation into the mineral soil is rapid.

Table V shows that the soil in the transitional stage contains less moisture during a prolonged dry period than the soils of the open field or of the older stands. However, this lack of moisture is not reflected in slow tree growth to the extent that it is in the establishment stage. This may be due to reduced competition with the ground vegetation, and to the larger root systems of the trees being better able to take advantage of the available moisture. The high moisture content of the soil following a heavy rain (Table V) is misleading, since all the samples were taken midway between the rows in the area of greatest drip from the foliage (Voigt, 1960).

The gradual reduction in herbaceous cover is probably the result of decreasing light as well as moisture. The increase in grasses may indicate more xeric conditions, but the inability of many herbs to fruit and flower suggests insufficient light.

The reduction in wind velocity by the young trees, and their open crowns, results in greater snow accumulation in this stand than in the older, closed plantations, and like the 1960 stand, in shallower soil freezing (Table IV).

The monoculture stage begins when crown closure is complete. The time of closure depends on site conditions and tree spacing; in the study area closure usually occurs about the fifteenth year. The closed canopy restricts penetration of sunlight and air circulation, a thick layer of needles accumulates on the ground (Fig. 7), and ground vegetation disappears except in small openings left by tree mortality.

The old-field red pine plantation is a true monoculture at this stage, with the red pine maintaining complete dominance of the site. In addition to the vegetation, the climate changes drastically from that of the open field. The surface climate has moved from about 1 foot above ground level (the surface of the ground vegetation) to the crown surface, over 20 ft above ground. Beneath this, a crown climate and a trunk-space climate have appeared (Geiger, 1957).

The interior of the stand is cooler and more humid than that of the open field. The crowns hold the snow off the ground longer in the fall, the temperatures drop lower, and frost usually penetrates the soil to greater depths than in the open. The snow and frost leave the ground considerably later in the spring (Table IV), and this coupled with earlier fall cooling results in a shorter growing season than in the younger stands (Fig. 8).

Closed crowns intercept more rainfall, and evaporation from the foliage is incresaed (Kittredge, 1948). However, the thick litter layer insulates the soil, and coupled with lack of air movement, prevents excessive evaporation from the ground. Although soil moisture conditions are not appreciably improved over those of the transitional stage, the lack of ground vegetation provides the trees with undisputed use of the supply.

TABLE IV. Snow depth and soil freezing and thawing in 4 red pine plantations in Kirkwood Township, Ontario, 1960-62.

Stand	Date ground thawed Spring, 1960	Depth soil freezing 1960-61	Average snow depth December to April 1961-62
1960	April 15	6 inches	17 inches
1950	April 21	6 inches	23 inches
1939	May 15	18 inches	16 inches
1929	May 8	15 inches	15 inches

TABLE V. Moisture content of surface 6 inches of soil in 4 red pine stands, Kirkwood Township, Ontario, 1963[1]

Condition	1960 Stand	1950 Stand	1939 Stand	1929 Stand
Dry	9.1±1.4%	7.0±0.9%	7.9±1.0%	10.2±2.3%
Wet	17.0±2.1%	18.7±2.7%	17.6±2.7%	18.0±2.6%

[1]Dry samples taken after 2 weeks without rain. Wet samples taken immediately following 1 inch of rainfall.

Litter accumulates on the surface of the soil more rapidly than it breaks down, probably due to low temperature, and lack of light and moisture (Tamm, 1950). This results in the development of a thick needle

FIG. 7. Needle litter, 1939 stand, Kirkwood Township, Ontario, 1962.

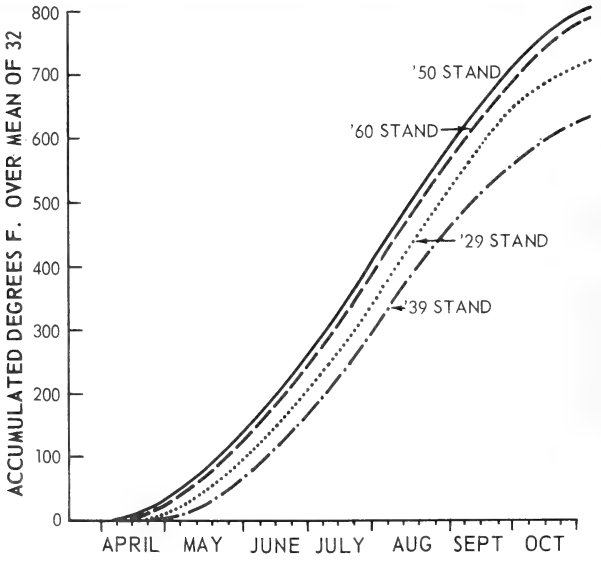

FIG. 8. Day-degrees calculated from weekly means of soil-surface temperatures in 4 red pine stands, Kirkwood Township, Ontario, 1961.

layer over a thin fermentation layer, with no measurable humus layer. The needles on the surface tend to dry out quickly, providing very poor conditions for seed germination, and this probably prevents the establishment of many groundcover plants.

Following closure, sunlight is prevented from reaching the lower parts of the crowns. The foliage dies and the non-foliar crown stratum appears. Eventually, the bottom branches are pruned naturally or mechanically and an open area between the soil surface and the lowermost branches, the trunk space, results.

The young-forest stage begins with the completion of the first thinning. The usual practice in Kirkwood Township in the past has been to remove every second row after the trees have passed 25 years of age. The immediate effect is to reduce crown coverage from 100% to about 60%.

Light available for tree growth is increased, mean maximum temperatures are raised, and mean minimum temperatures are lowered. More precipitation reaches the ground, and although evaporation is greater, there is an increase in available soil moisture. Soil temperatures are higher, snow and frost leave the ground earlier in the spring, and the growing season is lengthened (Cheo, 1946).

Increased temperature, light, and moisture stimulate a more rapid breakdown of organic matter, and the litter layer becomes stabilized. The improved stand climate and the soil scarification resulting from the thinning operations encourage re-establishment of herbaceous vegetation, shrubs, and tree species other than red pine.

Discussion

In a purely botanical sense, the developing red pine community changes from the relatively complex organization of the old field to the simple situation found in the monoculture stage, and then to the more complex young forest.

The soil changes from a simple old-field profile with a shallow plant-feeding zone, to a multi-layered, young podsol profile with a much deeper zone of organically active mineral soil. As the trees increase in size, the original crown stratum becomes divided into several distinct ecological strata; the foliar crown, the non-foliar crown, and the trunk space. The young-forest stage marks the beginning of typical woodland conditions, and further stratification of herbs, shrubs, and trees is indicated.

It is natural to believe that changes in insect fauna parallel these developments in vegetation, soils, and climate. If we can assume that most plants attract certain herbivorous insects, and that these insects in turn attract certain predatory and parasitic species, then we should expect the insect fauna in the 1960 stand, which supports 20 species of plants in relative abundance, to be quite different from that of the 1939 stand, which supports only very small numbers of 9 plant species. On the other hand, we might expect that the soil fauna in the 1960 stand, with its shallow, humus-poor plow-layer, should support much smaller numbers of mites, springtails, and flies than the 1939 and 1929 stands with their thick layers of decaying organic matter. If this is the case, then we should look for a larger, and possibly more varied, carabid, staphylinid, and spider fauna in the older stands.

The fauna of the soil and the ground vegetation in each stand should be reflected in that of the trees, particularly with regard to the less selective predatory species; and the herbivorous insects of the ground vegetation

should exert an indirect effect on the herbivores of the trees by serving as alternate or alternative hosts for parasites.

The principle of species diversity and ecological stability is not new; the more recent literature on the subject has been discussed by Pimental (1961), and need not be repeated here. Red pine plantations appear to offer an excellent medium to determine whether this principle works in nature. Attempts toward the clarification of some of these relationships will be the subject of future contributions.

Summary

A synecological study of old-field red pine plantations was begun in 1959 in Kirkwood Township, Ontario, to determine the relationships of the insect fauna during community development and succession. This paper consists of a preliminary survey of several red pine plantations and describes the physical and historical features of the study area, and the general ecological organization of the red pine community.

The plantations were established on an extensive sand plain of deltaic origin, originally covered with a forest of yellow birch, maple and white pine. Following lumbering, the land was cultivated, grazed and repeatedly burned from 1880 until 1929 when reforestation began.

Four adjacent old fields, planted with red pine in 1929, 1939, 1950, and 1960, were selected for study purposes. Measurements showed that the red pine grew rapidly until crown closure occurred about the fifteenth year, and then annual height growth levelled off and diameter increment decreased. Thinning at 27 years of age resulted in increased annual diameter increment, but had little effect on height growth.

The natural vegetation consisted of 20 herbaceous and shrub species in the 1960 stand. This flora decreased as the red pine gradually assumed dominance, and the 1939 stand was essentially a monoculture. Following opening of the 1929 stand by thinning, many of the old-field plants reappeared in addition to several typical woodland herbs and shrubs.

The soil profile changed from a relatively simple old-field type with a shallow plow-layer in the 1960 stand, to a young podsol with its numerous distinct horizons in the 1929 stand.

Community development is traced from the establishment stage in the old field, through transitional and monoculture stages to a young forest stage. The effects of the trees on stand climate, soils, and vegetation are discussed, and the increasingly complex stratification of the community is outlined.

The red pine plantations are regarded as communities which have been very much simplified by man, and they offer an excellent opportunity to study the principle of species diversity and ecological stability in the field. This preliminary survey is intended to provide an introduction and background for future reports of more specialized faunal studies.

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THE INSECT ECOLOGY OF RED PINE PLANTATIONS IN CENTRAL ONTARIO III. SOIL-SURFACE FAUNA AS INDICATORS OF STAND CHANGE[1]

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Introduction

Research was begun in 1959 on some of the ecological relationships of insects during the development of old-field red pine (*Pinus resinosa* Ait.) plantations in Kirkwood Township, Algoma District, Ontario. The physiography and historical background of the area, the soils, vegetation, and the development of the red pine community from old-field to young forest was described previously (Martin, 1965).

Studies of insect societies in several of the strata of red pine stands of various ages have been underway since 1960 and this paper deals with the fauna of one of these strata, the soil surface. Fichter (1941) defined soil-surface fauna as "populations composed of those species which travel, for the most part, over the surface of the ground, and, though closely associated with the litter as material for abode, constitute, when active (not resting, hiding, or hibernating), a distinct society".

In red pine plantations, during the transition from old field to forest, the differences in the soil-surface fauna should best reflect the changes in climate, soil, and vegetation in the stand as a whole, since the animals of this stratum are probably most affected by these changes. Kühnelt (1961) stated: "the species composition of a given habitat is, according to experience, the best indicator for the conditions prevailing there are is essentially more revealing than a series of measurements of individual factors even if carefully carried out". And Balogh (1963) concluded: "while the species with a large ecological valency play by their very masses an important role in the matter and energy turnover of the soils, a portion of the soil organisms react extremely sensitively on even the finest alterations of the environment. By this property, such species function like living instruments".

[1]Contribution No. 1090, Forest Entomology and Pathology Branch, Canada Department of Forestry, Ottawa.

This study is primarily concerned with the composition of the soil-surface anthropod populations during various stages in the development of red pine plantations, and secondly with the changes in relative density of the species between stands of different ages from year to year. If, from these studies, suitable indicator species or groups can be selected, subsequent experimental investigations will be carried out to determine the factors on which these biological indicators depend.

The author is pleased to express his appreciation to V. R. Vickery for identification of Orthoptera, C. D. Dondale for identifying spiders, and the Entomology Research Institute in Ottawa for the remainder of the insect identifications.

Methods

Stand Description

This research was conducted in four adjacent red pine plantations established in 1960, 1950, 1939, and 1929. Each stand represented a distinct stage in the development of the red pine community; the establishment, transitional, monoculture, and young-forest stages, respectively. Since these stands were previously described in detail (Martin, 1965), only their pertinent characteristics will be outlined here.

The soil, uniform throughout the area, consisted of deep, medium to coarse, stone-free sand of deltaic origin. The land was originally covered with a mature forest of yellow birch, *Betula alleghaniensis* Britt., maple, *Acer saccharum* Marsh., and white pine, *Pinus strobus* L., and following lumbering, was cultivated, grazed, and repeatedly burned from 1880 until 1929 when reforestation began.

The establishment stage, with a typical old-field soil profile characterized by a shallow, surface plow-layer and no appreciable organic horizon, supported a poor ground cover consisting of 16 herbaceous and two shrub species (Fig. 1A). The red pine were spaced 4 by 7, and were 1.3 ft high in 1962.

In the transition stage, litter had begun to accumulate directly beneath the trees, and although the ground vegetation showed essentially the same species complex, the average coverage and frequency of the herbaceous plants were reduced, while the density and frequency of the shrubs had increased (Fig. 1B). The trees were spaced 7 by 7 ft, and they were 11.7 ft high with their crowns covering about 75% of the ground in 1962.

The trees in the monoculture stage averaged 29.1 in height and were spaced 6 by 8 ft. Their crowns were completely closed. Ground vegetation was much reduced, and largely restricted to small openings resulting from tree mortality. A thick needle litter covered the soil surface (Fig. 1C), and a young podsol soil profile had begun to develop.

An alternate-row thinning was done in the 1929 stand in 1956 and this marked the beginning of the young forest stage. The residual trees were spaced 8 by 15 ft, and were 45.1 ft high, with their crowns covering 77% of the soil surface in 1962. The litter layer was thinner than that of the 1939 stand, and herbaceous plants had reappeared (Fig. 1D), although their coverage and density was much lower than that found in the two young stands.

Sampling Procedure

Four alcohol-pitfall traps, similar to those designed by Fichter (1941), were permanently installed 150 ft apart in each stand from 1960 through

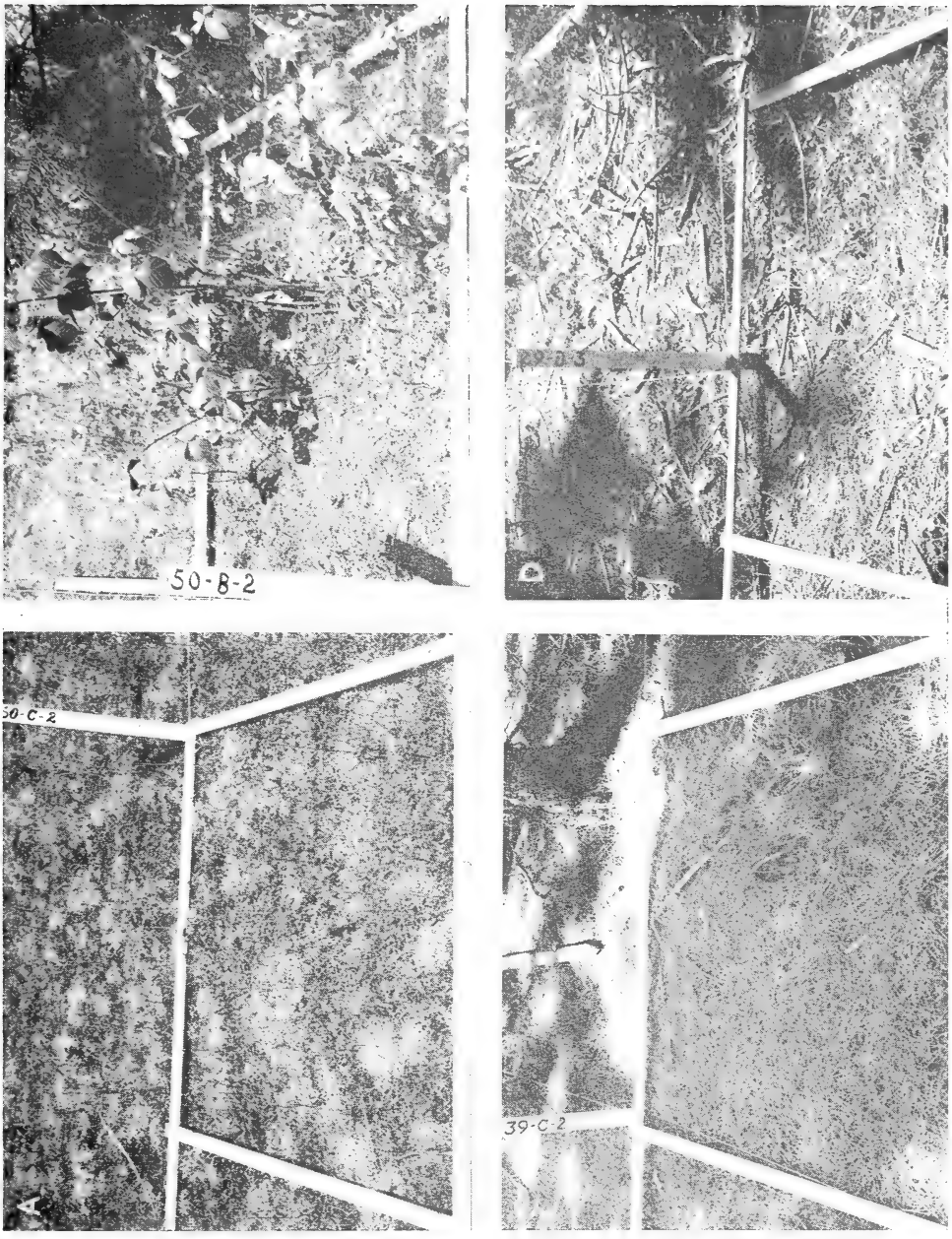

FIG. 1. Soil surface of: A, 1960 stand (establishment stage); B, 1950 stand (transition stage); C, 1939 stand (monoculture stage); D, 1929 stand (young-forest stage).

1964 (Fig. 2). The catch was collected from these traps once each week from the time the snow left the ground in April until October. The species were separated, listed, and counted in the laboratory.

Pitfalls have been used primarily as collecting aids for many years, but recently they have been utilized for a variety of ecological studies of soil-surface animals, and some disagreement has arisen concerning their value.

FIG. 2. The Fichter pitfall trap in operation.

Fichter (1954) stated that the pitfall trap does not measure any given unit of soil-surface population at any given time but does appear to indicate population trends. Van der Drift (1959) concluded that pitfalls yielded information on activity periods, life cycle, fluctuations in population density, local distribution, and phenology, and he stated that for any one species the numbers trapped during a certain time are sufficiently comparable with respect to season and place to indicate seasonal activity and local density, and that changes in total catches exceeding 25 per cent are caused by higher or lower density.

Briggs (1961) compared the efficiency of pitfall traps and soil sampling in determining the populations of two carabid species, and he concluded that the numbers of beetles trapped cannot be used as an indication of population levels—their use should be reserved for qualitative purposes such as defining the period of activity.

Williams (1958), on the other hand, conducted an experiment to determine the bias of the pitfall trap, and he concluded that sampling by pitfall traps, despite the inherent variability, is sufficiently sensitive to show real differences of ecological significance.

Williams (1958) and Briggs (1961) found that variations in the construction of the traps affected the size of the catch. Briggs (1961) and van der Drift (1959) concluded that the traps did not materially decimate the population in the area. Workers generally agreed that traps were selective; certain species avoided them, while others were actually attracted to them.

In the present study, the author was primarily seeking qualitative information on the occurrence of various soil-surface species in red pine plantations during different stages of development. From a quantitative standpoint, the author was satisfied that pitfalls provided a satisfactory indication of the relative density of certain species or groups in adjacent stands during similar periods of time. Pitfall traps may also be used to indicate seasonal population trends, but, as van der Drift (1959) stated, only substantial differences in numbers should be considered.

The Fichter pitfall trap was used in these studies because it captured more specimens than any of several simpler types of pitfalls tested. Additional advantages were: the collecting jar could be used with or without alcohol, and the alcohol was protected from dilution by rain and excessive evaporation.

Results

Pitfall captures from 1960 to 1963 indicated that soil-surface arthropod activity was greatest in the establishment stage, least in the monoculture stage, and about equal in the transitional and young forest stages of the red pine community (Table I). Although over 160 arthropod species were captured in pitfalls during this study, many were not true soil-surface animals, but merely strays from other strata in the community. Since the latter species will be discussed in future papers in relation to their natural abodes, they are largely disregarded here. In view of the almost total absence of studies of this kind in Canada (Kevan, 1960), a list of all species of arthropods encountered during the study is included as Appendix I because of its value from the standpoint of distribution records.

Faunal Changes and Community Development

Araneida and Phalangida

The spiders and harvestmen made up about one third of the arthropod fauna in the two early stages, but increased to one half of the total population in the later stages of community development (Table II).

The ground hunters (Lycosidae and Gnaphosidae) were the most abundant species in the establishment, transitional, and young forest stages, but they were outnumbered by the irregular web makers (Micryphantidae, Linyphiidae, Hahniidae, and Theridiidae) in the monoculture stage (Table III).

Five lycosids were common: *Geolycosa missouriensis* (Bks.), *Schizocosa avida* (Walck.), *Trochosa pratensis* (Em.), *Alopecosa aculeata* (Cl.) and *Pardosa mackenziana* (Keys.). The first two species were numerous in the establishment stage, and occurred occasionally in the transition, but were not found after the crowns closed. *T. pratensis* was present in all four stages, but was most abundant in the two older stages of the developing community. *A. aculeata* and *P. mackenziana* appeared during the transition period, and although found in the monoculture stage, they were trapped in larger numbers in the more open conditions of the transition and young forest stages (Table IV).

The Gnaphosidae constituted about one third of the ground hunters until the late transitional stage, but fewer than one tenth of the group in the two older stages. Table IV shows that the *Drassodes* species occurred only in the establishment stage, and *Gnaphosa parvula* Bks. through the first two stages. *Haplodrassus signifer* (L. Koch) was common until crown closure took place, disappeared in the monoculture stage, but reappeared in the semi-open condition of the young forest. *Drassyllus depressus* (Em.) and *G. muscorum* (L. Koch), although found in all stages, were most abundant prior to crown closure. *Zelotes* species were common throughout the development of the community.

The irregular web makers made up half the spider fauna of the monoculture stage, but they were found in much smaller numbers in the transitional and young forest stages, and they were rare in the establishment stage.

The foliage hunters (Thomisidae and Clubionidae) were common in the younger stages of the community where herbaceous plants were abundant, but they were much reduced in numbers in the older stages.

The harvestmen (Phalangida) were relatively rare in the establishment stage, but were common in the three later stages.

TABLE 1. Total annual catches of soil-surface arthropods (excluding Acarina and Collembola) in four stages of the developing red pine community, Kirkwood Township, Ontario, 1960-1963.

Stage	1960 Catch	1961 Catch	1961 % change from 1960	1962 Catch	1962 % change from 1961	1963 Catch	1963 % change from 1962	Average catch 1960 - 1963
Establishment	2580	2789	+ 8	3001	+ 7	1553	—48	2480
Transitional	1830	2069	+13	2785	+34	1235	—55	1979
Monoculture	765	1390	+86	2130	+53	1370	—35	1413
Young Forest	1893	1940	+ 2	2424	+24	1530	—36	1946

TABLE 2. Percentage composition of soil surface arthropod fauna (excluding Acarina and Collembola) as indicated by pitfall captures in four stages of red pine community development, Kirkwood Township, Ontario, 1960 to 1963.

Order	Year	Stage			
		Establishment	Transitional	Monoculture	Young Forest
Araneida (including (Phalangida)	1960	35	35	49	62
	1961	26	33	48	61
	1962	32	32	60	44
	1963	33	36	44	48
	Mean	31	34	50	54
Coleoptera	1960	20	22	25	26
	1961	26	26	26	20
	1962	25	28	22	30
	1963	18	31	32	27
	Mean	22	27	26	26
Orthoptera	1960	28	16	—	—
	1961	36	16	—	—
	1962	11	4	—	—
	1963	14	3	—	1
	Mean	22	10	—	—
Hymenoptera	1960	13	18	4	6
	1961	8	14	2	6
	1962	17	14	3	9
	1963	21	17	4	15
	Mean	15	16	3	9
Diptera	1960	1	4	20	3
	1961	1	7	22	10
	1962	3	9	12	11
	1963	4	6	7	6
	Mean	2	6	15	7
Hemiptera	1960	1	1	—	—
	1961	—	—	—	—
	1962	7	8	—	2
	1963	7	1	—	—
	Mean	4	2	—	—
Lepidoptera	1960	1	—	—	—
	1961	—	—	—	—
	1962	1	—	—	—
	1963	1	2	—	—
	Mean	0.7	—	—	—

TABLE 3. Percentage composition of the spider and harvestman fauna based on the total season's catch in pitfall traps in four developmental stages of a red pine community, Kirkwood Township, Ontario, 1963.

Ecological Group	Stage			
	Establishment	Transitional	Monoculture	Young Forest
Ground Hunters (Lycosidae, Gnaphosidae)	86	68	39	79
Irregular Web Makers (Micryphantidae, Hahniidae, Linyphiidae, Theridiidae)	1	15	50	11
Foliage Hunters (Thomisidae, Clubionidae)	12	4	0.5	1
Harvestmen	0.5	13	10	9

TABLE 4. Occurrence and relative abundance of some lycosids and gnaphosids in four developmental stages of a red pine community as indicated by pitfall traps, Kirkwood Township, Ontario, 1964

Species	No. specimens trapped May 1 to September 30			
	Establishment	Transitional	Monoculture	Young Forest
LYCOSIDAE				
Geolycosa missouriensis	17	1	—	—
Schizocosa avida	194	4	—	—
Trochosa pratensis	4	16	114	73
Alopecosa aculeata	—	125	96	211
Pardosa mackenziana	—	5	1	48
GNAPHOSIDAE				
Drassodes spp.	24	—	—	—
Gnaphosa parvula	3	1	—	—
Haplodrassus signifer	44	14	—	1
Drassyllus depressus	39	21	1	2
Gnaphosa muscorum	3	8	1	6
Zelotes spp.	43	36	21	47

Coleoptera

Although the Coleoptera as a group showed negligible variation in relative abundance in the four stages of community development (Table 2), differences in species composition were considerable. Over 70 species were captured in pitfalls from 1960 to 1963 (Appendix I), but many were strays from other strata in the community, and could not be considered true soil-surface fauna. The carabids were selected as the best indicators of environmental changes because they were numerous, and spent most of their adult life on the soil surface.

Table V shows that of the common species, *Stenolophus conjunctus* Say, *Calosoma calidum* F., *Amara* spp., and *Carabus serratus* Say appeared only in the open or semi-open conditions prior to crown closure. The two former species were most abundant in the establishment stage, and the remainder were found in about equal numbers in both stages in 1964.

At least four and possibly six species of *Harpalus* were recorded from the four stages, but their separation awaits taxonomic revision of the group. At present, all that can be said is that species of this genus, while occurring in all stages, were abundant only prior to crown closure.

Synuchus impunctatus Say and *Calathus* probably *gregarius* Dej. were found in all four stages, but the former species was common only in the relatively open conditions of the transition and young forest stages, while the latter was extremely abundant under the closed crowns of the monoculture stage. *Pterostichus pennsylvanicus* Lec. was found in the three older stages, and like *Calathus* was most numerous in the monoculture period.

TABLE 5. Occurrence and relative densities of some carabids in four developmental stages of a red pine community as indicated by captures in pitfall traps, Kirkwood Township, Ontario, 1964.

Species	No. specimens trapped May 1 to September 30			
	Establishment	Transitional	Monoculture	Young Forest
Stenolophus conjunctus	35	2	—	—
Calosoma calidum	19	1	—	—
Amara spp.	27	21	—	—
Carabus serratus	2	3	—	—
Harpalus spp.	51	47	5	13
Synuchus impunctatus	6	61	8	70
Calathus gregarius	7	42	403	67
Pterostichus pennsylvanicus	—	13	156	79

Orthoptera

The Orthoptera averaged 22% of the total sample of soil-surface fauna for the years 1960 to 1963 in the establishment stage, 9% in the transition stage, and 1% or less in the two older stages (Table II). Eleven species were commonly captured, and of these only one, the camel cricket, *Ceuthophilus maculatus* (Harris), was found after crown closure.

Pigmy locusts (three species), short-horned grasshoppers (three species), and field crickets (five species) were found in the two early stages. The numbers of pigmy locusts fluctuated strikingly from year to year, and the short-horned grasshoppers, although occasionally caught in pitfalls, were essentially inhabitants of the herbaceous vegetation rather than the soil surface.

For the purposes of this study, the crickets; *Gryllus pennsylvanicus* (Bur.), *G. veletis Alex.* and Big., *Nemobius fasciatus fasciatus* (DeGeer), *N. carolinus* Scudder, and *N. allardii* Alex. and Thom., were grouped and considered as a single indicator of stand change. During the period 1960 to 1963, the mean annual catch of gryllids in the establishment stage was 527, whereas only an average of 188 were taken in the transition stage, and none following crown closure.

Other Groups

Small numbers of hemipterous insects were captured in the establishment and transitional stages, but they were rare or absent in the later stages. Most species were associated with the ground vegetation, and were strays on the soil surface.

The Hymenoptera caught in pitfalls consisted mostly of ants, but bees and wasps appeared occasionally. Although the habitat relationships of the ants are not absolutely clear at present, it would appear that *Tapinoma sessile* (Say), *Dolicherdus* sp., *Lasius sitkaensis* Pergande, *Formica subintegra* Emery, and *F. lasioides* Emery occurred prior to crown closure, whereas *Myrica lobicornis fracticornis* Emery and *Lasius alienus* (Foerster) Em. appeared only in the monoculture and young forest stages.

Although adult Diptera are not true soil-surface inhabitants, and pitfalls are not the best device for trapping them, the catches do reflect differences in species composition and density between the various stages of community development that are borne out by studies in other strata. The greatest dipterous activity occurred in the monoculture stage where the species were mainly representatives of the Heliomyzidae, Mycetophilidae, and other fungus-feeding families. Fewer flies were captured in the young forest stage, but the species complex was quite similar to that of the former stage. The two younger stages were represented by small numbers of flies, consisting mostly of metopiids, muscids, tachinids, and syrphids.

Annual Fluctuations of Arthropods

The number of specimens captured in pitfalls increased annually in all stands from 1960 to 1962 but showed a marked decrease in 1963 (Table I). This reduction was probably related to severe drought, since only 17.32 inches of rain fell from April 1 to November 30 in 1963, compared to an average of 26.12 inches during the same period in the three previous years (Fig. 3).

Water is undoubtedly the most important factor limiting plant growth on the Kirkwood sands (Martin, 1965), and in both 1962 and 1963, the ground vegetation wilted and died as a result of drought in June and July. In 1962, partial recovery occurred following heavy rains in August and September, but in 1963 unusually dry conditions prevailed throughout the growing season.

The loss of the ground cover in 1963 was reflected by decreases of 48 and 55% from the previous year in pitfall captures in the 1960 and 1950 stands, respectively, whereas in the two older stands, where ground vegetation was not an important factor in relation to soil-surface fauna, the decrease was only 35%. The reduction in density of the gryllids in both 1962 and 1963 was probably partly due to destruction of the ground-cover. Although gryllids are usually considered omnivorous, they are undoubtedly dependent on vegetation for a large part of their food.

The smaller pitfall captures in dry years or during dry periods do not necessarily indicate lower population densities, particularly with reference to predators that have no direct relation to ground vegetation. Drought may have a depressing effect on locomotor activity, and this would be reflected in smaller catches in the traps (Briggs, 1961).

The annual percentage increase in the 1939 stand from 1960 to 1962 was much greater than that of the remaining stands. This trend followed a pruning operation in January 1961 when the lower branches, from ground level to 10 feet in height, were removed from the trees of the 1939 stand (Fig. 4). Pruning resulted in increased air circulation and higher temperatures in the stand, and this may have stimulated a more rapid breakdown of the thicker litter layer, with larger attendant populations of soil and soil-surface organisms.

The author suspected that the opening of the stand by pruning encouraged more flying insects to enter the stand. Window flight traps (Chapman and Kinghorn, 1955) placed in adjacent pruned and unpruned stands for two weeks in June and July, 1963, indicated that activity was greater in the pruned stand (Table VI). This would affect the numbers of insects captured in pitfalls, since some of these insects would spend a certain amount of time on the soil surface.

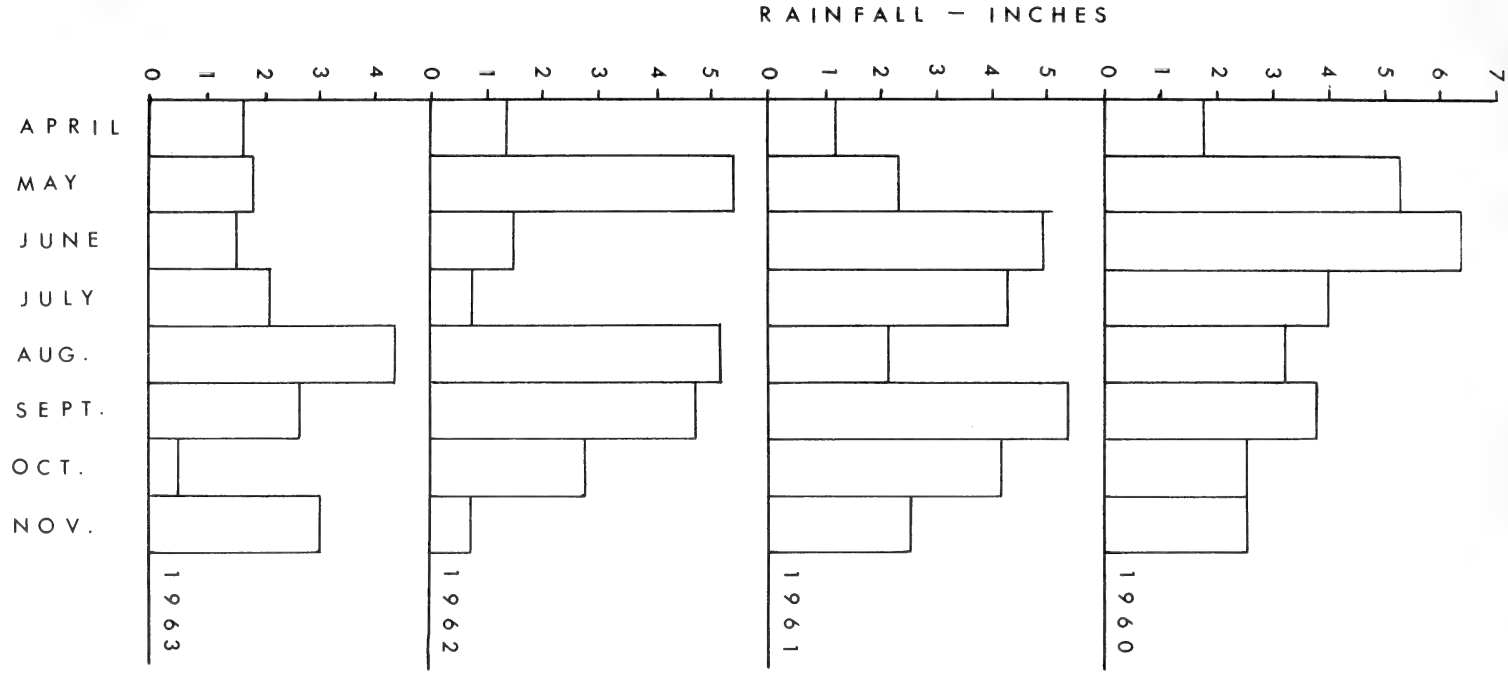

FIG. 3. Monthly rainfall, Kirkwood Township, Ontario, 1960-63.

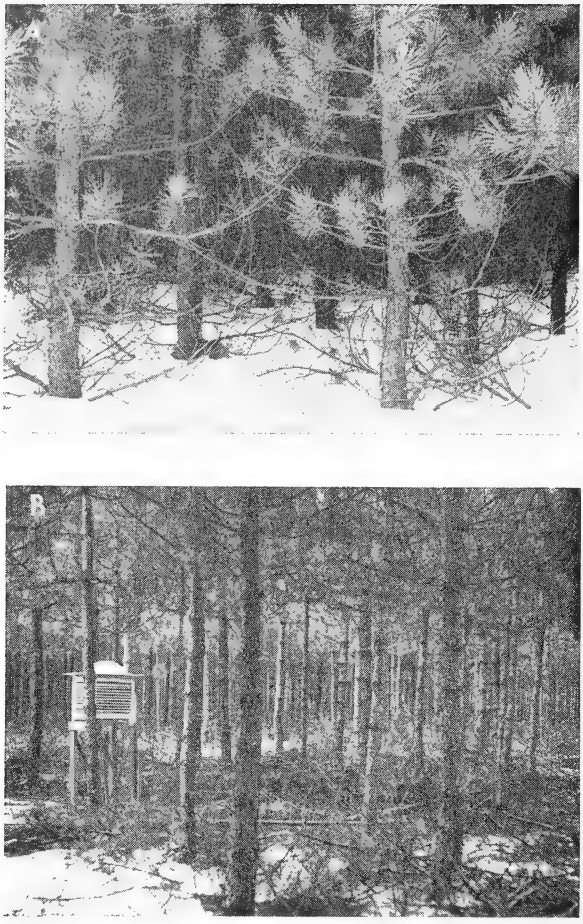

FIG. 4. The 1939 stand. A, before pruning; B, after pruning, 1961.

TABLE 6. Flying insects captured in four glass-pane traps placed between 4 and 6 ft above ground in adjacent pruned[a] and unpruned red pine stands, June 21 to July 5, 1963, Kirkwood Township, Ontario

Order	No. of insects captured	
	Pruned stand	Unpruned stand
Diptera	6010	3843
Lepidoptera	142	53
Coleoptera	124	49
Hymenoptera	117	53
Others	37	19
Total	6430	4017

[a]In the pruned stand, the lower branches were removed to a height of about 10 ft.

Discussion

The composition of the soil-surface fauna in the four stages suggests that definite successional trends coincide with stand development, and the species fall readily into a number of distinct groups.

First, there are those species which are typical of old-field conditions. They are common in the 1960 stand, but their numbers are steadily reduced as the trees grow larger, and they disappear by the time crown closure occurs. Examples of this group are: the gryllids; the lycosids, *G. missouriensis* and *S. avida;* the carabids, *Amara* spp., *S. conjunctus, C. calidum* and *C. serratus;* and the ants, *T. sessile, Dolicherdus* sp., *L. sitkaensis, F. subintegra* and *F. lasioides.*

Secondly, there is a group which occurs under old-field conditions, but appears in increasing numbers as the stands develop. Examples are: the lycosid, *T. pratensis;* and the carabids, *S. impunctatus* and *C.* probably *gregarius.*

A third group is absent in the old field, but appears during the transition stage and usually increases in numbers as the stands grow older. The lycosids, *A. aculeata,* and *P. mackenziana;* the carabid, *P. pennsylvanicus;* and the ants, *M. lobricornis fracticornis* and *L. alienus* are typical examples.

Some of the irregular-web making spiders, the lycosid, *T. pratensis;* the carabids, *C.* probably *gregarius* and *P. pennsylvanicus;* and certain Diptera prefer the deeply-shaded conditions of the closed stand, whereas the lycosid, *A. aculeata* and the carabid, *S. impunctatus* are more abundant in the semi-open conditions prior to closure, and again following thinning.

In general, the successional trend consists of rapid and broad changes in species composition during the transition stage, from the relatively stable composition of the old-field fauna to that of the young forest. The species composition of the late transitional stage bears considerable resemblance to that of the young forest stage, probably because of the somewhat similar semi-open conditions. The differences between these two stages and the monoculture stage are probably related to the different meso and microclimate of the completely closed stand, and the lack of ground vegetation. One would expect that the faunal composition established in the young forest stage (as typified by the 1929 stand) would remain relatively the same for many years, barring drastic changes in stand structure and composition.

Except for the gnaphosids, *Zelotes* spp., it is interesting to note that investigations have not revealed any species of wide ecological valency ranging in about equal numbers throughout the four developmental stages of the red pine stand. Most of the species encountered were either restricted to certain stages, or were found throughout several stages, but reached their highest densities at a particular period in community development.

Future studies will attempt to determine whether the occurrence of these species in any particular habitat is indicative of food preferences, physical agreeability, or a combination of both factors.

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Appendix I

Appendix 1. List of arthropods (excluding Acarina) taken in pitfall traps in red pine plantations in Kirkwood Township, Ontario, 1960-1963.

ARANEIDA

Gnaphosidae

Gnaphosa muscorum (L. Koch)
Gnaphosa parvula Bks.
Zelotes Hentzi Barrows
Zelotes puritanus Chamb.
Zelotes subterraneous (C.L.K.)
Drassyllus depressus (Em.)
Drassodes sp.

Thomisidae

Xysticus trigutattus Keys.
Xysticus pellax O.P.-C.
Xysticus canadensis Gertsch.
Xysticus elegans Keys.

Agelenidae

Cicurina brevis (Em.)
Cicurina itasca C. and I.

Hahniidae

Neoantistea agilis Keys.

Theridiidae

Enoplognatha sp.

Lycosidae

Trochosa pratensis (Em.)
Schizocosa avida (Walck.)
Pardosa mackenziana (Keys.)
Pirata sp.
Lycosa helluo Walck.
Geolycosa missouriensis (Bks.)
Alopecosa aculeata (Cl.)

Araneidae

Araneus nordmanni (Thorell)

Linyphiidae

Lepthyphantes zebra (Em.)
Meioneta sp.

Micryphantidae

Ceraticelus fissiceps (O.P.-C.)
Ceratinops crenata (Em.)
Eperigone trilobata Em.
Tunagyna debilis (Bks.)
Grammonota angusta Dondale
Ceratinella brunnes Em.
Souessa spinifera (O.P.-C.)
Maso sp.

PHALANGIDA

Leiobunum calcar (Wood)
Odiellus pictus (Wood)

COLLEMBOLA

Bourletiella hortensis (Fitch)
Sminthurinus aureus (Lubbock)
Sminthurides lepus Mills
Lepidocyrtus unifasciatus Jam.
Lepidocyrtus cyaneus Tullberg
Lepidocyrtus curvicollis Bour.
Entomobrya sp.
Hypogastrura nivicola (Fitch)
Metakatianna macgillivrayi (Banks)
Orchesella pallens Maynard
Orchesella hexfasciata (Harvey)
Isotoma viridis Bourlet
Isotoma violacea (Tullberg)
Tomocerous flavescens (Tullberg)

ORTHOPTERA

Tetrigidae

Nomotettix cristatus cristatus Scudder
Acridium ornatum (Say)

Acrididae

Melanoplus bilituratus (Walker)
Camnula pellucida (Scudder)
Chorthippus eurtipennis (Harris)

Gryllacrididae

Ceuthophilus maculatus (Harris)

Gryllidae

Gryllus pennsylvanicus (Bur.)
Gryllus veletis Alex. and Big.
Nemobius fasciatus fasciatus (DeGeer)
Nemobius carolinus Scudder
Nemobius allardii Alex. and Thom.

HOMOPTERA

Misc. families

Aceratagallia prob. *sanguinolenta*
Erythroneura coxi Ross. and Del.
Agallionsis prob. *novella*

HEMIPTERA

Misc. families

Metapterus uhleri (Banks)
Neides muticus (Say)
Sphaerobius insignis (Uhl.)
Emblethis vicarius Horv.
Amnestus pusillus Uhl.

COLEOPTERA

Cicindelidae

Cicindela duodecimguttata Dej.

Carabidae

Carabus serratus Say
Calosoma calidum F.
Calosoma frigidum Kly.
Notiophilus semistriatus S.
Notiophilus aeneus Hbst.
Dyschirius sp.
Clivinia fossor L.
Miscodera arctica americana Mann.
Nomaretus bilobus Say.
Galerita bicolor Drury
Stenolophus conjunctus Say
Metabletus americanus Dej.
Bembidion sp.
Badister neopulchellus Lth.
Agonum gratiosum Man.
Synuchus impunctatus Say
Calathus prob. *gregarius* Dej.
Calathus sp.
Pterostichus melanarius Ill.
Pterostichus coracinus Newm.
Pterostichus lucublandus Say
Pterostichus adstrictus Eschz.
Pterostichus mutus Say.
Pterostichus pennsylvanicus Lec.
Myas cyanescens Dej.
Anisodactylus rusticus Say.
Amara latior Kby.
Amara sp.
Harpalus compar Lec.
Harpalus affinis Schrk.
Harpalus spp.

Silphidae

Catops sp.
Eucinetus terminalis Lec.

Leiodidae

Leiodes sp.

Staphylinidae

Philonthus cyanipennis F.
Philonthus spp.
Mycetoporus sp.
Ontholestes cingulatus Grav.
Staphylinus violaceous Grav.
Quedius spp.
Aleocharinae spp.
Lathrobium sp.
Bryoporus sp.
Bolitobius sp.

Scaphidiidae

Baeocera concolor Fab.

Histeridae

Hister spp.

Lampyridae

Lucidota corrusca L.

Cantharidae

Podabrus modestus Say.

Elateridae

Ctenicera triundulata (Rand.)
Ctenicera propola propola Lec.
Ctenicera hieroglyphica (Say)
Ctenicera appropinquans Rand.
Ctenicera splendens (Zieg.)
Ctenicera bombycina Germ.
Ampedus pullus Germ.
Melanotus fissilis (Say)
Agriotes limosus (Lec.)
Cardiophorus gagates Er.

Byrrhidae

Byrrhus sp.

Nitidulidae

Glischrochilus sanguinolentus Oliv.
Epureae planulata Er.

Coccinellidae

Mulsantina picta (Rand.)

Scarabaeidae

Aphodius rubripennis Horn.
Phyllophaga fervida Fab.
Osmoderma scabra Beauv.
Osmoderma eremicola Knoch.
Geotrupes splendidus Fab.
Geotrupes hornii Blanch.
Diplotaxis tristis Kby.
Dialytes striatulus Say.

Cerambycidae

Clytus ruricola (Oliv.)
Rhagium inquisitor (L.)
Acmaeops proteus Kby.
Asemum atrum Esch.

Alleculidae

Ispmira quadristriata Couper

Buprestidae

Chalcophora fortris Lec.

Curculionidae

Brachyrhinus ovatus (L.)
Hylobius congener D.T.

Scolytidae

Hylastes porculus Er.
Hylurgops pinifex Fitch.
Orthotomicus caelatus (Eichh.)
Dendroctonus valens Lec.
Ips pini Say

HYMENOPTERA

Formicidae

Myrmica lobricornis fracticornis Emery
Tapinoma sessile (Say)

Dolichoderus sp.
Lasius sitkaensis Pergande
Lasius alienus (Foerster) Em.
Formica subintegra Em.
Formica lasioides Em.
Formica sp.

Misc. families
Lassioglossum leucogonium Sm.
Osmia subaustralia Ckll.
Anoplius tenebrosus (Cress.)
Sphex. arvensis (Dahlbom)
Rygchium spp.
Ichneumon canadensis Cress.

DIPTERA
Misc. families
Eumerus strigatus (Fall)
Suillia assimilis (LW)
Helina rufitibia (Stein.)
Muscina assimilis (Fall)
Lispocephala erythrocera (R.D.)
Phaonia bysia (Walker)
Cynomyia cadaverina R.D.
Atropharis insolita (Wlk)
Asilus novascotiae Macq.
Tipula (Vestiplex) fultonensis Alex.
Sciophila glabana Jon.
Syrphus vittafrons
Metasyrphus wiedmanni Johns.

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OVIPOSITION SITES AND THE VIABILITY OF EGGS OF *THYMELICUS LINEOLA* (OCHS.) (LEPIDOPTERA:HESPERIIDAE)

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Introdution

The European skipper, *T. lineola,* first discovered in North America near London, Ontario about 1910 (Saunders, 1916) continues to spread in Ontario and the North Eastern States. Various aspects of its distribution and habits have been reported by Rawson (1931), Clench (1956), Riotte (1960), Pengelly (1960), Buchner and Arthur (1961), and Arthur (1962). In most areas of its range, either because of the small numbers of individuals involved or because no damage has been observed, little attention has been given to this species during its spread. In parts of Ontario, especially the counties of Grey and Bruce, *T. lineola* has been destructive to hay and pasture grasses. In 1963 specimens were collected at Lion's Head on the Bruce Peninsula but no damage has been reported.

The economics of the areas involved and the nature of the crops were such that chemical control of this insect was not considered. A few small-scale tests were done with insecticides and preliminary trials done with *Bacillus thuringiensis* Berliner. The latter was reported to be very effective (Angus pers. comm.). At the present time it appears that control measures were unnecessary in most of southern Ontario. There was a build up of the population numbers during the 1950's but since then there has been an obvious decline. The damage done during 1962, 1963 and 1964 was not considered serious.

As part of the control aspect, studies were undertaken to determine the species of plants suitable as oviposition sites. Should these have proven to be limited to one or two species of cultivated grasses, then cultural control could have been suggested. This paper reports on studies conducted in Grey County near Priceville in southern Ontario.

Procedure

Various species of grasses found in pastures, hay fields, abandoned farms, roadsides and headlands were collected in late October. Attempts

to take square-foot samples proved to be too time consuming to be of value in this study. It was found advisable to sever the plants at ground level or to remove them by roots because of the location of eggs on the grass stems.

Results

The species of grasses collected are listed below:

Agropyron repens (L.)	Twitch grass
Agrostis alba L.	Red Top
Bromus inermis Leyss.	Brome grass
Dactylis glomerata L.	Orchard grass
Danthonia spicata (L.)	White Oat-grass
Phleum pratense L.	Timothy
Poa compressa L.	Canada Blue Grass
Poa pratensis L.	Kentucky Blue Grass

Many more plants of Orchard Grass, Brome grass and of the sterile form of Red Top were examined than reported. These did not contain eggs of *T. lineola* thus no record was kept of the numbers of plants involved. The grasses studied are shown in Table 1 and data presented on the numbers of plants with eggs, on the numbers of eggs and on their viability.

The numbers of eggs on each plant varied considerably. In one sample of plants of Red Top the distribution was 135 plants with no eggs, 3 plants with 1 egg, 3 with 2 eggs, 4 with 3, 12 with 4, 3 with 5, 6 with 6, 4 with 7, 4 with 8, 2 with 9, 4 with 10, 4 with 11, 2 with 12, 1 with 13, 3 with 14, 2 with 15, and single plants with 17, 20, 25, 26 and 36 eggs.

Eggs of *T. lineola* were deposited under the blades of the grass where they wrapped around the stems between the nodes. The position of the eggs on the plants in relation to the nodes was studied. Of the 57 eggs on 11 Timothy plants, 52 were above the first node and 5 above the second. On 100 stems of Red Top, 57 eggs were above the first node, 323 above the second node, 164 above the third and 5 above the fourth.

Discussion

The study of the kinds of grasses utilized by *T. lineola* as oviposition sites indicated that one of the criteria in host-plant selection was that the blade or leaf must be wrapped around the stem for much of the internodal distance. The uppermost parts of the plants were seldom utilized. This may have been influenced by the size of the stem or by the condition of the plant at the time eggs were deposited. The majority of the eggs were laid during the first two weeks of July. Orchard grass and the blue grasses were unsuitable as oviposition sites. In these plants, the blades were not wrapped around the stems or, if so, only slightly. The sterile form of Red Top and Brome Grass appeared to be suitable but none was used for oviposition.

The selection of oviposition sites did not appear to be related to the value of the species of plant as larval food. All grasses so far studied with the exception of meadow fescue and the cultivated grains were utilized by larvae.

The use of cultural control does not appear to be practical. The cultivation of pastures and hay fields to remove the plants favoured for oviposition by *T. lineola* would be difficult and perhaps too expensive to warrant it. These areas would have to be reseeded with grasses suitable for forage but of little or no value as oviposition sites. The major part of the damage to grasses by larvae of this insect was confined to the first

TABLE 1. The species of plants utilized for oviposition, the numbers of eggs deposited, and the viability of eggs of *Thymelicus lineola* (Ochs.) in southern Ontario 1961-1963.

Year	Species of Plant	Numbers of Plants Examined	Numbers with Eggs	Percentage with Eggs	Numbers of Eggs	Numbers of viable Eggs	Percentage of viable Eggs
1961	Red Top	107	65	60.7	1319	1144	86.7
1962	Red Top S*	22	0	0.0	0	0	0.0
	Red Top F*	216	62	28.7	417	286	68.6
	Timothy	41	17	41.5	191	155	81.2
	Oat-Grass	12	0	0.0	0	0	0.0
	Orchard	25	0	0.0	0	0	0.0
	Brome	32	0	0.0	0	0	0.0
1963	Timothy	135	13	9.6	73	60	82.2
	Red Top	584	102	17.5	874	723	82.7
	K. Blue	233	1	0.4	4	0	0.0
	C. Blue	25	0	0.0	0	0	0.0
	Twitch	27	3	11.1	28	27	96.4
					2906	2395	82.4

*Sterile form and Fertile form

three weeks of June. Thus, even the most heavily infested fields recovered and produced fodder later in the summer.

Early cutting of hay crops or severe grazing of pastures in June would not remove the oviposition sites. The majority of the eggs were found below the third node of the grass stem, usually within 6 cm of ground level. Following mowing or normal grazing by cattle there were ample oviposition sites remaining.

As mentioned previously there was an obvious decline in the numbers of this insect in the areas studied from 1960 to 1964. This was evident also in the numbers of plants containing eggs, Table 1. The percentage in Red Top dropped from 60.7 in 1961 to 28.7 in 1962 and to 17.5 in 1963. On Timothy the drop was from 41.5 per cent in 1962 to 9.6 per cent in 1963.

The spread of *T. lineola* and its numbers appear to have been developing in the manner typical of introduced animals. There was a period of about 50 years when only brief mention was made of the insect as it moved out of the area of original infestation. Between 1950 and 1960 its numbers reached a peak which was most obvious in Grey and Bruce counties. In the areas where the peak population was reached in the period 1956 to 1959 a decline was evident also after 5 to 6 years. Abnormal weather conditions existed during 1961 and 1962 which may have resulted in the reduction of numbers, thus there may be a return to previous levels. However, this may be the typical pattern of numbers increasing to a peak, dropping abruptly, and then stabilizing at some moderate level. If this is true we can expect temporary eruptions of the species in the newly invaded areas in the northern and eastern parts of Ontario. Undoubtedly the spread will continue until a barrier is reached. This barrier will probably be in terms of lethal low temperatures in the northern regions.

The species is well established in Ohio (Thomas, 1953) and Michigan (Clench, 1956) indicating a continued spread from the Detroit area where it was first recorded in the United States (Rawson, 1931). The limits to a southward movement will likely be determined by the low temperature required to break diapause. Movement westward is a likelihood in both Canada and the United States. Hay crops that are shipped from the areas of infestation may prove to be an effective means of transferring the species to new areas.

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GEOTACTIC RESPONSE OF THE TWO-SPOTTED SPIDER MITE, *TETRANYCHUS URTICAE* KOCH (ACARINA: TETRANYCHIDAE)

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Introduction

Tetranychus urticae Koch commonly occupies three different habitats during the year. It subsists on the ground cover plants of deciduous fruit orchards during the spring and early summer, mainly moves to the trees in mid-summer, and hibernates during the winter as a fertilized female in diapause under the bark and in crevices of trees, or on the ground. This seasonal distribution is well-documented in the literature for apple orchards, and to a much lesser extent for pear, plum, cherry and peach orchards. Although investigators in numerous fruit-growing areas have agreed that mites which overwinter on the trees move to the ground cover in the spring, there is apparently no information in the literature to explain this movement.

Methods

The possibility that diapause females were positively geotactic was examined in a greenhouse. Potted peach seedlings 18 to 24 inches high were stripped of all leaves except three or four at the tip and a like number at the base. A short stub of a leaf was left in the center of the plant. The stub served as a platform on which mites could be placed, but was not large enough to maintain even a small number of mites for very long. Tanglefoot[1] was placed around the stem at the base of the plant. Diapause and non-diapause females were placed on the center stubs of separate plants. One day after placement their distribution was recorded and the mites were returned to the stubs. This procedure was repeated for several days. Diapause females were obtained from three sources: beneath loose bark on McIntosh apple trees, from bean plants in a greenhouse, and from bean plants in an insectary. In the latter instance the mites were usually transferred in late October from the insectary to a refrigerated room and stored at a temperature of approximately 35°F until tested. Mites were not considered to be in full diapause if they fed and oviposited within four days after placement on the plants. Non-diapause females were reared in a greenhouse.

Results and Discussion

Tests showed that the majority of diapause females were positively geotactic and that non-diapause females were negatively geotactic (Table 1). Diapause females from greenhouse plants, and which had received no cold treatment, were positively geotactic for a longer period than those which had been exposed to low temperatures. Mites which had the typical orange color of diapause forms, but fed and oviposited prior to the fourth day, were negatively geotactic. Negatively geotactic mites placed on the center stub of a peach seedling which had lower leaves, but no upper leaves, travelled along the upper portion of the bare stem for several hours and then descended to the basal leaves.

In most instances the diapause forms started to feed and oviposit by the fifth or sixth day and had lost most of their orange color by the seventh

[1]Tanglefoot Co., Grand Rapids, Mich.

TABLE 1. Geotactic response of diapause and non-diapause females of *Tetranychus urticae*.

Form	Number of days after resumption of activity[a]	Number of mites tested	Distribution on peach seedlings		
			Upper leaves	Centre stub	Lower leaves
Diapause	1 — 2	353	43	35	275
	3 — 4	140	18	1	121
	5 — 6	87	30	1	56
	7 — 8	132	85	4	43
Non-diapause	—	549	394	24	131

[a]Mites were returned to center stub each day.

or eighth day. However, one mite which had been in a box in an insectary from October to January, and survived temperatures down to —5°F, neither fed for 20 days, nor oviposited for 22 days, and retained its orange color for 26 days. In 10 separate transfers to the center stub prior to the first egg deposition this mite always went to the lower leaves. During the six days between first egg deposition and loss of orange color it went to the lower leaves after three transfers and to the upper leaves on the other three. Subsequent to a complete loss of orange color it went to the lower leaves after three transfers and to the upper leaves after seven transfers.

In April, 1958, it was noted that 56% of the mites still hibernating under the bark showed a negative response. This indicated they had probably been active for a number of days and had lost some of their diapause characteristics. In 1959, frequent tests of geotatic response were made from late fall to spring and an attempt was made to correlate spring activity with tree development and temperature.

Of mites tested between October, 1958 and March, 1959, 80.5% were positively geotactic. However, only 17.6% of the hibernating forms showed a positive response from April 15 to 21. All mites were active beneath the bark at this time and it was evident that large numbers had left. The mean maximum temperature during the first 15 days of April was 51.7°F, with a high of 66°F. The mean maximum from April 16 to 21 was 58°F, with a high of 71°F. There was no foliage on the trees on April 15 and only ¼ to ½-inch of green tissue at the tips of the buds on April 21.

The data are interpreted as follows. A positive geotactic response in the fall ensures that mites will find shelter on the lower parts of trees and on the ground, rather than remain in an exposed area when in diapause. In the spring, with its variable weather, there might be periods of activity beneath the bark alternating with periods of inactivity. Mites which emerged from hibernation soon after becoming active would be positively geotactic and move to the ground cover. Those which remained in hibernation for a longer period after activity commenced would experience a gradual reversal in geotactic response. On leaving the hibernation site some of the latter would move up the trunk and others down. Because there was little or no foliage on apple trees during the period when most of the mites emerged, those which went up would undoubtedly come back down the trunk in their search for food. Some evidence that this might occur was obtained in the greenhouse. A similar occurrence in the orchard would explain the paucity of *T. urticae* on apple trees in the spring.

A negative geotactic response by the non-diapause females was noted previously by Attiah (1963), Foott (1963) and Hussey and Parr (1963). The present investigation appears to be the first report of a positive geotactic response by the diapause female.

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SOME FACTORS INFLUENCING CONTROL OF THE TWO-SPOTTED SPIDER MITE *TETRANYCHUS URTICAE* KOCH (ACARINA: TETRANYCHIDAE), ON GREENHOUSE CUCUMBERS

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Introduction

One of the most persistent problems for the growers of greenhouse cucumbers in southwestern Ontario is control of the two-spotted spider mite, *Tetranychus urticae* Koch. The opportunity to use almost all forms of chemical control such as sprays, dusts, aerosols, smokes and fumigants does not appear sufficient to offset the highly favorable conditions for mite development in a greenhouse. The results of an investigation to ascertain some of the factors which appeared to encourage mite infestations and to suggest methods for reducing the intensity of the problem are reported herein.

Materials and Methods

Twenty-five greenhouses were visited during the investigation. Included were both large and small establishments, houses where cucumbers were grown for many years, and new houses. Each grower was questioned as to the chemicals used for control and the method and frequency of application during both the year of inspection and in previous years. Information was also sought on their sanitation methods and the possible source of their infestation.

The plants in each greenhouse were examined and when colonies of mites were found a sample was collected, returned to the Research Station for propagation, and later tested for possible resistance to acaricides. The outside of each greenhouse was examined and a record made of the number of greenhouses which were surrounded by mite-infested weeds. Samples of mites from these sources were also collected for propagation and treatment with acaricides. If predatory mites were found in the greenhouse or on the weeds they were preserved and forwarded to a specialist for identification.

In initial tests with acaricides, discs were cut from leaves of Clark's bush lima bean plants, ringed with Tanglefoot[1], placed on water-soaked pads of absorbent cotton in Petri dishes, and populated with five adult females for four days. The egg-bearing leaf discs were sprayed in a settling tower for one minute with wettable powder formulations of the following acaricides, each material being applied at the active ingredient rate per 100 gallons of water shown in brackets: 50% chlorfenson (3.0 oz)[2], 18.5% dicofol (1.11 oz)[3], 25% malathion (1.5 oz)[4] and 25% tetradifon (1.5 oz)[5]. Correspondingly-prepared dishes were treated with distilled water to serve as checks. All treatments and controls were replicated twice. The effectiveness of all materials tested in this investigation was based on the percentage of mites which failed to reach the adult stage. Information on the settling tower and spray equipment used in these experiments was published in an earlier paper (Foott, 1960).

As very low mortality occurred when the 1.5 oz rate of malathion was used, further tests with this material were made at rates of 3, 4, 6, 8 and 12 oz of actual toxicant per 100 gal against both the eggs and early immature stages. Subsequently, populations from six different locations were selected for more intensive studies. In the latter instance, early immature stages of each population were treated with a minimum of five rates and the LD_{50} for each population was calculated by the method of Finney (1952). All treatments and distilled-water checks were replicated three times. The six populations were also treated with technical parathion, 98.5% active[6], to test for cross-resistance. The lack of a suitable area for application of highly toxic materials with spray equipment necessitated the use of the dipping method for this toxicant. The parathion was incorporated with water and acetone at a ratio of 9:1 to give dilutions of 0.01, 0.05 and 0.075% actual toxicant per volume of liquid. Homogeneity of test solutions was obtained by placing a stirring bar in the solution and mixing with a magnetic stirrer. Entire bean leaves infested with early immature stages were dipped in the solutions for 30 sec and the excess liquid allowed to drip off to avoid the accumulation of parathion in depressed areas on the leaves. The leaves were ringed with Tanglefoot and maintained on water-soaked pads of absorbent cotton until the mortality was determined. Each acaricide treatment and distilled-water check was replicated three times.

To examine the possibility that there was an interchange of resistant mites between greenhouses and outside weeds the susceptibility to an acaricide of five greenhouse populations was compared with that of mites obtained from weeds surrounding the respective greenhouses. Early immature stages were sprayed with 25% malathion wettable powder at dilutions of 2 and 8 oz of actual toxicant per 100 gal of water. All treatments and distilled-water checks were replicated six times.

The fecundity of populations susceptible and resistant to organic phosphates was compared by placing two-day old adult females, from each of the six selected populations referred to earlier, on bean leaves in a rearing room. The average egg deposition of 24 females from each popula-

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[1]Tanglefoot Co., Grand Rapids, Mich

[2]p-chlorophenyl p-chlorobenzenesulphonate. Dow Chemical Co., Midland, Mich.

[3]1,1-bis (p-chlorophenyl) 2,2,2-trichloroethanol. Rohm and Haas Co. of Canada, Ltd., West Hill, Ont.

[4]S-[1,2-di(ethoxycarbonyl)ethyl] dimethyl phosphorothiolothionate. Niagara Brand Chemicals, Burlington, Ontario.

[5]2,4,5,4'-tetrachlorodiphenyl sulfone. Niagara Brand Chemicals, Burlington, Ontario.

[6]0,0,-diethyl-0-p-nitrophenylthiophosphate. Cyanamid of Canada Ltd., Montreal, Quebec.

tion was determined daily. Temperatures in the rearing room were 72 ± 1°F during 16 hr of illumination from overhead fluorescent tubes and 70 ± 1°F during 8 hr of darkness.

Results and Discussion

The main factors which appeared to encourage mite infestations will be discussed under the headings of treatment programs, miticide resistance, sources of infestations, and predation.

Treatment Programs

Few mites were observed by most growers during the early part of the season and these appeared to be limited in distribution. A common practice at this time was to treat a very small area of the greenhouse in the belief that control could be established. Undoubtedly mites had dispersed beyond the treated area and by not treating the entire house the growers lost an opportunity to obtain control while the populations were low. As the season progressed infestations increased and control became more difficult. By June, 22 of the 25 greenhouses examined were infested and the other 3 had been infested previously.

Very few growers appeared to have a planned program of treatment or to maintain adequate records of chemicals used and dates of application in the current or past seasons. They often did not understand the limitations of the materials used. Consequently, when a greenhouse was treated with a smoke, failure to retreat within a few days allowed mites which had been in the egg stage at the time of treatment to hatch and continue the infestation. When sprays or aerosols were used too infrequently new foliage was left unprotected. Inadequate coverage on the lower leaf surface was responsible in some cases for poor control. One grower made four applications of dicofol dust at weekly intervals, but found that the mites continued to increase. An examination of his plants showed that there was a dense accumulation of acaricides and fungicides on the upper surfaces of the leaves, but only a trace of these materials on the lower surfaces. The inefficiency of his dusting operation was particularly evident from the distribution of powdery mildew. The upper surfaces of the leaves were almost devoid of the disease while the lower surfaces were heavily infected.

One of the three growers who controlled the mites had used five different materials in a total of nine applications. The second had used a smoke twice within a short interval while the population was low. The third used only three sprays throughout the season but obtained excellent coverage because he first sprayed the lower areas of the plants and then with the aid of a ladder sprayed the upper parts.

There are at least three other factors which limit effective control in the spring and early summer. First, as temperatures increase the rate of mite development also increases. Secondly, the planting and harvesting of outside crops greatly reduces the time available to the grower for inspection and treatment of greenhouse crops. Thirdly, a dense canopy of leaves at the top of the supporting wires prevents adequate coverage.

Miticide Resistance

All populations were highly susceptible to chlorfenson, tetradifon and dicofol at rates of 3.0, 1.5 and 1.11 oz a.i., respectively, per 100 gal of water. Very poor control was obtained with malathion at 1.5 oz a.i. per 100 gal of water. When rates of the latter material were increased to 3, 4, 6, 8 or 12 oz a.i. per 100 gal of water a great range in susceptibility was evident.

Resistance to malathion to some degree occurred in 11 of the greenhouse populations. Four of the 11 resistant populations, plus two others which appeared highly susceptible, were selected for more extensive tests with a wide range of rates against the early immature stages. The LD_{50} and other pertinent data for each population are shown in Table 1. At the highest rates used against the Countess and Wilkinson populations there was a very heavy deposit on the leaves and it is doubtful that increased rates would have increased mortality appreciably. Hoskins and Gordon (1956) noted that in the case of insects an increase in an already large dose of toxicant does not result in an appreciable increase in effect because much of the toxicant is not accessible to the insect.

TABLE I. Regression coefficients and LD_{50} values for six populations of *Tetranychus urticae* treated with 25% malathion wettable powder

Population	Slope of regression line	LD_{50}, ounces actual toxicant per 100 gal water[a]	5% fiducial limits	
Mastronardi	2.714 ± 0.193	0.356	0.301	0.422
Malott	1.486 ± 0.137	3.126	2.474	3.948
DiMenna	1.038 ± 0.093	7.709	5.579	10.651
Krahn	0.706 ± 0.085	26.870	23.690	30.477
Countess	2.737 ± 0.211	135.944	115.416	160.108
Wilkinson	0.973 ± 0.144	145.616	100.092	211.844

[a]Mites were sprayed in the early immature stages in a settling tower.

Tests in which bean leaves infested with early immature stages were dipped in parathion solutions indicated that there was a cross-resistance to this material (Table II). The order of susceptibility for the six populations was approximately the same as for malathion.

The Wilkinson greenhouse had just been purchased by a new owner who had no information on the acaricides which had been used in previous years. However, because it had been used for cucumbers for a number of years, a resistant population might have developed from frequent use of organic phosphates. The Countess greenhouse was new and in its first year of production. Therefore this would be an instance in which a resistant strain was introduced into a greenhouse.

TABLE II. Percentage mortalities for six populations of *Tetranychus urticae* treated with three rates of technical parathion[a]

Population	Per cent mortality in relation to per cent active ingredient			
	Check	0.01	0.05	0.075
Mastronardi	3.9	69.2	95.3	100.0
DiMenna	4.7	36.3	79.2	89.9
Malott	4.7	33.1	76.1	88.7
Krahn	4.4	23.9	50.1	76.2
Countess	3.9	7.5	25.2	33.0
Wilkinson	4.6	7.2	21.8	33.3

[a]98.5% active. Bean leaves infested with early immature stages were dipped in the solutions for 30 sec. There were three replicates per treatment.

In a similar survey conducted in Holland, Helle (1959) found that 20 of 22 greenhouse populations tested were resistant to organic phosphorus compounds. Fjellddalen and Stenseth (1962) tested five populations from five different parts of Norway and found all were resistant to organic phosphates.

Hoskins and Gordon (1956) stated that the fertility of arthropods highly resistant to pesticides is often very low. Lehr and Smith (1957) and Henneberry *et al* (1960) noted that strains of *T. urticae* susceptible to organic phosphates deposited more eggs than resistant strains. Dittrich (1961) observed that the fecundity of four strains of *T. urticae* with different degrees of resistance to demeton, but the same genetic origin, was directly correlated with the degree of resistance. High resistance was linked with low fertility and low resistance with high fertility. Watson and Hansen (1963) found that the difference in egg production between strains susceptible and resistant to parathion was no greater than that expected by chance. In the present investigation with six populations with different degrees of susceptibility to organic phosphates there was no correlation between fecundity and resistance (Table III).

TABLE III. The fecundity of six populations of *Tetranychus urticae* with varying degrees of resistance to organic phosphates[a]

Population	Average egg disposition per female per specified period of oviposition			
	1 week	2 weeks	3 weeks	4 weeks
Mastronardi	63.8 (24)[b]	121.4 (22)	170.8 (14)	222.4 (8)
Krahn	64.3 (24)	122.1 (24)	170.9 (20)	198.7 (6)
Wilkinson	68.4 (24)	127.2 (22)	176.1 (20)	220.2 (12)
Malott	71.0 (24)	135.4 (24)	181.7 (20)	204.3 (10)
DiMenna	78.1 (24)	142.9 (24)	190.9 (20)	206.5 (8)
Countess	79.2 (24)	143.4 (22)	185.8 (12)	225.7 (8)

[a]The relative resistance of the populations is shown in Table I.

[b]The figures in brackets indicate the number of mites on which the average was based.

Sources of Infestations

There is evidence that mites are inadvertently brought into cucumber greenhouses on other vegetative matter and equipment.

Female mites often hibernate in crevices of beehives and become active soon after they are brought into a greenhouse. A colleague of the author found that cracks in some old stakes brought into a greenhouse harboured enough mites to initiate an infestation. Straw mulch is another source of hibernating mites.

Some growers plant an annual crop of chrysanthemums immediately after removal of the cucumbers. Since the former are purchased as rooted cuttings from other greenhouses they are often infested with mites. In this instance there is the added danger that resistant strains might be involved.

A further source of infestation is from weeds, particularly clover, around the outside of some greenhouses. Of the 25 establishments visited 10 had mite-infested weeds bordering the outside walls. The susceptibility of five of the populations collected from weeds was compared with that of populations from the respective greenhouses (Table IV). The close cor-

relation in degree of resistance between the greenhouse and outside populations for Mastronardi and Reynolds suggests that there might have been a recent movement of resistant forms from the greenhouse to the weeds or vice versa. The outside population of Koop was more resistant than the greenhouse population. The most logical explanation for this is that resistant forms moved from the greenhouse to the weeds, but there was a dilution of resistance in the greenhouse because of a faster rate of development. A subsequent movement of mites from the outside to the greenhouse would increase the resistance of the greenhouse population. Because the outside population of Di Menna and both the greenhouse and outside populations at the Remark establishment showed a very low level of resistance, there was no evidence of an interchange of mites between weeds and greenhouse. Helle (1959) did not detect organic phosphate resistance in any outside populations and concluded that resistant mites found in the greenhouse did not survive outside.

TABLE IV. Percentge mortalities when greenhouse and outside populations of *Tetranychus urticae* were treated with 25% malathion wettable powder[a]

Population	Location	Per cent mortality in relation to ounces of actual toxicant per 100 gal of water[b]		
		Check	2 ounces	8 ounces
Mastronardi[c]	Greenhouse	3.5	15.8	28.3
	Outside	4.1	17.5	32.0
Reynolds	Greenhouse	3.4	11.6	27.7
	Outside	2.8	11.8	18.0
Koop	Greenhouse	3.8	57.0	81.1
	Outside	3.3	26.8	50.7
DiMenna	Greenhouse	3.4	31.7	54.5
	Outside	3.6	69.7	87.0
Remark	Greenhouse	3.7	54.9	80.7
	Outside	3.2	60.6	94.4

[a]The greenhouse populations were obtained from cucumbers. The outside populations were on weeds bordering the respective greenhouses.

[b]Mites were sprayed in the early immature stages in a settling tower. There were six replicates per treatment.

[c]This was a different Mastronardi population than the one shown in Tables I-III.

Predation

There was no evidence that predators influenced the intensity of mite infestations in the greenhouse. Predatory mites were observed in only two greenhouses and in small numbers. One of the greenhouses had not been treated with an acaricide for two months and the other for one month. Predatory mites were also found on clover outside three of the greenhouses and coccinellid larvae of the genus *Stethorus* outside one greenhouse. All samples of predatory mites were identified as *Amblyseius fallacis* (Garman).

Alleviating the Mite Problem

From observations made during the greenhouse survey and discussions with growers and colleagues it was apparent that some of the practices which perpetuate the problem of mite control are being corrected, whereas others remain relatively unchanged from year to year.

The problem of organic phosphate resistance has become less important because a large percentage of growers now use materials which are more effective and safer. Many have realized that weeds around the greenhouse provide a source of infestation for mites, whiteflies and aphids and have established a grass border around the outside or kept the ground bare of vegetation. The rotation of flowers with cucumbers is becoming less common and has largely become one of tomatoes with flowers. Tomatoes are much less subject to attack by this mite.

Sanitation requires more attention. At the end of the crop season, when the plants are removed, infested leaves often remain on the soil surface. Undoubtedly many of the mites on these leaves would later move to crevices in the greenhouse structure to hibernate. Kingham and Gould (1964) also found that many mites moved into the greenhouse structure during the last few weeks of cropping when the plants became senescent. There is no evidence that fumigants presently available will eliminate mites within the structure. Accordingly, growers should make careful checks of the plants around the perimeter of their houses early in the season.

The introduction of new populations might be reduced by several methods. Young plants should be examined for mites before they are transplanted. If they are infested, they should be treated in the propagating house. Growers should place beehives in an adjacent glass or plastic lean-to rather than in the greenhouse. This would reduce the opportunity for hibernating mites in crevices of the hives to move to the crop. Another advantage of this system is that the bees can be shut-off from the greenhouse when insecticides are applied. If it is necessary to place hives within the greenhouse it would be advisable to treat the house soon after placement of the hives. Similarly, a treatment after the introduction of mulch might be beneficial.

A thorough treatment when mites are first observed on an established crop would have two advantages. First, small infestations can be more easily controlled than a well-established population. Secondly, it is doubtful that a grower can obtain satisfactory coverage with an acaricide after a thick canopy of leaves has formed at the top of the support wires. Gould and Kingham (1964) investigated the efficiency of high volume spraying subsequent to the formation of this canopy and found that there was a range of deposit patterns from complete cover to no deposit. On the average only about 50% of the leaves sampled had deposits which could be classed as light to run-off.

It would be of great benefit to growers if they kept a better record of their treatment programs. This would ensure that treatments are applied at proper intervals to obtain maximum control. Also, a planned program involving an alternation of materials would delay, and possibly prevent, the development of resistance. Because of the necessity to use chemicals which permit picking within one to a few days after application, cucumber growers are already limited in the number of materials they can use. The development of resistance to these materials would make the problem of mite control far more critical.

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LIFE CYCLE AND DEVELOPMENT OF *LEIOPHRON PALLIPES* CURTIS (HYMENOPTERA: BRACONIDAE, EUPHORINAE) IN FIVE MIRID HOSTS IN THE BELLEVILLE DISTRICT

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Introduction

Little is known of the holarctic euphorine *Leiophron pallipes* Curtis aside from the fact that it is a primary parasite of various species of plant-feeding Miridae. The hosts previously recorded are *Lygus sp.* (Muesebeck, 1936), *Calocoris norvegicus* Reut. (Brindley, 1939), *Adelphocoris lineolatus* (Goeze) (Craig, 1963), and *Chlamydatus* sp. and *Plagiognathus medicagus* Arrand (Arrand and McMahon in Craig, 1963). *Leiophron pallipes* was found in the Belleville area for the first time in 1962, when larvae were dissected and reared from nymphs of *Leptopterna dolobrata* (L.). Other grass and legume mirids were then examined to see whether additional hosts were present and to observe details of the parasite's life history.

Leiophron pallipes was dissected and reared from *Adelphocoris lineolatus* (Goeze), *A. rapidus* Say, *Liocoris lineolaris* (Beauv.), *Labops hirtus* Knight and *Leptopterna dolobrata* (L.). All are reported to be injurious to some extent, especially *Adelphocoris* spp. on forage legumes and *Liocoris lineolaris* on a great variety of cultivated crops. The life-history of *Labops hirtus* was not reported before. Collections in the Belleville district show that *L. hirtus* breeds on timothy, *Phleum pratense* L., has one generation in the year, and overwinters in the egg stage. The nymphal instars (N I-V) apparently feed near the crowns of the grass stems as they were not easily swept or caught by a mechanical suction sampler. Knowlton (1937) found the species "running on the ground" among range grass in Utah. The nymphs develop early in the season, as new adults were abundant around Belleville by early June of 1963 and 1964. The population was chiefly adult by May 30, 1963, and in the same area chiefly nymphs V on May 18, 1964. *L. hirtus* is reproductive in June and early July. About 40% of females dissected June 2, 1963 (and all on June 13) were gravid. Adults were commonly swept from timothy until mid-July.

Jewett and Townsend (1947) described the life-history of *L. dolobrata,* a destructive species in Kentucky on Kentucky blue-grass and other grasses. Timothy is the favoured host in the Belleville district, as noted also by Osborne (1918) in Maine. The mirid has one generation in the year and overwinters in the egg stage. Nymphs II predominated in the early and mid-May collections as nymphs I were not readily picked up in the sweeps. The development from one instar to the next is shown in Fig. 1. The population of *L. dolobrata* in 1963 was chiefly adult on June 27. Adults appeared first on June 14, and persisted until July 17. Copulating pairs were common from June 14 to 28, and by June 27 nearly all the females were gravid.

Adelphocoris lineolatus and *A. rapidus* breed in alfalfa and other forage legumes, have two generations in the year, and overwinter in the egg stage. Times of hatching and occurrence of the nymphs of the first generation were somewhat later than that of *Leptopterna dolobrata.* First adults of *A. rapidus* were collected on June 16, 1963 and of *A. lineolatus* on June 20. Females of the first generation of *A. lineolatus* were ovipositing as early as June 20 when nine of 22 dissected were gravid, and as late as August 2 when 12 of 13 dissected were gravid. Nymphs I and II of the second generations of *A. lineolatus* and *A. rapidus* occurred from early July, and by late August nymphs V predominated in the population. Both generations of *A. lineolatus* overlapped somewhat, e.g., nymphs III were collected each week from May to August.

Liocoris lineolaris, the ubiquitous tarnished plant-bug, is the only host of *L. pallipes* to overwinter in the adult stage. As a result the nymphs of other host mirids, which overwinter in the egg stage, appeared before those of *Liocoris lineolaris,* and their development was advanced. For example, on June 11, 1963, 30% of the nymphs of *L. lineolaris* were nymphs III, compared with 2% of *A. rapidus,* 4% of *A. lineolatus* and 0% of *Leptopterna dolobrata* and of *Labops hirtus. L. lineolaris* is a bivoltine, polyphagous species and breeds on numerous plants. In the Belleville district, observations indicate that forage crop legumes, such as, alfalfa, red clover, and trefoil, support development of the first generation, and weeds, chiefly *Chenopodium alba* L. and *Amaranthus retroflexus* L., the second. The overwintered adults lay eggs from May to July. The proportion of these females to non-gravid new females decreased steadily from late June to July 16, 1963, as nymphs of the first generation matured to adults. From July 22

to August 13, as the ovaries of new females matured, the proportion of gravid females increased, reaching a maximum of 88%. These females, however, apparently oviposited only for a short period, as the proportion of gravid individuals decreased from August 13 onward, and by September 18 the female population was completely non-gravid. This relatively short oviposition period would account for the fewer nymphs of the second generation noted by Guppy (1958). Immature populations on alfalfa were chiefly nymphs IV on June 14, 1963; nymphs IV and V on June 21; nymphs V and adult June 30, July 7, 14, and 21. Immature populations on *Chenopodium alba* and *Amaranthus retroflexus* consisted of all nymphal instars in August, but only nymphs IV and V in early September. The most favoured feeding plants of adult *L. lineolaris* in the fall, until freeze-up, were *Solidago canadensis* L. and *Chrysanthemum* spp. In late October 1964, adults were common on *Brassica* sp.

Internal Development and Effects of Parasitism

A single egg of *Leiophron pallipes* is deposited in the haemocoel of a mirid nymph. This egg, like that of other euphorines, is a ripe öocyte which upon deposition absorbs nutrients and fluids from the haemolymph. The embryo is surrounded by a trophamnion. There are five larval instars (L I - V), but the ecdysis of the larva V occurs only at about the time of emergence from the host. Of the five nymphal instars of the host usually nymphs II and III were attacked by *L. pallipes*, though occasionally in the laboratory nymphs IV of *Adelphocoris* spp. and *Liocoris lineolaris* were parasitized. The chorion of the egg is stretched by the growth of the embryo and trophamnion and the egg increases from its ovarian size of 0.07 by 0.01 mm to 0.21 by 0.17 mm. At eclosion the larva I is about 0.47 mm long, not the 1.0 mm noted by Brindley (1939), which is the length of the mature larva I. The larval instars are typically euphorine: the first is caudate with a sclerotized head capsule, and the four successive instars are grub-like.

As the embryo of *L. pallipes* hatches, the cells of the trophamnion dissociate and spread between the internal organs and into other areas of the haemocoel. They are then less than 0.03 mm wide, and transparent or slightly cloudy, but they increase in volume as the larva develops and become opaque. The maximum diameter of cells associated with mature larvae I was 0.12 mm; with larvae II-III, 0.16 mm; and with larvae IV, 0.26 mm. There was always a range of cell size in any one host, and some remained small, e.g., less than 0.08 mm wide. Cells of the latter size were found in nymphs and adults from which parasite larvae had emerged. The larger cells were often irregular in shape, some more oblong than spherical. Such cells collapsed readily in the saline dissection fluid because the membrane was greatly stretched by the volumetric increase of the cell. The larva IV, which at maturity occupies much of the haemocoel, probably crushes the large cells and ingests the fatty contents with haemolymph. The larva emerges from either side of the abdomen of the host, in *Leptopterna dolobrata* between the 5th and 6th segments.

The development of *L. pallipes* in the field, from egg to emerged larva, was five to six weeks, based on dissections and rearings; Brindley (1939), in England, suggested 34-36 days. At 23°C, the larva V emerged from *L. dolobrata* 15 - 21 days after egg-deposition. Superparasitism was common in laboratory rearing but relatively rare in the field, e.g. one in 123 parasitized *L. dolobrata* in 1963. Supernumaries either died after eclosion of the larva I or remained alive without feeding or development; some were

found alive after the developed larva left the host. The emerged larva spun a cocoon in the surface debris of the soil, from which the adult emerged in the following year.

L. pallipes consistently emerged from the nymph V in some hosts, and from the adult in others. When the nymph was host for all instars of larval development the most obvious effect of parasitism was the reduced wing-pads of the nymph V. The wing-pads were flattened, shortened and empty of developing adult wings: the average lengths and standard deviations of the fore-and hind-wings of 10 nymphs V of *Adelphocoris lineolatus* were 0.50 ± 0.05 and 0.38 ± 0.03 mm, compared with 0.62 ± 0.04 and 0.51 ± 0.03 mm in unparasitized nymphs V. Brindley (1939) reported that parasitized nymphs of *Calocoris norvegicus* failed to reach the nymph V instar, but this effect was not seen in any of the material that I examined or reared. When the adult was host for larval development, as with *Labops hirtus* and *Liocoris lineolaris*, the ovaries were undeveloped and no eggs formed. Whether the male was also castrated was not determined. The emergence of the larva of *L. pallipes* always killed the host, but its death was not immediate. At 23°C, a nymph V of *L. dolobrata* from which a larva emerged about 4:00 pm June 5, 1963, was active the following day and finally died on the morning of June 7. In the field, similar nymphs of *L. dolobrata* were frequently swept from grasses at the peak of parasite emergence in June of 1962 and 1963. They were characterized by a shrunken, decurved, and flattened abdomen, by a melanized emergence tear on one side of the abdomen, and by a hesitant, slow-walking gait.

Field Development of *Leiophron pallipes*

Adults of *L. pallipes* were swept from May to September and immature stages were found in each of the five mirid hosts at various somewhat overlapping intervals. The earliest host attacked was *Labops hirtus*, followed by *Leptopterna dolobrata*. *Liocoris lineolaris* was parasitized in two distinct periods: the first in June with the other species and the second in late July, August and September. *Adelphocoris* spp., though double-brooded like *L. lineolaris*, apparently were parasitized in June only.

Development in Labops hirtus

The occurrence of euphorine parasites in *L. hirtus* was first noted on May 30, 1963. Of 98 adults dissected, 16 contained advanced instar larvae and five showed signs of emerged larvae V. Parasite larvae in adults dissected June 7, and 13, 1963 were also advanced and emerged respectively. Of the 65 dissected June 13, only four were parasitized, suggesting that most of the larvae had matured and emerged. No eggs of *L. pallipes* were found in nymphs in 1963 as they had matured to nymphs V or adults by late May. In 1964, two mature eggs were recovered from nymphs III on May 18. This finding indicated the tail-end of the oviposition on *L. hirtus* as its population then was chiefly nymph V, and *L. pallipes* attacks only early instar nymphs.

Development in Leptopterna dolobrata

The development of *L. pallipes* in *Leptopterna dolobrata* from egg to emergence of mature larvae in 1963 extended from May 15 to June 27. Of this period, it was possible to parasitize *L. dolobrata* only from mid-May to early June when the early instars II, III and IV predominated. The incidence of *L. pallipes* in each instar, and its development, are shown in Fig. 1. Mature eggs of *L. pallipes* were found May 15 in nymphs II, and

hatching eggs on May 30 in nymphs III. Early larvae I instars which had recently eclosed were found from May 15 to June 6. A maximum incidence of 42 parasites per 100 nymphs, chiefly larvae I in nymphs IV, occurred June 7. This incidence is an accumulation of stages, as the immature parasite was carried in all stages of development from earlier nymphal instars, emerging finally from the nymph V host. Nymphs V from which larvae of *L. pallipes* had emerged were found from June 8 to June 27, and the peak of emergence occurred between June 14 and 21.

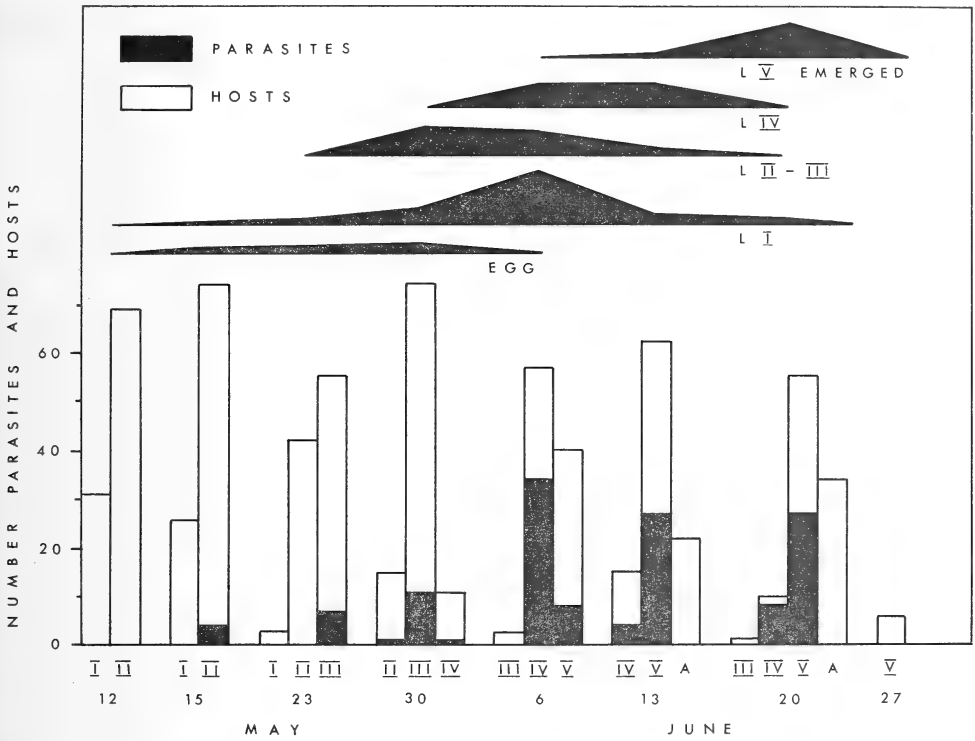

FIG. 1. Development of *Leiophron pallipes* and its mirid host, *Leptopterna dolobrata*, at Belleville, Ontario, 1963.

Development in Adelphocoris species

Leiophron pallipes was dissected from *A. lineolatus* and *A. rapidus* throughout June, 1963; all immature stages and instars were found in this period. Eggs and larvae I parasites were recovered June 4, and larvae I-IV parasites from mid-June to early July. A maximum incidence of 49 parasites per 100 nymphs of *A. lineolatus* occurred on June 11, and 42 per 70 of *A. rapidus* on June 8. On these dates the parasites were chiefly larvae I and the hosts nymphs IV. The incidence on *A. lineolatus* decreased to two larvae per 59 nymphs on July 3, and on *A. rapidus* to eight per 39 nymphs on June 28. This decrease indicates that a high proportion of the larvae of *L. pallipes* had matured and emerged. No immature parasites were found in the second brood of nymphs that developed in July and August.

Development in Liocoris lineolaris

The initial parasitism of *Leiophron pallipes* on *L. lineolaris* undoubtedly begins in May, though larvae I parasites were recovered first on June 5, 1963 in nymphs III and IV. The June and early July collections were dominated by larvae I parasites in nymphs IV, V and the adult of *L. lineolaris*. The concentration of this instar from June 14 to 30 apparently resulted from slow, or possibly arrested, development after eclosion, which was accelerated or resumed after the host became adult. A similar case, one in which the larva V of *Leiophron* sp. emerged from the adult of *Plagiognathus* sp., was reported elsewhere (Loan, 1965). The carry-over of larval I parasites into the adult population was clearly evident on June 30, when 23 of the 38 parasites found were from adult *L. lineolaris*. One week later 16 of the 30 parasites found in 100 adults were larvae II-III, and IV, indicating rapid development of the larva after the host nymph became adult. Larvae V emerged from field-collected, adult *L. lineolaris* in insectary cages from July 11 to 19. Of the 130 larvae reared, nearly all formed cocoons, but no adults emerged until the following year. The August and September parasitism of *Leiophron pallipes* was clearly indicated by the occurrence of all internal immature stages and instars in nymphs of *L. lineolaris*: eggs from August 7 to 21; larvae I parasites from August 7 to September 3; and larvae II-III and IV from August 14 to September 5. Larvae V emerged at 23°C. from nymphs and adults collected August 27, September 5 and September 20. The maximum incidence did not exceed 12 parasites per 100 nymphs of *L. lineolaris*.

Discussion

From 45 to 60 parasites per 100 nymphs of *Adelphocoris* spp. and *Liocoris lineolaris*, important pests of forage legumes, were found in collections at Belleville, Ontario, in 1963. This high incidence contrasts to the 3% parasitism of *Adelphocoris lineolatus* by *L. pallipes* reported by Craig (1963) in Saskatchewan. Undoubtedly the population levels of the mirids that it attacks are influenced by parasitism of *L. pallipes*. From an immediate control aspect, the chief weakness of *L. pallipes* is that the parasitized nymphs continue to feed and injure the host plant during parasite development, a period of five to six weeks.

The seasonal development of *L. pallipes* is closely related to the life cycles of the host mirids. Each host, except *Liocoris lineolaris* of which the first generation is parasitized in early summer and the second in August and September, supports one period of parasite attack and development in the season. The origin of adult parasites in late summer is unknown at present as it is doubtful if spring-emerged adults would survive until then. No adults emerged from cocoons formed throughout the summer though they emerged the following spring. Extensive rearings, however, might show a further emergence from these cocoons later in the season.

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APHIDIUS SMITHI SHARMA AND SUBBA RAO (HYMENOPTERA: APHIDIIDAE) A PARASITE OF THE PEA APHID NEW IN SOUTHERN ONTARIO

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Attempts to control the pea aphid, *Acyrthosiphon pisum* (Harris) (Homoptera: Aphididae), biologically included the introduction to North America of a small hymenopterous parasite, *Aphidius smithi* Sharma and Subba Rao, from India. The original stock was imported in 1958 by the Entomology Research Division of the United States Department of Agriculture, which subsequently supplied material to other establishments for field release and experimental breeding.

The parasite was released from 1958 onward and presumably became established in large areas of the western United States: Washington, Oregon, Idaho, California, Utah, Colorado, and Arizona (Hagen and Schlinger 1960; Coop. Econ. Insect Rep. 11: 410, 475, 545, 673, 1090; 12: 268; 13: 660; 14: 387). It was also released in the eastern United States (Table I) but evidence of establishment is lacking to date. In addition, it was released and definitely became established on the Hawaiian Islands of Maui, Oahu and Kauai (Coop. Econ. Insect Rep. 10: 1118; 11: 60, 412; 12: 234).

In early May 1963, a breeding stock of *A. smithi* was received at the Belleville Institute from Dr. R. van den Bosch, of the Division of Biological Control, University of California, at Albany. The material consisted of ca. 800 mummified specimens of *A. smithi* that had been field collected on

TABLE I. Releases of *Aphidius smithi* Sharma and Subba Rao in eastern North America.

Year and month of release		Location	Number released [1], [2])
1958	May	Smyrna, Del.	1,865
	May, August	Dover, Del.	2,070
	June	Newark, Del.	2,100
	May, July	Moorestown, N.J.	2,400
	May, June	Mt. Holly, N.J.	2,000
	July	Freebold, N.J.	2,100
	May, July	So. Philadelphia, Pa.	2,185
1959	April, June	Dover, Del.	1,295
	April	Middletown, Del.	1,124
	April, May	Onancock, Va.	1,065
	April, May	Columbus, N. J.	2,382
	May	Medford, N. J.	800
	May	Flemington, N. J.	465
	April - June	Mt. Holly, N. J.	2,887
	May - July	Rancocas, N.J.	4,680
1960	—		
1961	August	Rancocas, N. J.	400
1962	—		
1963	—		
1964	June, July	Sheffield Farm, N. S.	7,800*
	June, July	Annapolis Royal, N. S.	5,700*
	June	Canard, N. S.	1,350*
	June	Coldbrook Station, N. S.	3,600*
	July	Sweet's Corners, N. S.	1,000*
	July	Mantua, N. S.	1,000*

1) All numbers refer to adult parasites except those marked by asterisks (*), which refer to mummies.

2) Releases in the eastern United States were made by the Moorestown, N.J., laboratory of the Insect Identification and Parasite Introduction Research Branch, Agr. Res. Service, U.S. Dep. Agr. In addition, the parasite was shipped from Moorestown to locations in Maine (Presque Isle), North Carolina (Raleigh), South Carolina (Florence), Florida (Belle Glade, Quincy), Georgia (Fort Valley, U. S. D. A. Expt. Sta.), Washington (Walla Walla), Oregon (Corvallis), California (Riverside), Utah (Logan), Colorado (Palisade), and Arizona (Tempe, Tucson). No information as to eventual liberation of this material is available. The above data were communicated by Mr. P. B. Dowden.

Releases in eastern Canada were carried out by the senior author in co-operation with Dr. H. B. Specht, Research Station, Can. Dep. Agr., Kentville, N.S.

alfalfa in the San Joaquin Valley, California. At Belleville, the parasite was kept under strict quarantine and used only in laboratory experiments designed to evaluate its efficiency as a biological control agent in relation to other parasites of the pea aphid, both indigenous and foreign. On the basis of the Indian parasite's performance under laboratory conditions, trial releases were made in certain pea growing areas of Nova Scotia in mid 1964 (Table I). At the same time, an extensive survey of aphids that feed on commercially grown and on wild legumes, and of the hymenopterous parasites that attack them, was conducted in southern Ontario, in particular within 50 miles of Belleville. The success or otherwise of the Nova Scotia releases shall be reported in due course. Results of the Ontario survey are the main subject of the present paper.

The survey revealed *Praon pequodorum* Viereck (= *simulans sensu auctt.*) and *A. pulcher* Baker (=*pisivorus* Smith) to be the principal and most common parasites of the pea aphid in southern Ontario. Of secondary importance were *Praon* sp. (= *occidentale sensu* Smith, 1944) and *Aphelinus semiflavus* Howard (Hymenoptera: Aphelinidae). Other hymenopterous parasites that were reported in the literature as attacking the pea aphid, i. e. *Ephedrus californicus* Baker, *Monoctonus paulensis* (Ashmead) and *Aphelinus howardii* Dalla Torre, were not encountered.

The first specimens of *A. smithi* taken in Ontario were discovered in the fall of 1964 among material collected on commercially grown alfalfa near Consecon, Prince Edward County. The parasite was fairly abundant, outnumbering the native *A. pulcher* by a ratio of about four to one in the sample taken, though less abundant than *P. pequodorum*. As the collecting locality was only 15 miles away from Belleville by air, the possibility of an accidental escape from the quarantine stock was first considered. However, as the species had been liberated in various localities of the eastern United States as early as 1958 (Table I), an immigration via the Niagara Peninsula or across the upper St. Lawrence River (Thousand Islands) seemed more likely. On that assumption an intensive 3-day search was conducted in southern Ontario late in September 1964. *A. smithi* was found commonly on alfalfa throughout the two southernmost counties of Lincoln and Welland. In most fields it was the dominant species and

TABLE II. Records of *Aphidius smithi* Sharma and Subba Rao in southern Ontario (1964)

Location	Aphid Host Plant	*Parasite Records*			
		A. smithi	*A. pulcher*	*P. pequodorum*	*Praon* sp.
Co. Welland					
Chippawa	*M. sativa*	+	+	m	
Crystal Beach	*M. sativa*	+		m	
6 mi. E. Fort Erie	*M. sativa*	+		+	
Co. Lincoln					
Queenston, Hwy. 8 at Davids R.	*M. sativa*	+		×	+
Queenston, Hwy. 8 at Martin R.	*M. sativa*	+		+	
St. Catharines, Airport	*M. sativa*	+		+	
Vineland, 7 & 17 St. Louth	*M. sativa*	×		+	+
Vineland, 7 & 19 St. Louth	*M. sativa*	×		m	
Vineland, 7 & 21 St. Louth	*M. sativa*	×		+	
Co. Halton					
5 mi. W. Palermo	*M. sativa*				+
Campbellville	*Vicia* sp., *Melil. alba*			m	
Co. Peel					
Brampton	*M. sativa*		+	+	
Co. Prince Edward					
Consecon	*M. sativa*	+	+	×	+
Co. Hastings					
Frankford	*M. sativa*			+	+

Symbols — (+) Collecting and rearing record. (×) Most abundant species in sample taken. (m) Mummies collected but no adults emerged; identification to species not possible at present.

apparently had largely replaced the native *pulcher* (Table II). *P. pequodorum* seemed to be less affected than *pulcher* by the occurrence of the Indian parasite, though it never reached the same abundance that *smithi* reached in certain localities. Only a few individuals of *Praon* sp. and none of *A. semiflavus* were collected which, in the light of collections in 1962 and 1963, must not be attributed to competition with *A. smithi*. The Indian wasp was not found in the counties of Halton and Peel, where numerous alfalfa fields were sampled for parasites. The most common parasite of the pea aphid in that area was *Praon; Aphidius* mummies were observed only rarely.

It would seem that *A. smithi* immigrated into southern Ontario from the release areas along the eastern seaboard, probably via the Niagara Peninsula. This would mean that the parasite not only is established in the eastern United States (which is unreported so far) but, in addition, has spread a minimum of about 260 miles within six years at the most. These data seem to be moderate when compared with the dispersal of winged aphids by wind. As there is no information as to which other areas, if any, were invaded as well, the above data are minimum assumptions and should not be taken as indicative of the parasite's potential to disperse. Furthermore, it remains to be seen whether *A. smithi* is actually established in southern Ontario or merely invades this part of the country annually from the eastern United States. The possibility of the parasite's invasion from release areas in the western United States appears to be so slight that it need not be discussed here.

If the parasite should perform to its expected capacity it will doubtlessly play an important role in the biological control of the pea aphid. In laboratory experiments *A. smithi* was superior by far to any other of the tested species in oviposition potential and in searching activity. This, combined with a shorter generation time as compared with those of *A. pulcher* or *P. pequodorum*, may eventually allow the Indian wasp to displace some of the native species, except in marginal areas. The most crucial question is whether or not *A. smithi* will survive the relatively severe Canadian winters. Hagen and Schlinger (1960) surmised that the parasite has no diapause. This would exclude *A. smithi* from becoming established here. However, observation of the Indian parasite in the diapause stage in northeastern California, an area of severe winter cold (van den Bosch, *in litt.*), casts some doubt on the hypothesis.

Acknowledgments

We wish to thank the following persons who supplied us with mainly unpublished information on liberations and recoveries of *A. smithi* Sharma and Subba Rao: Mr. Philip B. Dowden, Assistant Chief, Insect Identification and Parasite Introduction Research Branch, Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland; Dr. Richard L. Doutt, Chairman, and Dr. Robert van den Bosch, Entomologist, of the Division of Biological Control, Department of Entomology and Parasitology, University of California, Albany, California. Mrs. Thelma Finlayson, of this Institute, helped us by identifying the cast skin of final-instar larvae within some of the parasite mummies.

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EFFECTS OF TWO CARBAMATES ON SEVERAL PESTS OF PEACH

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Introduction

Of several materials currently recommended in Ontario for the control of the oriental fruit moth, *Grapholitha molesta* (Busck), in peach, Sevin (carbaryl) has been used extensively in recent years. This insecticide has the great disadvantage of being ineffective against the European red mite, *Panonychus ulmi* (Koch), as reported by (Putman 1960).

Information supplied by the manufacturer on another carbamate compound, Bayer 37344[1], indicated a potentiality for the control of *G. molesta* and *P. ulmi* on peach. With this in mind, the relative merits of the two carbamates, as assessed in orchard experiments during 1962 and 1963 are reported at this time.

Methods and Materials

In 1962, an 18-tree group of mature Elberta peach trees and in 1963, a similar group of 12 trees was used for the experiment. The groups of trees were subdivided each year into blocks of three trees, and treatments were randomized for single tree plots in each block.

Each carbamate was used as a 50% wettable powder at the rate of 8 lb of formulation per acre. Because of the lack of acaricidal activity of Sevin, an 18.5% wettable powder formulation of Kelthane (dicofol) was used in combination with the former at 8 lb/acre. Fifty per cent captan wettable powder, at 8 lb/acre, was applied with each carbamate and alone on check trees to control brown rot on the fruits.

All materials were applied by hand with a John Bean Spraymaster gun equipped with a no. 6 disc. The gun was attached by hose to the take-off on a Turbo-Mist sprayer, the pump of which was operated at 400 psi.

The sprays were applied on June 26, July 5 and August 21 in 1962, and at comparable developmental stages of peach on July 4, July 17 and August 7 in 1963.

Injury to fruits by *G. molesta* was evaluated as per cent of the total fruit at harvest on each tree by visual examination to discover injury. In addition, 10% of the fruit without visible injury was cut to determine hidden damage caused by the entry of early larval instars. The latter was projected to the entire crop to give total injury.

Samples of 20 leaves taken at random around the periphery of each tree at a height of 4-6 ft at approximately 2-week intervals were examined with a stereoscopic microscope for *P. ulmi*. Counts of immature *Lecanium cerasifex* Fitch were obtained simultaneously with those of the mite. Also, in 1963, observations were made on the occurrence of the mite predators *Stethorus punctillum* Weise and *Chrysopa* sp., together with the occurrence of the peach silver mite, *Aculus cornutus* (Banks), and parasitism of *L. cerasifex* on August 26.

Percentages of fruit injury were transformed by the angular method according to Snedecor (1956) and statistically evaluated by the analysis of variance.

[1](4-Methylthio)-3, 5-xylyl methylcarbamate. Chemagro Corp., Kansas City, Mo.

Results and Discussion

Initial populations of *P. ulmi* were appreciably lower in 1962 than in 1963. During the latter year the numbers of the mite in untreated plots increased more rapidly and to much higher levels (Fig. 1). Despite such differences in initial and subsequent untreated populations, Bayer 37344 inhibited the increase of the mite as well as Sevin plus Kelthane in both years.

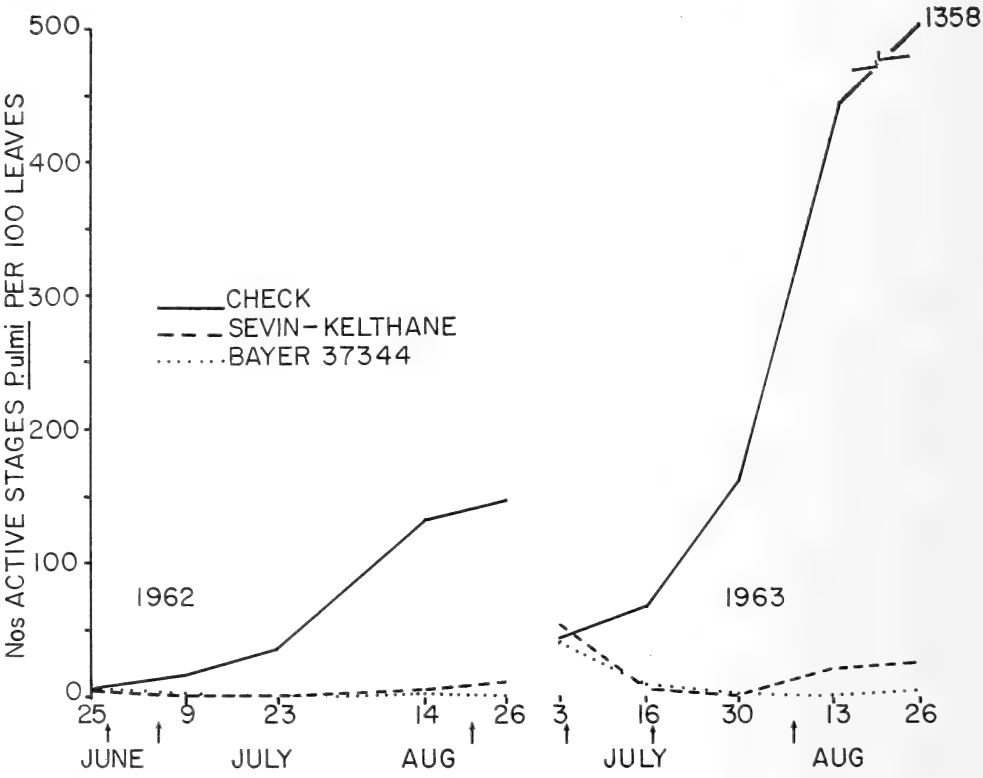

FIG. 1. Numbers of active stages of *P. ulmi* per 100 leaves in relation to treatment and sampling dates in 1962 and 1963. First date for each year is pretreatment record. Arrows indicate treatment dates.

The predatory coccinellid, *Stethorus punctillum* Weise, and *Chrysopa* sp. were absent from leaf samples on trees treated with Bayer 37344 or Sevin plus Kelthane in 1963. Both species were common on untreated trees but did not appear to have any appreciable effect on *P. ulmi.*

Injury to peach fruits at harvest by *G. molesta* was appreciably reduced by Bayer 37344 and Sevin plus Kelthane in both years. But in 1962, against a higher population of larvae during July and August Bayer 37344 appeared to be slightly more effective (Table I). From the standpoint of commercial control both materials were satisfactory.

Infestation by *L. cerasifex* was considerably higher in 1962 than in 1963. Nevertheless, Bayer 37344 and Sevin plus Kelthane treatments were equally effective in reducing numbers of the scale in both years (Table II). The result of the treatments was particularly noticeable on August 27, 1962, when immature stages of the second generation of the scale were very abundant on the leaves of untreated trees.

TABLE I. Percentages of Elberta peach fruits damaged by *G. molesta* in 1962 and 1963

Treatment 1962	Per cent of fruits damaged per replicate						Mean
Bayer 37344, 50% W.P.	6.8	1.8	2.3	0.8	2.0	7.0	3.4**
Sevin, 50% W.P. + Kelthane, 18.5% W.P.	8.2	6.0	3.4	2.6	2.2	1.7	4.0*
Check	6.0	31.6	9.8	7.3	21.6	8.9	14.2
Treatment 1963							
Bayer 37344, 50% W.P.	0.0	0.0	0.3	0.0			0.1**
Sevin, 50% W.P. + Kelthane, 18.5% W.P.	1.6	0.6	0.0	0.8			0.7**
Check	22.5	7.6	2.4	5.1			9.4

**Significantly less than check at 1% level.
*Significantly less than check at 5% level.

TABLE II. Average numbers of immature *L. cerasifex* per 20-leaf sample in 1962 and 1963 from various treatments

Sampling dates 1962	Average[a] number *L. cerasifex* per 20-leaf sample		
	Check	Sevin + Kelthane	Bayer 37344
June 25[b]	50	48	58.0
July 9	47	3	1.5
23	42	3	1.0
Aug. 14	27	2	1.5
27	155	2	1.3
Sampling dates 1963	Average[c] number *L. cerasifex* per 20-leaf sample		
July 3[b]	0.5	0.5	1.0
16	2.0	—	—
30	1.5	—	—
Aug. 13	1.7	—	—
26	3.0	0.2	—

[a]Average of six replicates per treatment
[b]Average numbers before first application of treatment
[c]Average of four replicates per treatment

Parasites of immature stages of *L. cerasifex* on August 27, 1962 were so few that no significant effect on them of either Bayer 37344 or Sevin plus Kelthane could be detected. Conversely in 1963, the parasites were somewhat more numerous, though the scale population was very considerably lower on untreated trees. On August 26, 1963, 58% of the scales were parasitized on check trees but, because scales on treated trees were so scarce (Sevin plus Kelthane) or completely absent (Bayer 37344), it was impossible to determine whether the lack of parasitism was caused by destruction of adult parasites, or by depletion of the host. In either case, the effect of each of the treatments was similar.

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TESTS FOR INHERITANCE OF DIELDRIN-RESISTANCE IN THE CABBAGE MAGGOT, *HYLEMYA BRASSICAE* (BOUCHE)

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Introduction

Resistant strains of the cabbage maggot, *Hylemya brassicae* (Bouché), are now known to be present in various areas of the United States, in one region in England, and in British Columbia, Ontario, Quebec, Prince Edward Island, and Newfoundland in Canada (Harris, Manson and Mazurek, 1962; Coaker, Mowat and Wheatley, 1963; Morris, 1963). However, there are areas in each of the above Provinces where insecticides have been used extensively and yet no resistance has been reported. In Prince Edward Island two regions about 25 miles apart have resistant strains of the pest, each area being roughly 3 to 5 miles in diameter, but there is no indication of resistance in surrounding areas where cruciferous crops are grown in abundance and where aldrin and heptachlor have been used extensively for 8 to 10 years. The purpose of the present study was to determine how cyclodiene resistance is inherited (whether single or multiple factors are involved) and if hybrid or resistant individuals could be selected from apparently susceptible populations.

Methods and Results

During the studies all insects were reared in soil cylinders in the greenhouse according to the method reported by Read (1965), with the eggs, larvae and pupae being reared at about 65°F and the adult flies, in ⅝ sq. ft. screen cages above the soil cylinders, kept at a fluctuating temperature of about 70°F at night and 80°F during the day. The flies were fed a mixture of whole wheat flour, sugar, brewer's yeast, and honey in the ratio of 8:8:4:3.

Preliminary studies with more than 1800 adult flies from susceptible populations from Prince Edward Island (Kildare-S and Mt. Stewart-S strains) and resistant strains from Ontario (Freelton-R), Quebec (St. Jean-R), Prince Edward Island (Argyle-R), and Newfoundland (St. George-R) revealed that the resistant strains of flies, kept in the same cages with susceptible flies, lived much longer than the susceptible ones (Fig. 1) and also that the resistant females laid more eggs. Tests with 50 female flies from each of two strains showed that Argyle-R flies produced an average of 152 eggs as compared with 70 eggs per female laid by the Kildare-S strain. It should be stressed that the longevity of the flies and the numbers of eggs produced per female are comparative for the susceptible and resistant strains reared in the same cages and at relatively high temperatures of 70 to above 80°F. When kept at a temperature of 70 to 80° F in cages by themselves susceptible flies lived an average of about 16 days (5-30 days) with the females always surviving longer than the males. Under the same conditions the resistant flies lived an average of about 37 days (24-53 days). Again, when kept at about 70°F each strain lived even longer and proportionately more eggs were laid per female at the lower temperatures. Unmated susceptible females kept at 70°F lived up to 70 days. Many other reports are given in the literature for varying lengths of life

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for the adult flies under specific conditions. In the tests reported herein, the higher fluctuating temperatures of 70 to 80°F were used firstly to produce a generation of the root maggots in a short period of time (with the females laying almost all of their eggs between 4 and 12 days after emergence) and secondly to prevent the pupae from going into diapause. It is fully appreciated that concealed parasitism such as to the fungus, *Empusa muscae* Cohn, could be a factor in decreasing longevity. However, it is unlikely that this could have been the case in these examinations since the resistant strains, in reciprocal crosses, were kept in the same cages with susceptible ones. There is the possibility that the resistant flies in some unexplained way affected the longevity of the susceptible flies.

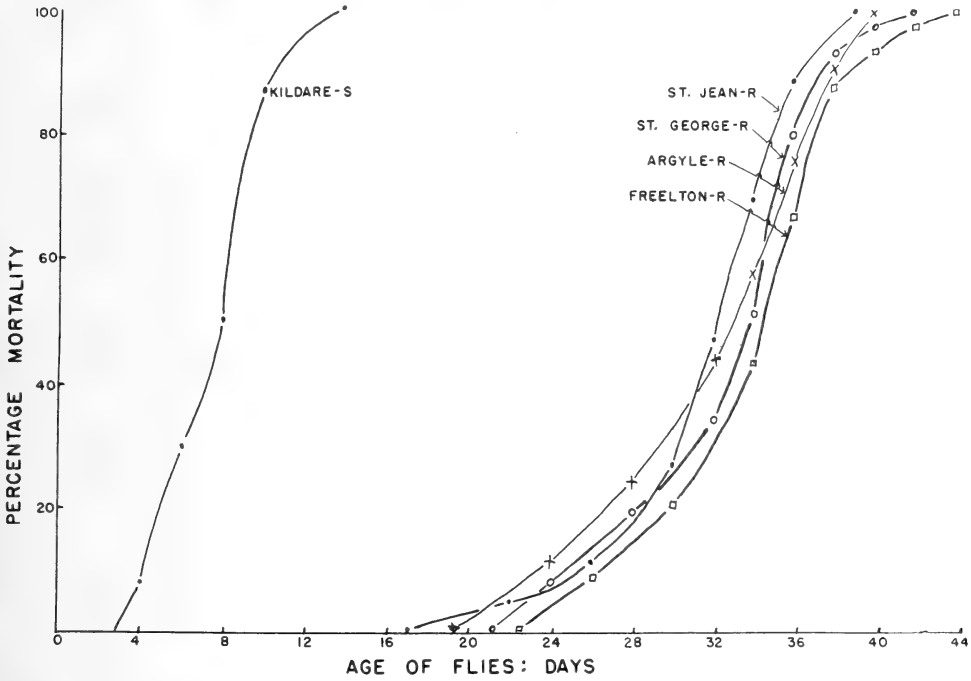

FIG. 1. Longevity of adult flies from dieldrin-resistant and susceptible strains of the cabbage maggot; flies reared at about 70 to 80°F with susceptible and resistant reciprocal crosses being reared in the same cages.

For studies on inheritance of resistance, selection for resistance from populations assumed to be resistant in the field, was carried out by exposing developing larvae to rutabagas treated with a 2.5% solution of dieldrin in acetone or by exposing flies to pads of food that had been treated with a 5% solution of dieldrin. Solutions containing 0.004% dieldrin on rutabagas and food pads destroyed all susceptible larvae and flies within 48 and 24 hr respectively.

To test for susceptibility of *H. brassicae* to dieldrin, flies were tested by topical application to the mesonotum of the flies with droplets of a 9:1 mixture of acetone and olive oil carrying various concentrations of dieldrin, and larvae were tested by exposing first instar larvae to 1x½x¼-inch dieldrin-treated slices of rutabaga. For the larval test, the rutabaga slices were suspended on pins with plastic handles and dipped for 10 sec in various concentrations of dieldrin in acetone. They were then left exposed

to the atmosphere for 20 min to allow evaporation of the acetone and finally placed in petri dishes containing two layers of moist blotting paper and a layer of black silk cloth. Fifty-five embryonated eggs (just before hatching when they were about 70 hr old) were placed on the cloth beside a slice of rutabaga, (Fig. 2) and the eggs and rutabaga slices were covered with a second piece of moistened silk cloth which was held down with a smooth-rimmed plastic container and a lead weight (Fig. 3). The blotting paper and cloth were moistened again after 24 hr and mortality records were taken after 48 hr by counting the number of dead larvae around the slice of rutabaga. The eggs and larvae were kept in a temperature controlled cabinet at 71 $\pm$ 1°F. Ninety to 100% of the eggs hatched and there was never any control mortality. Each test was replicated four times and the average percentage mortality was plotted on a graph.

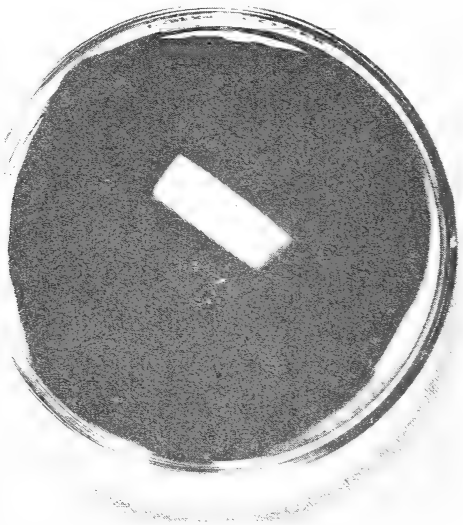

FIG. 2. Setup of eggs and treated slice of rutabaga in petri dish for testing susceptibility of cabbage maggot larvae to dieldrin.

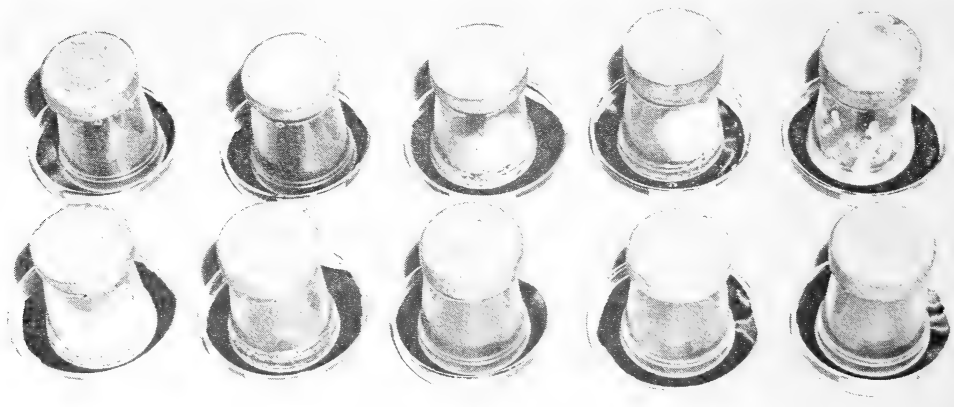

FIG. 3. Weighted plastic dishes over eggs and rutabaga slices in petri dishes used in dieldrin-susceptibility tests with larvae of the cabbage maggot.

The above methods of testing the pest were chosen since the topical application test provided a means of determining the actual amount of insecticide applied to the insect and the larval method enabled tests to be carried out against the larvae — the stage of the pest being attacked in the field. Both these methods were used for crosses and backcrosses between susceptible, resistant and hybrid insects. The susceptible and resistant strains were reciprocally crossed and the hybrids were backcrossed with each parent.

With the larval test technique, where 200 larvae were tested at each concentration of dieldrin, the hybrids proved to be intermediate and did not overlap either parent; the dosages clearly separating the three types were approximately 0.005 and 1.0% dieldrin. This segregation also indicated that both the susceptible and the resistant parents were pure for homozygotes since they carried no admixture of the heterozygous hybrid type.

One diagnostic that the genetic character is due to a single factor is a 1:2:1 or a 3:1 ratio in the Mendelian F_2 obtained by intercrossing the F_1. The results of such crosses with *H. brassicae* approximated a 1:2:1 segregation. However, a clearer diagnostic is a 50:50 ratio in the offspring of the backcross between the resistant or the susceptible parent with the hybrid, and larval test studies showed a very close approximation to the 50:50 ratio. The quantitative details of this investigation will be reported in a later paper on the genetics of resistance in the cabbage maggot.

With the topical application method, solutions of acetone and olive oil containing concentrations of 0.0001 to 5.0% of dieldrin were applied to the mesonotum of the adult flies at the rate of 0.5μliter per fly. The results of these tests were similar to those obtained with the larval test technique and diagnostic dosages separating the three genotypes were about 0.05 and 2.5μg per adult fly. The males were somewhat more susceptible to dieldrin than the females in the susceptible, hybrid and resistant strains (Fig. 4).

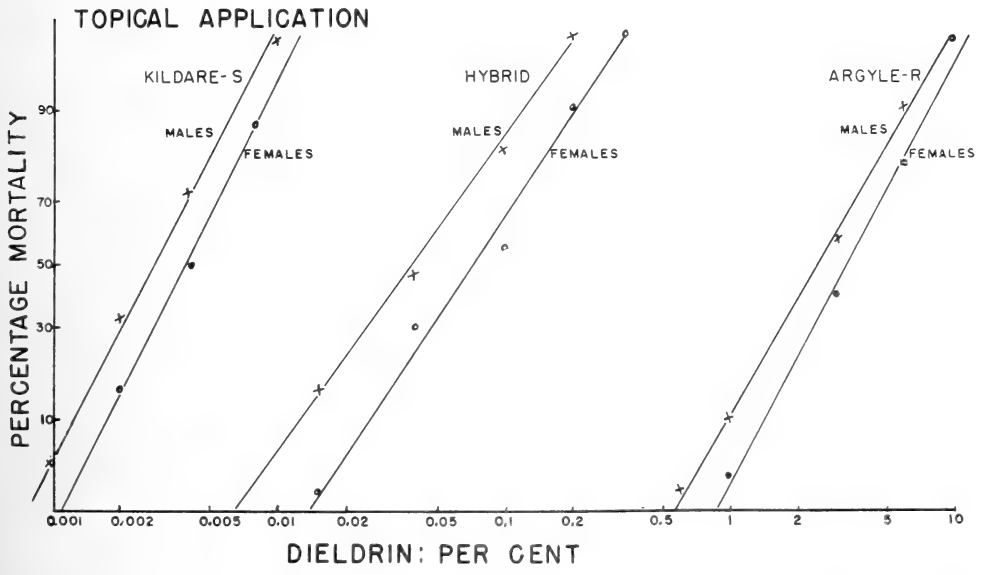

FIG. 4. Dosage mortality relationships for males and females from susceptible, hybrid and resistant strains of the cabbage maggot by the topical application method.

Since the hybrids carrying 1 gene for resistance were about half as resistant as the homozygous resistant ones with 2 genes for resistance, and since the backcrosses of the hybrids with the resistant and susceptible strains segregated approximately in a 1:1 ratio, it was concluded that dieldrin-resistance in *H. brassicae* is inherited as a single gene and that the gene for resistance is neither dominant nor recessive.

Further tests were conducted with susceptible populations (Kildare-S strain) to determine if any specimens showing at least one gene for resistance (i.e. heterozygotes) could be detected. Starting with approximately 2000 flies, a portion of the F_1, F_2 and F_3 generations of adult flies were tested by exposing the larvae produced by them to rutabagas treated with 0.002% dieldrin in acetone. An estimated 400,000 larvae were tested in this manner and not a single one survived. It was indicated that mutations giving genotypes carrying a dieldrin-resistance allele occur rarely, although alternative causes beyond the scope of this investigation, such as uneven selection pressures from differing soil residues, remain possibilities which should be investigated. Nevertheless the results of this test might explain why broadcast applications of aldrin and heptachlor may be used successfully for six to eight or more years before sudden explosions of resistant populations develop in restricted regions of the country. This rapid buildup in resistant populations is also probably partly due to the fact that the insecticides destroy natural enemies of the pests, (Coaker, Mowat and Wheatley, 1963; Read, 1962, 1964). In a specific case in 1963, no predators or parasites were found in more than 14,000 *H. brassicae* pupae taken from aldrin-treated fields in Prince Edward Island that were heavily infested with cyclodiene resistant populations, whereas about 70% of the pest pupae obtained in untreated fields (containing susceptible pest populations) were parasitized by one parasite, the rove beetle *Aleochara bilineata* (Gyll.).

A full presentation of the genetical work on the cabbage maggot, which is still in progress, will be published at a later date in a joint paper with Dr. A. W. A. Brown, Head, Department of Zoology, University of Western Ontario.

Acknowledgements

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IV. RESEARCH NOTES

MORTALITY DUE TO *BACILLUS THURINGIENSIS* IN POST-LARVAL STAGES OF SOME LEPIDOPTERA

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Bacillus thuringiensis Berliner and its varieties comprise a group of spore-forming bacteria that are pathogens of a number of species of Lepidoptera. It is widely accepted that the pathogenicity depends principally on the action of two entities found in cultures: proteinaceous parasporal inclusions (popularly, crystals) and endospores (popularly, spores). One effect of the crystals is to create conditions favouring successful germination of the spores; the resultant vegetative cells multiply to cause a lethal septicemia. The crystals are active only in the mid-gut and must be ingested. The economically significant feeding of Lepidoptera is largely that of larvae so *Bacillus thuringiensis* is ordinarily used as a larval pathogen (Heimpel and Angus, 1963).

In some recent tests of the potency of a commercial preparation[2] of *Bacillus thuringiensis* var. *thuringiensis*, a number of species of Lepidoptera were used. The larvae were from field populations and in their final instars when the tests began. Small aspen trees were sprayed with a preparation of *B. thuringiensis* and colonised with larvae of *Malacosoma disstria* (Hbn.) The trees were caged to prevent losses to birds and other predators. When feeding had ceased, and all surviving larvae had spun up (10 days), the cocooned and dead larvae were removed. Larval mortality amounted to 53% (294 out of 550) and all of the dead larvae contained vegetative cells of *B. thuringiensis*. The dead larvae were typically almost black in colour, lighter in weight than living larvae, and eventually became shrivelled and distorted. The cocooned larvae were stored to await emergence (3 weeks at 70°F); 37% (92 of 243) failed to eclose and 95% of these were positive for *B. thuringiensis*. Some had died as prepupae, and some as pupae; all were blackened and shrivelled.

Larvae of *Sarrothripus (Nycteola) cinereana N.D.* were reared in glass petri dishes on foliage sprayed with *B. thuringiensis*. Most of the insects died as larvae but a few spun cocoons. This species forms only a partial cocoon in petri dishes and so the development of cocooned larvae can be inspected by viewing from the underside. It was noted that all of the cocooned larvae died as prepupae or pupae. All were blackened and shrunken, and positive for *B. thuringiensis*.

Larvae of *Nymphalis antiopa* (L.) were reared on aspen foliage sprayed with *B. thuringiensis*. Most died as larvae but a number successfully developed into chrysalids. On storage these became much darker

[1]Contribution No. 70, Insect Pathology Research Institute, Department of Forestry, Canada.
[2]Thuricide 90T, supplied by Stauffer Chemical Co., U.S.A. through Chipman Chemical Co., Hamilton, Ontario.

(almost blue-black) than normal, were markedly lighter in weight, the integument was brittle rather than resilient, and puncturing released a black, viscid, foul-smelling fluid which contained enormous numbers of *B. thuringiensis* cells. None of these abnormal chrysalids developed into adults.

Tyumentsev (1963) has found that if larvae of *Dendrolimus sibericus* Tschetverikov are artificially infected in the fifth and sixth instar with spores of *B. thuringiensis,* the larvae become carriers and die after cocooning. Legner and Oatman (1962, 1964) have found there is a decrease in the size of moths from *Spilonota ocellana* (Denis and Schiffermuller) larvae reared on leaves sprayed with *B. thuringiensis,* and that there is increased mortality of overwintering larvae in their hibernacula.

It is apparent then that if *B. thuringiensis* is ingested by larvae, especially almost mature larvae, death may occur in subsequent stages.

Malacosoma, Sarrothripus and *Nymphalis* adults emerge in the same season as larvae, therefore pupal mortality is easily detected. In species such as *Pieris* and *Anisota,* where there is an extended pupal diapause, mortality could be overlooked. The period of observation following spraying or dusting with *B. thuringiensis* should be extended to encompass the pupal and adult stages because counts restricted to dead and surviving larvae will, with some species, yield incomplete results. The possibility that late larval infection in Lepidoptera leads to reduced vigour and fecundity in surviving adults deserves additional study.

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THE RESPONSE OF *RHAGOLETIS POMONELLA* (WALSH) ADULTS AND OTHER INSECTS TO TRAP BOARDS BAITED WITH PROTEIN HYDROLYSATE BAITS

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Introduction[1]

Rhagoletis pomonella (Walsh) is a major pest of apples, plums, apricots and blueberries. Seasonal variations in temperature can cause peak emergences to vary over a considerable period of time. Since many factors

[1]Mich. Agr. Exp. Sta. Journal Article No. 3588.

can vary the emergence of *R. pomonella* it is important to have efficient techniques for detecting the presence of this pest in the field. A knowledge of the duration and intensity of populations in fruit orchards and blueberry plantations is essential if control is to be maintained. The purpose of this work was to evaluate materials that might be employed as attractants. To determine the attractiveness of the baits for other insects, all insects on the trap boards were identified to order when the boards were removed.

Methods and Materials

The following baits were evaluated:

No.	Name	Description
1	Sheffield Hy Case 802	Protein hydrolysate powder
2	Amber MPH	Enzyme hydrolyzed meat protein powder
3	Amber CTPH	Enzyme hydrolyzed cottonseed protein powder
4	Amber BYF 300	Fraction of autolyzed brewers yeast powder
5	Amber EHC	Enzyme hydrolyzed casein powder
6	Staley 43-FB	Hydrolyzed vegetable protein liquid
7	Staley No. 7	Protein hydrolysate liquid

Sheffield Hy Case 802 powder is manufactured by Sheffield Chemical, P. O. 630, Norwich, New York. The Amber baits were obtained from Amber Laboratories, Inc., 3456 North Buffum Street, Milwaukee, Wisconsin. The Staley materials were products of A. E. Staley Manufacturing Co., Decatur, Illinois.

Baits were sprinkled on 8 x 4-inch canary yellow colored boards covered on both sides with Stickum Special. Three grams of powder were used for each side of the bait board. When liquid baits were employed, 6 cc of Staley 43-FB or Staley No. 7 were encorporated into the Stickum for each side. Stickum Special is a viscous material consisting of polmerized butene, iso-butene and inert materials manufactured by Mickel and Pelton Company, Emeryville, California. The boards were suspended from the trees or bushes by a wire. A total of four boards for each bait were employed at each site. Three apple orchards located at Fennville, Kalamazoo and Gull Lake and an abandoned blueberry plantation at Grand Junction were employed for evaluating the baits. The bait boards were visited weekly to record and remove the catch of *R. pomonella*. The boards were renewed every three weeks. Other insects on the boards were identified to order at this time.

Results and Discussion

Sheffield Hy Case 802, a protein hydrolysate powder, was by far the most effective bait for *Rhagoletis pomonella*. As shown in Table I, trap boards baited with this material provide a simple and efficient method of detecting the presence and relative populations of *R. pomonella* in the field. This method has an advantage over the conventional ammonium carbonate traps in that the baits remain attractive to the flies for a much longer period than traps using ammonium carbonate. As shown in Table II the most abundant insects trapped by all baits were of the order Diptera. The two Staley vegetable protein baits were particularly attractive to dipterous insects. About 20% of the catch for all baits were coleopterous insects with

TABLE I. The average number of *Rhagoletis pomonella* adults per location trapped during weekly intervals on boards baited with different attractants—Michigan 1964

Week Ending	Bait Number[a]						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
June 29	15.0	2.0	2.0	2.5	3.0	0	0
July 7	31.2	2.5	4.0	8.0	6.0	6.5	4.0
July 13	53.0	10.0	17.0	16.0	18.5	3.5	3.5
July 20	11.0	8.5	5.5	2.7	6.7	6.5	1.5
July 27	10.7	6.2	3.5	5.5	5.5	18.5	0.5
Aug. 3	2.2	3.5	0	1.5	2.0	3.5	0
Aug. 10	7.0	3.0	2.0	6.2	4.2	3.5	1.5
Aug. 17	17.5	5.5	5.0	6.7	6.2	11.0	2.0
Aug. 24	28.0	10.7	6.0	9.2	7.0	7.0	5.5
Aug. 31	16.2	7.5	2.0	6.5	2.5	2.5	2.5
Sept. 7	3.0	1.5	1.2	2.0	0.3	0	0.5
Sept. 14	3.7	0.3	1.0	1.2	0.5	0.5	0
Sept. 21	2.2	0.7	0.3	0.5	0.5	0	0
Sept. 26-Oct. 5	2.0	0.3	0.5	0.3	0.5	1.0	0
Oct. 16-23	1.0	2.5	1.2	0	0.3	0	0
Total	203.7	64.7	51.2	68.8	63.7	64.0	21.5

[a]See "Methods and Materials"

TABLE II. The percentage of insects of different orders trapped at all locations from July 15 to August 19, 1964 on boards baited with different attractants

Order	Bait Number[a]						
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7
Diptera[b]	42	46	45	49	45	72	71
Neuroptera	3	5	8	4	2	3	2
Coleoptera	16	25	19	18	20	12	13
Hymenoptera	13	6	8	5	9	5	5
Hemiptera	7	2	1	1	4	2	1
Homoptera	19	16	19	23	20	6	8

[a]See "Methods and Materials"
[b]These figures *exclude* apple or blueberry maggot
Note: No Lepidoptera, Mecoptera or Ephemerida were collected

the Amber hydrolyzed meat protein bait being the most attractive to this group of insects. Insects of the order Homoptera comprised from 5 to 23% of the catch in the different baits. Canary yellow is attractive to a number of Homopterous insects, hence it appears probable that some of the insects, particularly aphids and leafhoppers, were attracted by the color of the boards rather than the bait.

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SPIDERS AND THEIR INSECT PREY FROM HEADS OF OX-EYE DAISY, *CHRYSANTHEMUM LEUCANTHEMUM* L., IN SOUTHWESTERN ONTARIO

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During June 1963 collections were made of spiders and their prey found on the flowering heads of ox-eye daisy, *Chrysanthemum leucanthemum* L., in two localities in southern Ontario. On June 16 they were collected in fields in Dunn Township, Haldimand County, about one mile west of Dunnville. The locality is shown as area E6 on the map illustrating a report by Judd (1963). The fields were in a large clearing in woods. The day was sunny and there was no wind so that flower heads were motionless as the field was patrolled and several hundred thousand heads were scanned for the presence of spiders and their prey. On June 18, collections were made in London, Ontario in a field adjacent to the northeast corner of Oxford Street and Hyde Park Sideroad. This field has since then been subdivided and is now occupied by houses on Queen Anne Circle in Oakridge Park subdivision. The weather on the day of collection was sunny and several hundred thousand heads of daisies were scanned for spiders.

When a spider was found on a daisy head it, and any prey with it, were captured by clapping the daisy head between the lid and the jar of a poison jar and removing the head with the captured creatures. The spiders were preserved in fluid and the insects were pinned. Most of the spiders were found sitting on the white ray florets with their heads pointing toward the centre of the flower, but some were sitting on the central patch of yellow disc florets. In a few cases a spider had tied a few ray florets together with silk and had bent them over the disc, thus making a shelter in which the spider was hidden. In several instances a spider when disturbed would scuttle over the edge of the flower and sit on the lower surfaces of the ray florets or on the upper stem of the plant.

Spiders were identified by Dr. C. D. Dondale, Entomology Research Institute, Belleville, Ontario and insects were identified by the following taxonomists of the Entomology Research Institute, Ottawa: J. G. Chilcott (*Hylemya*), L. A. Kelton (Hemiptera), G. E. Shewell (Agromyzidae, Calliphoridae), J. R. Vockeroth (Phoridae). All specimens are retained in the collection of the Department of Zoology, University of Western Ontario except those noted as "kept" in the institutions in which they were identified.

Dunn Township

Altogether 26 spiders were collected. Five of these, as follows, were holding prey when captured:—

Misumenops asperatus:	bug, *Adelphocoris lineolatus*
Misumenops asperatus:	bug, *Arhyssus* sp.
Misumenops asperatus:	fly, *Pollenia rudis*
Misumena vatia:	nymph, Tettigoniidae
Dictyna foliacea:	fly, *Hylemya ?inconspicua* (kept)

Twenty-one spiders, not holding prey, were captured on flowers, as follows: 6 *Misumenops asperatus*, 14 *Misumena vatia* and 1 *Xysticus funestus* (kept).

London

Altogether 29 spiders were collected. Eight of these, as follows, were holding prey when captured:

Misumenops asperatus:	fly, *Hylemya florilega*
Misumena vatia:	fly, *Pollenia rudis*
Dictyna foliacea:	fly, *?Melanagromyza* sp.
Dictyna foliacea:	fly, *Hylemya florilega*
Dictyna foliacea:	fly, *Megaselia* sp.
Dictyna foliacea:	unidentified fly
Dictyna foliacea:	chalcidoid wasp
Dictyna coloradensis:	unidentified fly

Twenty-one spiders, not holding prey, were captured on flowers, as follows: 5 *Misumenops asperatus*, 3 *Misumena vatia*, 7 *Dictyna foliacea* (2 kept), 1 *Icius similis*, 2 *Metaphidippus galathea* (kept) and 3 *Phidippus* sp.

Discussion of Collections

Spiders

Thomisidae — Thirty-five crab-spiders, more than half the total catch, were collected. The predominance of these spiders in the collection is in accord with the report of Gertsch (1948) that some species conceal themselves in flowers where they lie in ambush. The commonest species, *Misumena vatia* (Clerck), was particularly well camouflaged in its most usual position in the flower, its white body being superimposed on the white ray florets and its head directed toward the centre of the flower. The next most common species was *Misumenops asperatus* (Hentz). Only one *Xysticus funestus* Keyserling was taken.

Dictynidae — The dictynids were second in abundance to the crab-spiders. The commonest species, *Dictyna foliacea* (Hentz), is reported to make its web on leaves of plants (Gertsch 1948). Only one *Dictyna coloradensis* Chamberlin was caught.

Salticidae — Six representatives of this family of jumping spiders were caught. The three *Phidippus*, being immatures, were identified only to genus. Gertsch (1948) reports that *Icius similis* Banks occurs throughout most of the United States. Two *Metaphidippus galathea* (Walck.) were collected.

Insects

Some of the insects which were prey of the spiders were dismembered to the point they were not identifiable but most were recognizable to some extent. One small tettigoniid nymph was grasped by a spider. Many insects in the family Tettigoniidae occur on plants (Blatchley, 1920). The bugs, *Adelphocoris lineolatus* Goeze (Miridae) and *Arhyssus* sp. (Coreidae) are in families which include many species which frequent plants (Blatchley 1926). All the small flies identified *Megaselia* sp. (Phoridae) *?Melanagromyza* sp. (Agromyzidae), *Hylemya florilega* Zett. and *H. ?inconspicua* Huck. (Anthomyiidae) are in families which include insects found on the flowering heads of plants (Comstock, 1950; Curran, 1934). Cluster flies, *Pollenia rudis* (Fab.) (Calliphoridae), were collected in both Dunn Township and London. Hall (1948) records that this species occurs on various plants and is not easily disturbed when feeding. The

chalcidoid wasp collected was too completely dismembered to be identified; Muesebeck *et al.* (1951) record many species in several chalcidoid families occurring on plants.

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NOTE ON BIVOLTINISM IN THE LESSER PEACH TREE BORER, *SYNANTHEDON PICTIPES* (G. & R.)

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Boyce (1962) suggested the possibility of the occurrence of a partial second brood of *S. pictipes* in southwestern Ontario.

In late May, 1964, all infested areas on an eight-year old Redhaven peach tree were removed by scraping and cutting. The tree was caged with factory cotton supported on a wooden framework. Beginning on June 8, adults of both sexes were obtained from cocoons collected in district peach orchards. The adults were released in the cage for a period of five weeks.

From August 7 to 24, a total of 15 adults of a second generation emerged. This was indicated by the empty pupal cases which projected from the margins of areas freed from larvae of the previous year. Thus it was evident that a partial second generation of adults developed. The emergence of adults occurred despite lower than normal temperatures from August 7 to the end of the month. This is the first report of the occurrence of more than one generation of adults of *S. pictipes* per season in Canada.

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ARE *HYLEMYA CILICRURA* AND *H. LITURATA* TWO SEPARATE SPECIES?[1]

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Two of the closely related seed maggots in southwestern Ontario are the seed-corn maggot, *Hylemya cilicrura* (Rondani), and the bean-seed fly, *Hylemya liturata* (Meigen). These two species are so closely related that reliable morphological differences are lacking in adult females and only males can be separated accurately (Huckett, 1924; Brooks, 1951). The two species were present in the ratio of 9:1 *cilicrura:liturata* during the 1950's (Miller and McClanahan, 1960), but Begg (1962) found the opposite throughout southwestern Ontario in 1959. Harris *et al.* (1963) and Telford and Brown (1964) found that the cyclodiene-resistant population was made up of *H. liturata*. It was thought that the shift in populations was the result of the inability of *H. cilicrura* to develop resistance (Telford and Brown, 1964). Telford and Brown (1964) advanced the idea that *H. cilicrura* and *H. liturata* were not separate species but one in which the morphological characteristics of *H. liturata* were inherited along with the gene(s) for resistance. They were unsuccessful in their attempt to cross these two species and concluded that they were in reality two separate species. However, conflicting statements on their ability to rear the *H. liturata* strain cast considerable doubt on the validity of the experiments on interspecific crosses. It would appear that their *H. liturata* culture was infected with *Entomophthora muscae* (Cohn).

At this laboratory it has never been possible to rear *H. liturata* in pure culture. Whenever a mixed population of flies was collected from the field, numerous eggs, larvae, and adults of the F_1 generation of both species were obtained, but in the subsequent generation reared in the laboratory there were no *H. liturata*.

With the recent development of a more suitable adult diet for *H. cilicrura* (McLeod, 1964) an attempt was made to rear *H. liturata* and to cross these two species of *Hylemya*.

The *H. cilicrura* flies used were from a stock culture that has been maintained at this laboratory for five years and has never revealed any *H. liturata* in periodic checks of the adult males. *H. liturata* adults were obtained from the F_1 of a field-collected population. The males were identified to species but the females could not be separated. Consequently crosses involving *H. liturata* females also contained some *H. cilicrura* females. At the time the experiment was set up the *cilicrura:liturata* ratio was 3:2.

All flies emerged into individual glass vials. Twenty males and 20 females, less than 24 hr old, were placed in each of their respective cages. The cubic-foot cages were covered with 30-mesh per inch screen; the oviposition pots were 1-pint, waxed, cardboard containers holding a larval diet developed by Harris and Svec (unpublished data). The adult food was a 1:1 mixture of brewers' yeast and yeast hydrolysate (Nutritional Biochemicals Corp., Cleveland, Ohio), with honey and water presented separately. All cages and larval containers were kept in a room (10 x 10 ft) at a temperature of 20 ± 1° C and 75-85% relative humidity.

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[1]Contribution No. 60, Entomology Laboratory, Canada Department of Agriculture, Chatham, Ontario.

Table I shows that, with the exception of cage 1, the interspecific crosses were unsuccessful; even mating between males and females of *H. liturata* failed. The results of cage 1 indicate that interspecific crosses can occur, but it is obvious that the two species seldom interbreed. A repeat of this cross in cage 7 was unsuccessful producing no progeny. Cage 3 contained *H. cilicrura* females as well as *H. liturata* females. To determine if any of these progeny carried the "*liturata*" gene, an F_2 was reared. No *H. liturata* occurred in this generation either. Cage 5 was set up with the F_1 adults of a field collection that contained only *H. liturata* (by male identification). Here again *H. liturata* failed to reproduce.

TABLE I. The results of crosses between *H. liturata* and *H. cilicrura*

Cage no.	Parents		Progeny			
	♂♂	♀♀	Pupae	*cil.*♂♂	*lit.*♂♂	♀♀
1	*lit.*	*cil.*	18	0	5	13
2	*lit.*	wild	0	0	0	0
3	*cil.*	wild	894	430	0	391
4	*cil.*	*cil.*	254	93	0	122
5	*lit.*	*lit.*	0	0	0	0
6	F_1 of 3	F_1 of 3	400	183	0	134
7	*lit.*	*cil.*	0	0	0	0

It is clear from this table that while the rearing method is quite good for *H. cilicrura* it lacks some essential requirement for *H. liturata*. The *H. liturata* flies were healthy and lived as long as the *H. cilicrura* flies, and neither culture showed any signs of the fungus, *Entomophthora muscae*.

Thus, although the experiment is of limited value because the *H. liturata* control failed to reproduce, this very fact is evidence that they are separate species. An unfulfilled environmental requirement for *H. liturata* separates it from the morphologically similar species *H. cilicrura* much as environmental requirements are used to separate species of bacteria.

This argument becomes more convincing if you are able to demonstrate the nature of the requirement, and an attempt to this end was tried in the next experiment. It was known that *H. cilicrura* females required a protein for ovarian development (McLeod, 1964). It was thought that perhaps *H. liturata* females were not feeding on the dry brewers' yeast/yeast hydrolysate mixture, but they were known to feed on honey. To induce the adults to take up some of this protein, it was presented to the flies in a pasty solution with honey.

In this experiment 10 males and 10 females, less than 24 hr old, were placed in each cage. The cages (2½x4x7 inches) were covered with 30-mesh per inch screen. In each cage was placed a vial of water, an oviposition site (Barlow, 1965), and a small amount of protein (as above) and honey separately, or protein mixed with honey (4:1:1 mixture of honey:brewers' yeast:yeast hydrolysate).

Table II shows that mixing the protein with the honey did not provide the missing requirement. The striking difference in the number of eggs produced and the failure of the *H. liturata* eggs to hatch are evidence of this. The females of both species were dissected after death and had mature ovaries in most cases. This could only be if the females had taken up protein.

TABLE II. The effect of mixing the adult food on egg production of *H. cilicrura* and *H. liturata*

Species	Food	Cages	Eggs/♀	% hatch
H. cilicrura	protein + honey	2	185.6	64.6
	protein-honey mix	2	140.9	45.1
	honey	2	0	
H. liturata	protein + honey	5	6.8	0
	protein-honey mix	5	4.2	0

Thus, although the nature of the missing requirement could not be demonstrated, the data support the conclusion that *H. cilicrura* and *H. liturata* are separate species.

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THE STATUS OF THE NAME *PROSIMULIUM ALBIONENSE* ROTHFELS

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The name *Prosimulium albionense* first appeared in a paper by Rothfels (1956), and, to the author's knowledge, the only subsequent reference is in a book review by Peterson (1964) in which the name was stated to be a *nomen nudum*. Current research on the taxonomy of black flies requires

clarification of whether or not the name *P. albionense* was properly validated by its author. It is the contention of the present writer that *P. albionense* must be considered a *nomen nudum* until properly validated.

Rothfels did not meet the provision of Article 13, section (a) (i), of the Code, which requires a statement that purports to give characters differentiating the taxon. The closest he came to fulfilling this criterion was by his statement (p. 121) : "A second group comprises *multidentatum* . . . and *"albionense"*. They are homologous band for band. They share terminal and basal homologies with group 1 . . . and differ essentially by a central inversion involving the "blister". This common inversion associates *multidentatum* and *"albionense"* with each other and separates them from all others, thus corroborating the conclusions previously founded . . . ". This might be interpreted as a statement that differentiates *albionense* from *multidentatum;* in reality, Rothfels was separating the two species as a group from other species groups.

Furthermore, there is no statement in Rothfels' paper to indicate that the species is new, no type or locality data are provided, and quotation marks around the name *albionense* are used consistently, presumably to indicate its status as a provisional, not a valid, specific name.

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THE ESTABLISHMENT OF A LABORATORY COLONY OF THE TOMATO HORNWORM *PROTOPARCE QUINQUEMACULATA* HAW. (LEPIDOPTERA: SPHINGIDAE)

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Introduction

A recent paper by Walbauer, Yamamoto and Bowers (1964) has described the continuous laboratory rearing of the tobacco hornworm, *Protoparce sexta* Johannson, originally collected in the vicinity of Urbana, Illinois. In the environs of Ottawa, Ontario it appears that the tomato hornworm, *Protoparce quinquemaculata* Haworth is the local species and wild larvae have been used to initiate and supplement a colony in this laboratory. *P. sexta* and *P. quinquemaculata* are very similar, but the larvae can be separated by body pigmentation and by length and angle of the larval dorsal horn (Gilmore, 1938). Both species will feed on tobacco and tomato foliage and on related solanaceous plants. Since there are some

points of difference between the rearing methods used for *P. quinquemaculata* and those described for *P. sexta,* the method is reported here in full.

Methods and Results

Adults

The moths are placed in 3x3x6-ft screened cages at a temperature of 22°C ± 1°C, photoperiod 16 hours. A shaded, 40-watt incandescent lamp is placed about 20 ft from the cage and programmed to simulate dusk. The adults are fed by hand daily on a solution of sugar containing 5% fructose and 5% glucose. The solution is taken up into a 2 ml hypodermic syringe fitted with a 2-inch, 20-guage needle the point of which has been rounded. The moth is held between the forefinger and thumb, the tip of the needle is placed in the proboscis coil (method of Walbauer et al 1964), and a drop of solution is expelled from the syringe. As the drop diminishes, more solution is added until feeding ceases. A moth which is reluctant to feed can sometimes be induced to do so by teasing the proboscis or by applying slight pressure and release movements to the thorax with the fingers holding the insect. Moths fed in this manner often live up to 14 days. Mating takes place within three days of emergence and occurs during the hours of dusk; oviposition commences 3 to 4 days later. A female moth which does not feed lives for only a few days and lays no eggs.

Eggs

To obtain eggs, a small plant or branch of tomato foliage standing in water is placed in the oviposition cage with the moths and the eggs are deposited on the undersides of the leaves. The foliage is changed daily and the eggs are transferred onto fresh leaves and held in 7x3x2-inch plastic boxes. The boxes are lined with moist blotting paper and placed in a rearing cabinet at 27°C; the lid is kept on the box to maintain a high humidity.

Larvae

Individual rearing

The larvae are reared individually in 7x3x2-inch plastic boxes as described above. They are supplied with fresh tomato foliage daily. The blotting paper should be replaced as necessary, but not moistened after the fourth instar. When the larvae have ceased feeding, the foliage and the blotting paper are replaced by a thick layer of moist peat moss; the larvae readily pupate in this material. After pupation the pupae are transferred to wooden boxes with screened removable tops, and placed on a one-inch layer of peat moss. Pupae should not be handled during the 2 or 3 days prior to emergence.

A diet containing tomato leaf homogenate was used successfully by Walbauer et al (1964) to maintain larvae through the fifth instar. We fed a total of 81 larvae, mainly fifth instar, on this diet, but of this number only 17 emerged as adults, 7 of which had deformed wings. We noticed that many of the pupae showed an abnormality in the dorsal thoracic region which appeared as a portion of unsclerotized cuticle. The area was soft and clear and the underlying haemolymph could be seen. The type of adult deformity which occurred was typical of that shown by insects reared on a diet deficient in fatty acids (Dadd, 1961, 1964). It is possible that the corn oil used in our diet did not fulfil the minimum requirement of linoleic and linolenic acids for normal development of *P. quinquemaculata.* The requirements for these components by *Trichoplusia ni* (Hubner), have been discussed recently by Chippendale, Beck and Strong (1964). Diet-fed

fifth instar larvae develop faster than foliage-fed insects. For 10 diet-fed insects the average length of the instar was 9.6 days; for 28 foliage-fed larvae reared under similar conditions it was 11 days. The diet-fed larvae become extremely turgid.

Mass rearing

Newly hatched larvae may be reared successfully on plants in a growth chamber or greenhouse. Fifth instar larvae will often wander in search of food and later on, in search of a place to pupate and should be removed and confined at this time. For this purpose we use covered, 12x9x4-inch plastic boxes and added a layer of peat moss to accommodate the pupae. These containers are suitable for 12 to 15 larvae.

Discussion

Walbauer et al (1964) reported that pupae of *P. sexta* do not enter diapause if the larvae have been exposed to a 16-hr photoperiod throughout their development, whilst a large number do so if exposed to an 11-hr photoperiod. The temperature at which these larvae were reared is not clear. Svec (1964) has indicated that temperature rather than photoperiod is the main factor influencing diapause in *P. quinquemaculata*.

We have found that at 27°C, under continuous light or continuous dark conditions, eggs hatch in 4 to 5 days, the larvae mature in about 23 days, there is no diapause and the adult emerges 15 to 16 days after pupation. At 20°C the eggs hatch in 6 to 7 days and the larvae mature in approximately 35 days. Pupae diapause at this temperature under conditions of continuous light or continuous dark; however, the conditions at both 27°C and at 20°C were not quite constant as the intensity of light in the light cabinet varied between 5 pm and daybreak and the dark cabinet was opened for short periods daily. In other experiments insects were reared under identical conditions of temperature (24°C±3°C) in a divided cabinet. The compartments received an 8-hr and a 16-hr photoperiod respectively and only those insects which had been maintained on the 8-hr photoperiod entered diapause. Pupal diapause is broken when the insects are placed in cabinets at 27°C under continuous light. Emergence takes place approximately 25 days after the change in conditions, but 4 or 5 days before emergence the adult markings are visible through the pupal cuticle.

It is of interest that larvae reared at 20°C are frequently much darker in colour in the fifth instar than those reared at higher temperatures. Colour divergence at low temperatures, in pupae of the Asiatic common looper, *Autographa nigrisigna* (Walker) has been recorded recently by Ichinose and Asawa (1964). Those insects are reported as being black in colour when reared at 20°C, yellowish brown when reared at 30°C, and intermediate between these colours when raised at 25°C. The susceptible age is considered to be the middle of the last larval instar. At Ottawa a high percentage of tomato hornworms moulting from fourth to fifth instar at 20°C became either black or dark green; dark forms seldom occur when larvae are reared at 27°C.

Acknowledgment

The author is indebted to Dr. B. N. A. Hudson, Entomology Research Institute, Ottawa for helpful advice throughout this investigation.

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(Accepted for Publication: April 23, 1965)

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A WAXED-PAPER LABORATORY CAGE FOR STERILIZATION STUDIES WITH THE ORIENTAL FRUIT MOTH, *GRAPHOLITHA MOLESTA* (BUSCK) (LEPIDOPTERA: TORTICIDAE)[1]

J. A. GEORGE and M. G. HOWARD[2]
Research Station, Canada Department of Agriculture, Vineland Station, Ontario

Testing the effects of gamma radiation and chemosterilants on the fertility and vitality of the Oriental fruit moth, *Grapholitha molesta* (Busck), requires a satisfactory means of collecting all of the eggs over the lifetime of the females. The eggs must then be incubated three days in a warm moist atmosphere and examined to determine the number that hatched. Moreover, optimum conditions (including free moisture) that can be replicated, must be provided for the mating and maximum longevity of adults. The cages must also allow the replication of various ratios of males to females without a change in the density of moths.

It has long been commonly known that females of the Oriental fruit moth deposit eggs readily on waxed paper. A very satisfactory yet simple cage can be constructed entirely of this material. A roll of "Rap-Rite"[3] waxed paper, 12 inches wide, is placed in a lathe and cut into two 6-inch rolls with a very sharp knife. From these rolls 9-inch lengths are cut. Then a small piece (approximately 1½ by 2 inches) of heavy brown waxed paper is heat sealed onto the centre of the sheet with a warm soldering iron to provide reinforcement for the cage opening. A hole is then made through the reinforcement of several sheets at once with a No. 8 cork borer, the hole being placed 4 inches from one end and 2½ inches from one side of the waxed paper. Each sheet is then wrapped around a cylinder 2½ inches in diam), with the hole reinforcement to the outside, and heat

[1]Publication No. 94 Research Station, Canada Department of Agriculture, Vineland Station, Ontario.
[2]Entomologist and Technician, respectively.
[3]Rite Paper Products Ltd., Montreal, Canada.

sealed along the overlap. The waxed-paper cylinder is now flattened at one end, folded over 1/4 inch, and heat sealed across the end with a warm soldering iron. The other end is similarly sealed with the fold at right angles to the first one, forming a cage with a rigid tetrahedral shape (Fig. 1). The hole of the cage is stopped with a cork. A wick of dental cotton passes through a hole in this cork and in another cork capping a vial of water or a solution of chemosterilant (Fig. 1). The hole in the cage can,

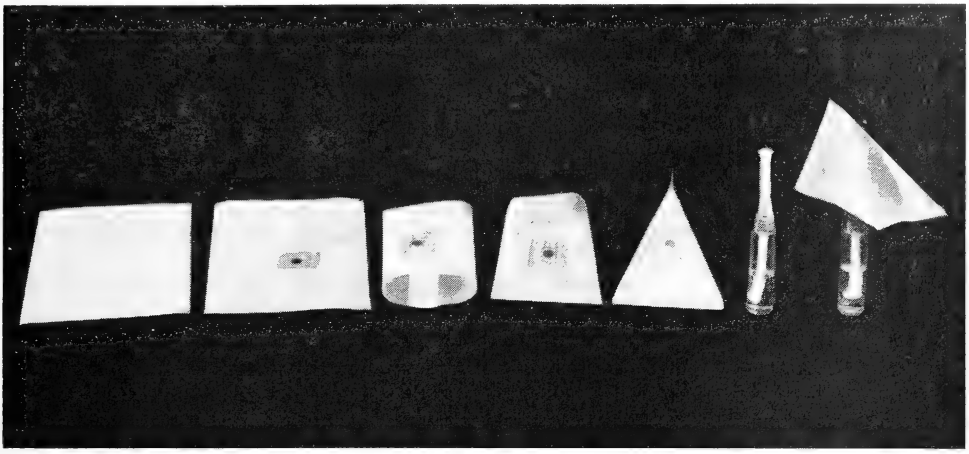

FIG. 1. Stages in the construction of the tetrahedral-shaped cage of waxed paper.

of course, be closed temporarily with a cork without a wick. Perforation of the cage with a pin provides ventilation. When the cages need be held at high humidity for a long period, they can be made of a double thickness of paper and the ends stapled, in addition to heat sealing, for added durability.

The moths are introduced or removed through the hole in the cage by aspirator. Cages of various sizes can be made for accommodating different numbers of insects. A cage of the size described here provides room for 40 moths of various sex ratios. The moths can be transferred every 2-4 days to a new cage, depending on the rate of egg laying. If many females are left too long in a cage, the eggs accumulate in overlapping clusters in the upper corner and the underlying eggs do not hatch. The eggs are laid almost entirely on the paper of the cage; none have been found on the wick and only a very few on the exposed end of the cork.For examination, the ends of the cage are cut off and the longitudinal seam is pulled apart to give a flat sheet on which the eggs can be easily examined. As the waxed paper of the brand used is transparent, any dead moths can be detected and removed daily in experiments on longevity.

(Accepted for Publication: January 6, 1965)

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V. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND FIRST ANNUAL MEETING ENTOMOLOGICAL SOCIETY OF ONTARIO

GUELPH, ONTARIO

September 2-4, 1964

The 101st Annual Meeting of the Society was held in the War Memorial Hall, University of Guelph. The meeting commenced at 1:45 p.m. on September 2 with the President, Dr. W. F. Baldwin, in the chair. Members were welcomed by Dr. J. D. MacLachlan, President of the University of Guelph, under whose auspices the meeting was held. After some business announcements by the Society's President, the guest speaker, Dr. R. H. Wright of the British Columbia Research Council, Vancouver was introduced, and gave a stimulating address "After pesticides, what?" which dealt with an approach to insect control based on insect behaviour (see Nature, Lond. 204: 121-125, 1964).

The meeting then proceeded for the next two days according to the printed program. A smoker was held at the Cutten Club on the evening of September 2, a conducted tour of the Imperial Tobacco Co. plant at Guelph on the afternoon of September 3, and on the same evening the Annual Banquet took place at the Royal Hotel with over one hundred guests present. After the Banquet, Professor R. W. Dent spoke on "New horizons in education: programmed learning today and tomorrow".

The following papers were presented during the meeting (some of these appear in the preceding sections of this volume). Those marked with * were read by university students for the President's Prize (for results of the awards see Appendix III).

WELCH, H. E. (Belleville). Impressions of a recent tour of Russia.

MUSGRAVE, A. J. (U. Guelph), MONRO, H. A. U. and UPITIS, E. (London, Ont.). Elimination of mycetomal microorganisms from *Sitophilus granarius* (L.) during selection for tolerance to methyl bromide.

FRIEND, W. G., BECKEL, W. E. and KURTZ, B. C. (U. Toronto). Studies of DNA duplication in *Rhodnius prolixus* (Stohl) using tritiated thymidine.

ANGUS, T. A. (Sault Ste. Marie). *Bacillus thuringiensis* as a pathogen of post-larval stages of some Lepidoptera.

BOYCE, H. R. (Harrow). Effects of two carbamate insecticides on several pests of peach.

BALDWIN, W. F. (Chalk River). Entomological vistas in Venezuela.

*BARRETT, F. M. (U. Toronto). A study of uric acid in the hemolymph of fith instar *Rhodnius prolixus*.

*READ, D. C. (U. Wrn. Ont.) Inheritance of dieldrin-resistance in the cabbage maggot, *Hylemya brassicae* Bouché.

*PICKETT, Catherine (U. Toronto). Free amino acids in the haemolymph of *Rhodnius prolixus* (Stohl).

*BODNARYK, R. (U. Waterloo). An analysis of the proteins in the haemolymph of *Musca domestica* L. during the first ovarian cycle.

PETERSON, D. G. (Guelph). Cyclodiene resistance in cocoa mirids.

GOBLE, H. W. (U. Guelph). The armyworm, *Pseudaletia unipuncta* (Haworth) in Ontario in 1964.

PETERSON, B. V. (Guelph). An entomologist's impressions of Iceland.

NIGAM, P. C. and MUSGRAVE, A. J. (U. Guelph). Effect of DDT on the antigenic composition of *Sitophilus granarius* (L.).

DIXON, S. E. (U. Guelph). Impressions of the XII International Congress of Entomology.

Annual Business Meeting

The annual business meeting was held at Memorial Hall, University of Guelph, on September 4, 1964, with the President, W. F. Baldwin, in the chair. Thirty-two members were present.

Minutes of the last Meeting

On motion of D. G. Peterson and G. G. Dustan, the minutes of the last meeting (Ottawa, Sept. 4, 1963), as published in Vol. 94 of the PROCEEDINGS were adopted.

President's Report

The President, W. F. Baldwin, briefly outlined the events of the year, which from the Society's viewpoint has been a quiet one. Mr. D. G. Peterson returned from Ghana in January and has resumed editorship of the PROCEEDINGS. However, the closing of the Insect Laboratory of the Department of Agriculture at Guelph and the transfer of Mr. Peterson and Dr. Steward to other stations will necessitate finding a new editor and secretary-treasurer.

On motion of D. G. Peterson and D. H. Pengelly the President's report was adopted.

Secretary-Treasurer's Report

The Secretary-Treasurer presented the 1963 annual financial report and a 1964 interim financial report to August 31, 1964. The 1964 financial statement is shown in Appendix I.

The result of the mail ballot shows the following members elected directors for the year 1964-65:

C. E. Atwood
H. E. Boyce
R. W. Fisher
A. Hudson
H. A. U. Monro
D. H. Pengelly
H. E. Welch
W. F. Baldwin (Past President)

The Secretary-Treasurer presented a report of the Programme Committee. The Library Committee report is shown in Appendix II. The Libary Exchange Committee report is given in Appendix II.

Volume 94 (1963) of the PROCEEDINGS is now in press and should be mailed to members by the end of this month.

Membership stands at 238. The Secretary-Treasurer announced with regret the death of Mr. A. R. Hall, of Whitby, Ontario, a senior and respected member of the Society.

On the motion of A. G. McNally and C. E. Atwood, the report of the Secretary-Treasurer was adopted.

Grant to Zoological Society of London

On motion of H. A. U. Monro and D. H. Pengelly, it was proposed to grant to the Zoological Society of London the sum of $100.00 for the year 1964-65 to assist in the publication of the "Zoological Record". Carried.

Resolutions and Votes of Thanks

D. G. Peterson and H. W. Noble moved two resolutions (see Appendix III) conveying the thanks of the Society to those concerned with the organization of the present meeting. Carried.

Moved by H. R. Boyce, seconded by L. A. O. Roadhouse, that the Secretary-Treasurer write letters of appreciation to Mr. W. C. Allan, and also letters of goodwill to Prof. A. W. Baker, Dr. Detwiler, and Prof. Ozburn. Carried.

Location of 1965 Annual Meeting

An invitation was received from H. A. U. Monro to hold the Society's 1965 annual meeting at London, Ontario. On motion of W. C. Allan and H. R. Boyce, this invitation was accepted unanimously.

Auditors for 1965

On motion of C. C. Steward and D. H. Pengelly, C. J. Payton and R. Saunders were reappointed auditors for 1965.

There being no further business, the meeting adjourned on motion of T. A. Angus and B. V. Peterson.

APPENDIX I

ANNUAL FINANCIAL STATEMENT FOR 1964

RECEIPTS		EXPENDITURES	
Membership dues	$2,006.05	Dues to Ottawa	$1,586.00
Exchange & Premiums on cheques	14.03	Exchange on cheques	4.50
Sales of reprints	293.00	Library maintenance	203.22
Sale of "Proceedings"	3.00	Petty cash, Postage, Express	247.25
Grant from Minister of Agriculture	300.00	Printing & Stationery	110.58
Receipts from Annual meeting	340.90	Printing of reprints	302.10
Cash returned after annual meeting	500.00	Grant to Zoological Society of London	100.00
Share of Centennial profits	66.78	Cash withdrawn for annual meeting	500.00
Bank Interest	48.34	Gift to retiring Secretary-Treasurer	23.75
Gov't. Bonds Interest	18.00	Auditors fees	5.00
	$3,590.10	Dues returned	10.00
		Purchase Insect Collector's Guide	20.15
		Annual Meeting:	
		President's Prize (2)	100.00
		Badges	6.13
		Accom. U. of Guelph	130.00
		Guest Speaker	234.00
		Programmes	46.25
		Chartered Bus	15.00
		Coffee for Sessions	29.48
		Banquet	204.35
		Smoker	55.09
		Expenses	$3,932.85
		Gov't. Bonds	$ 400.00
Bank Balance January 1, 1964	$1,356.61	Bank Balance January 1, 1965	$1,013.86
Gov't Bonds	$ 400.00		
	$5,346.71		$5,346.71

Auditors

C. J. Payton
R. Saunders

D. H. Pengelly,
Secretary-Treasurer
1 January 1965

APPENDIX II

COMMITTEE REPORTS

Library Committee

The library continued to serve the requirements of members, graduate students and staff of various Entomological Services. This was done by direct visitation and Library Loan systems.

All current numbers and volumes have been recorded and numbered so that they now have a ready and easy accessibility.

W. C. Allan, Chairman.

Exchange Committee

This Committee, consisting of Messrs. Vockeroth, Peterson, B. V., and Allan, met in the Library on September 4 and carefully examined all publications which the Library was receiving in exchange for the "Canadian Entomologist". As a result of this study it was agreed that seventeen publications should be removed from the exchange list. These were publications which were considered to be of little value to the Library and publications which had deteriorated in content value during the past few years. All publishers of such journals were notified of the committee's decision and their names removed from the exchange list. This reduction now leaves us with a total of seventy exchange agreements involving the "Canadian Entomologist".

W. C. Allan, Chairman.

APPENDIX III

RESOLUTIONS

WHEREAS the University of Guelph, by extending to our Society the facilities of its accommodations and services, has greatly contributed to the success of the Meeting,

BE IT RESOLVED that the Society, through the Secretary-Treasurer, express to the President of The University of Guelph, Dr. J. D. MacLachlan, its sincere thanks for the services placed at the disposal of our members.

WHEREAS the Program Committee and the Local Arrangements Committee have prepared an excellent program for this Annual Meeting,

BE IT RESOLVED that the Society, through its Secretary-Treasurer, express to the members of both these committees its appreciation and sincere thanks for their work and co-operative effort.

PRESIDENT'S PRIZE

Four papers were presented by students at the 101st annual meeting in the fourth annual competition for the President's Prize. (See list of titles above).

The judges, P. W. Fletcher, W. E. Heming and D. G. Peterson, unable to pick a single winner, awarded a prize to each of two contestants. A fifty dollar prize and certificate of Merit were presented to Miss Catherine Pickett and to Mr. F. M. Barrett by Dr. W. F. Baldwin at the banquet at the Royal Hotel.

Miss C. Pickett was born in Toronto, Ontario and entered the University of Toronto in Biology in 1959. She graduated in 1963 with the degree of Bachelor of Science. Miss Pickett continued at the University of Toronto, working on her Master of Arts degree under Dr. W. G. Friend on the amino acids in the haemolymph of *Rhodnius prolixus* (Stohl).

Mr. F. M. Barrett was born in Toronto, Ontario and entered the General Science Course in the University of Toronto in 1960. He graduated with the degree of Bachelor of Science in 1963. Mr. Barrett remained at the University of Toronto to study for the Master of Arts degree under the supervision of Dr. W. G. Friend. His thesis was based on a study of uric acid in the haemolymph of fifth instar *Rhodnius prolixus* (Stohl).

C. C. Steward,
Secretary-Treasurer.

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In Memoriam

DR. A. P. ARNASON (1903-1964)

Dr. Arni Pall Arnason was Arni to everyone who had more than the most formally casual association with him — which fact tells much of the man. Arni's path first crossed mine in the spring of 1928 at a farm near Drumheller, Alberta, whose owner was cooperating with the Government in entomological research. He was then an Insect Pest Investigator with the Dominion Entomological Laboratory at Saskatoon, Saskatchewan, and had been sent to make field observations on wireworms attacking wheat and to collect wireworms for experiments to be carried on at Saskatoon. By dint of questioning in spare time conversation — for Arni was never one to volunteer conversation on topics he considered uninteresting — I learned that his family had moved from Manitoba to a farm at Mozart, Sask., when he was three years old; that he had gone to normal school in Saskatoon and then had taught public school for two years before entering university; that this was his second summer as an I.P.I. at the Saskatoon Laboratory; and that he hoped to graduate in 1929 and continue in Entomology. Even in so short a time he had made a strongly favourable impression not only by his keen interest and thoroughness in his work but by his personality, integrity and general outlook as well. My opinion was never to change except to grow more appreciative.

Arni received his B.Sc., Honours Biology, from the University of Saskatchewan in 1929 as planned and, because of the experience gained during his two summers as I.P.I., was immediately appointed a full-time Junior Entomologist at the Saskatoon Laboratory under the Direction of Dr. K. W. King. Without interfering with his work at the Laboratory he took post-graduate studies at the Univesity of Saskatchewan to obtain his M. Sc. degree in Entomology there in 1931. Before 1935 he was made an Assistant Entomologist and later that year was granted a "transfer of work" for the school year to study at the University of Illinois where, in that time, he completed his *course work* towards his Ph. D. Since his thesis was based on an ecological project of the Saskatoon Laboratory and was to be prepared there, he returned at once to his regular work with that Laboratory and received his Ph.D. (Entomology-Ecology) in 1942 after assembling an unusual amount of original data and burning the midnight oil for many months. In 1946 he was named Acting Officer in Charge of the Saskatoon

Laboratory and its Officer in Charge in 1947. He was transferred to Ottawa as Associate Head of the Field Crop Insect Unit of the Entomology Division in 1952 and upon my retirement became Head of the Unit in 1956. The next year the Units of Field Crop, Fruit, and Stored Products Insects were officially amalgamated to form the Crop Insects Unit and he was appointed its Head. With the reorganization of the Department of Agriculture and the combining of *all* its research into one unit under the name of Research Branch, in 1959, he was made an Associate Director of Program (Entomology) and later Research Coordinator for that discipline.

In addition to his duties connected with administration and active insect investigations in Canada he took part in the work of any group organized to further the interests of scientists and scientific development nationally and internationally. For instance:—He was a member of many working committees both for the Canada Department of Agriculture and for the organizations to which he belonged. In 1949 he attended the Plant Protection Conference in London, England, and visited institutions conducting ecological research. He was Chairman of the Agricultural Entomology Section of the Program Committee for the Xth International Congress of Entomology in Montreal (1956) and a delegate from Canada at the XIth in Vienna (1960), and the XIIth in London (1964). He was an official Canadian representative at the 7th Commonwealth Entomological Conference in London (1960) and the Research Branch's Correspondent in Entomology for the Commonwealth Agricultural Bureaux. He attended the International Pollination Conference at Copenhagen in 1960 and was the official Canadian representative at the Second International Symposium on Pollination in London (1964). He also attended the International Aphid Conference in California in 1964. He was a member of the Entomological Society of Canada, *Entomological Society of Ontario*, Entomological Society of America, Quebec Society for the Protection of Plants, the Agricultural Institute of Canada, the Ontario Institute of Agrology, and the Professional Institute of the Public Service of Canada. At one time or another he served most of these societies in a responsible capacity, a head figure but never a figurehead.

While at the University of Illinois he had met Miss Elizabeth Heiss—also a candidate for a Ph. D. in Entomology — and in August 1938 they were married at Fort Collins, Colorado, where she had been teaching. This, to most of his Canadian Associates, was in the nature of a bombshell (that Arni thoroughly enjoyed!) for most of his friends had considered him a confirmed bachelor. The Arnasons' four children are Jeannie Elizabeth (Mrs. Bryan Hollebone) in England, where both she and her husband are studying for their Ph. Ds; Arni Neil, at Waterloo University, Ontario; and Alice Rose, Carleton University, and Jhon Thor, Fisher Park High School, at home in Ottawa with Mrs. Arnason, who herself handles some part time instruction at Carleton University.

Few entomologists today have had the wide and varied experience in all sectors of Entomology as was Arni's. His first work at Saskatoon was an ecological study on the changes in the arthropod population in the soil of native prairie grassland as it was subjected to various cultivations, crop production and crop rotation. At the same time he was conducting pioneer field observations and research on wireworms attacking cereal crops. Since then he had planned, directed and sometimes carried out research on practically all the insect pests of the Prairies and, after his transfer to Ottawa, this had been extended to include most of Canada. He collaborated with W. B. Fox, formerly with the Saskatoon Laboratory, in developing a seed treatment that provided the first practical control of wireworms in cereal crops. In cooperation with Dr. J. W. T. Spinks of the Physics Department of the University of Saskatchewan, he developed a method of using radioactive tags to follow the movements in the soil of wireworm and other soil-infesting insects. He also used this technique in studies on mosquitoes, black flies and grasshoppers. When the black fly, *Simulium articum* Mall. swarmed out of the Saskatchewan River, menacing man and livestock, studies on biology and control that he carried out with F. J. Fredeen, and others, were responsible for practically eliminating black-fly larvae for 100 miles downstream after a 15-min treatment at a single point in the river. He followed closely, too, the research on insects pollinating alfalfa and become interested in studies of the role of insects in all pollination.

Arni was an ideal planner, director and coordinator of entomological research. This was not only because of his wide knowledge and experience but also because of his thoroughness and intense interest in all facets of entomology, both in the field of research and in that of its practical application. Also he had the happy faculty of making staffs feel perfectly at ease with him. Any member could come to him anytime, freely and informally, confident of his interest in that person's project and problems,

and sure of companionable, helpful and constructive discussion — and sharp criticism when and where it was needed. Whether a project was designed to provide practical economic results or only to satisfy scientific curiosity he could review and discuss it with authority. Discussions with his associates, always free and frank, led to weak projects being strengthened or eliminated, and strong ones made stronger. He definitely favored coordinating work between laboratories where it was feasible, or produced quicker or more satisfactory results, and always he gave to every member of his staffs vital encouragement, stimulation and direction. I know of no entomologist who was more respected, more admired or better liked than Dr. Arni Arnason. We have lost one of the few remaining real entomologists who understand the whole complex subject of entomological research and the importance of its practical application, but more than that we and Entomology have all lost a true friend and counsellor. We and Entomology are the better for having had him with us. (reproduced by permission of the author and of the editor of the Aphidologist's Newsletter). Hod (H. L.) Seamans, former Head of the Field Crop Insect Unit, Ottawa.

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of the

ENTOMOLOGICAL SOCIETY OF ONTARIO

Volume Ninety-Six

1965

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ENTOMOLOGICAL SOCIETY OF ONTARIO

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1964 - 1965

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I REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS ATTACKING AGRICULTURAL CROPS AND ORNAMENTAL PLANTS IN ONTARIO IN 1965

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Fruit

In general, populations of insects and mites that attack fruit were smaller than normal as a result of cool weather in the spring and cool wet weather in August and September. There were some exceptions, particularly from the family Trypetidae. Infestations of the apple maggot, *Rhagoletis pomonella* (Walsh) were larger because of a prolonged emergence of the adults from early July to August and even into September. Damage was severe in some "farm" orchards with infestations in commercial orchards greater than in 1964. Cherry fruit flies *Rhagoletis cingulata* (Loew) and *R. fausta* (O.S.), also were more plentiful in and near uncared-for-orchards. The currant fruit fly, *Epochra canadensis* Loew caused some trouble on currants and gooseberries. The European red mite, *Panonychus ulmi* (Koch), and pear rust mite, *Epitrimerus pyri* (Nal.), while important in some orchards, were reported to be in smaller numbers than in 1964. The leaf rollers such as the red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.), and fruit tree leaf roller, *Archips argyrospilus* (Wlkr.), were present in small numbers as were also other Lepidoptera such as the codling moth, *Carpocapsa pomonella* (L.), and the Oriental fruit moth, *Grapholitha molesta* (Busck). Sap beetles, *Glischrochilus quadrisignatus* Say, continued to infest raspberries in Lambton, Elgin and Oxford counties and also contaminated a few fields of tomatoes resulting in a few loads being refused at processing plants early in the season. The pear fruit sawfly, *Hoplocampa brevis* (Klug), first discovered near Queenston in 1964 was found present in scattered pear orchards in the eastern half of the Niagara Peninsula but had caused no appreciable damage to the pear crop.

Vegetables

Damage to vegetables by insects and mites generally was not as severe as in 1964. Extremely heavy losses, however, occurred on individual farms with some of these large populations related to the development of insecticide-resistant strains. Root maggots, mostly *Hylemya brassicae* Bouché on cole crops and *Hylemya florilega* (Zetterstedt) on tobacco, were very abundant in May and June. A large number of fields of cabbage, cauliflower and rutabagas were severely damaged with a few completely destroyed. The heavy losses to cole crops occurred from the strain of root maggot resistant to control by the cyclodiene insecticides. The onion maggot, *Hylemya antiqua* (Meig.), was more plentiful than usual. The pepper maggot, *Zonosemata electa* (Say), was very scarce in Essex county in 1965 in

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the area where severe infestations occurred between 1960 and 1963. A newer species of flea beetle, *Phyllotreta cruciferae* was present in extreme numbers in plantings of rutabagas, rape and other cole crops. Flea beetle larval damage to the roots of rutabagas rendered some fields unmarketable. It is expected this species caused most of the root damage although adults of *P. striolata* (F.) were also present. Field crickets, *Acheta assimilis* F., caused damage to field-grown tomatoes in southwestern Ontario. The greenhouse whitefly, *Trialeurodes vaporariorum* (Westw.), as well as being a problem with some greenhouse cucumbers and tomatoes, infested tomatoes and tobacco in the fields in the Leamington area.

Field Crops

There were no reports of infestation or damage from the armyworm, *Pseudaletia unipuncta* (Haworth), in 1965. This was remarkable following the outbreak year of 1964. It is likely that the heavy parasitism reported in August, 1964, was largely responsible for this drop in population. The green cloverworm, *Plathypena scabra* Fabricius, was also at a low level. This, like the armyworm, is interesting as 1964 was an outbreak year. The corn leaf aphid, *Aphis maidis* Fitch, was very abundant on corn during July. Some corn fields were severely damaged by cutworms during June but the injury was restricted to a small percentage of the total crop. The Mexican bean beetle, *Epilachna varivestis* Muls., was present in small numbers in the bean growing areas of Lambton and Huron counties but, probably because of the cool weather in August, remained at a low level.

Ornamental Plants

The honey locust pod gall, *Dasyneura gleditschiae* O.S., continued to damage the Moraine locust. This gall insect has found this ornamental locust a preferred host to the honey locust. The birch leaf miner, *Fenusa pusilla* (Lepeletier), was plentiful on many of the birch in ornamental plantings. There was a greater than normal number of stalk borers, *Papaipema nebris* (Guenée), in the stems of dahlia, zinnia and many weeds and ornamental plants.

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HIGHLIGHTS OF FOREST INSECT CONDITIONS IN ONTARIO IN 1965

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Surveys of forest insect conditions in the forests of Ontario have been carried out annually since 1936, and are a responsibility of the Insect and Disease Survey Section, Ontario Region, Department of Forestry of Canada. The survey consists of 15 full-time and seasonal employees in entomology, engaged in laboratory functions, and 22 experienced field technicians whose work is divided between forest entomology and pathology. Generous support in various field

aspects of the program is provided by the Ontario Department of Lands and Forests and by interested individuals, many of whom are associated with the forest industry.

Regular and timely reporting of information on current insect conditions is an important function of this Section. The following resume is drawn from collections, records, and reports compiled by the Survey in 1965. Descriptions relating to indigenous insects are arranged separately by coniferous and deciduous host trees, as are the descriptions relating to introduced insects. Emphasis in this review is on pests of greatest economic consequence. Information in greater detail on specific problems will appear in the 1965 Annual Report of the Forest Insect and Disease Survey in the spring of 1966 (Sippell *et al., in press*).

Indigenous Insects

On Coniferous Trees

The outbreak of the spruce budworm, *Choristoneura fumiferana* (Clem.) that began about 1937 and caused widespread destruction in stands of spruce and fir in northern Ontario was confined to the Quetico Provincial Park area of northwestern Ontario, and to the vicinity of Long Lake, north of Lake Superior in 1963. The outbreak virtually collapsed in 1964, and the mortality of fir trees in these two areas continued but at a reduced rate in 1965. Except for a few minor infestations north of the Ontario-Minnesota boundary and at scattered locations in southern Ontario, endemic numbers of spruce budworm prevailed in 1965. Collections obtained by quantitative sampling at systematically arranged study areas across the Province were small, seldom exceeding two or three spruce budworm larvae per collection.

A close relative, the jack-pine budworm, *Choristoneura pinus* Free., has been an intermittent problem on jack pine in northwestern Ontario, and this year heavy infestations were confined to the area around Lawrence Lake, southwest of Dryden.

Eucosma gloriola Heinr., a serious pest of pine plantations in southern Ontario, caused less severe damage than in previous years except on white pine in parts of Bruce County and on jack pine regeneration in the Sudbury area where damage was appraised as severe.

Several other native insects, which are of little importance in natural forests, are demanding serious attention in the management of pine plantations. A high incidence of leader damage to Scots, white, and jack pines by the white pine weevil, *Pissodes strobi* (Peck.), was recorded in southern and central Ontario, and on jack pine and spruces in more northerly areas. Defoliation caused by the red-headed pine sawfly, *Neodiprion lecontei* (Fitch), has been increasing for several years and pockets of severe infestation were reported north from Lake Ontario, east of Georgian Bay, and along the North Channel. Consecutive years of harvesting Christmas trees in the same plantations in southern Ontario created a major insect problem involving the pales weevil, *Hylobius pales* Hbst. Beetles issue from the roots and stumps, feed on the bark of healthy trees, and cause severe "flagging" and branch mortality. Another weevil, the pine root collar weevil, *Hylobius radicis* Buch., killed trees in many Scots pine plantations in Simcoe County and near Parry Sound, Pembroke, and Tweed.

The following five species of colony-feeding sawflies created serious local problems or were abundant over sizeable areas: Swaine jack-pine sawfly, *Neodiprion swainei* Midd.; the jack-pine sawfly, *Neodiprion pratti banksianae* Roh.; *Neodiprion virginianus* complex; *Neodiprion pratti paradoxicus* Ross — all on jack pine — and the balsam fir sawfly, *Neodiprion abietis* complex, on open growing fir trees.

The larch sawfly, *Pristiphora erichsonii* (Htg.), a pest of questionable origin, is included among the native insects because of its lengthy history in Canada as a pest of tamarack. The last major infestations began in northwestern Ontario in the 1940's and later "moved" eastward and southward across central and southern Ontario. Infestations still persist in several European larch plantations in southern Ontario and in some tamarack stands in Bruce and Grey counties. This year, a sharp increase in the numbers of insects and in the degree of defoliation occurred in northwestern Ontario.

On Broad-leaved Trees

The current outbreak of the forest tent caterpillar, *Malacosoma disstria* Hbn., that began in northwestern Ontario and near Sudbury about 1961, has affected a progressively larger area of the Province each year for five years. The total area within which moderate to severe defoliation occurrd increased from 700 square miles in 1961 to 17,300 in 1962, 19,700 in 1963, 29,800 in 1964, and to 38,600 square miles in 1965. The main part of the outbreak occurred in northwestern Ontario, where moderate to severe defoliation of aspen stands occurred from the Manitoba-Ontario boundary to Lake Nipigon and from about Lac Seul southward to the International Border. Many other smaller elements of the outbreak occurred near Elliot Lake, Sudbury, the west end of Lake Nipissing, Muskoka Lakes, and Pembroke.

General forecasts for 1966 based on surveys of overwintering egg bands on host trees, light trap records, and population trends during the past season follow: a marked reduction in defoliation intensities for extreme northwestern Ontario and near Pembroke; considerable increases in the extent and severity of defoliation west and southwest of Lake Nipigon; and an appreciable enlargement of the Elliot Lake and Lake Nipissing infestations.

Two other tent caterpillars were commonly observed in 1965. Population levels of the eastern tent caterpillar, *Malacosoma americanum* (F.), which occurs on roadside shrubbery and black cherry trees, roughly south of a line joining Sault Ste. Marie and Sudbury, were extremely high. The greatest increases occurred within or adjacent to forest tent caterpillar infestations. Meanwhile, small scattered infestations of western tent caterpillar, *Malacosoma pluviale* (Dyar), on scrub cherry and willow occurred north and west of the above line.

Geometers on elm and other hardwoods showed noteworthy population trends. "Cankerworm" damage caused by mixed populations of spring cankerworm, *Paleacrita vernata* (Peck); fall cankerworm, *Alsophila pometaria* (Harr.); and linden looper, *Erannis tiliaria* (Harr.), with the first or second species usually more numerous, has been prevalent in southern Ontario for many years. Over the past three years, population levels of the fall cankerworm and linden looper have been on the wane and in 1965 they both became quite scarce. The spring cankerworm, which was a serious problem in 1964, declined sharply in numbers. Meanwhile, the Bruce spanworm, *Operophtera bruceata* (Hulst), a species that up to 1965 had rarely been recorded in Ontario but was abundant in Quebec in 1963 (Martineau, 1964), caused severe defoliation of maple in three widely-separated areas, Algonquin Park, Great Duck Island in Lake Huron, and north of Sault Ste. Marie.

A widespread and severe outbreak of the birch skeletonizer, *Bucculatrix canadensisella* Cham., that has gradually shifted northward from southern Ontario since about 1956, was centred in northeastern Ontario in 1964, in a broad band extending from the Quebec border to Lake Nipigon. Infestation intensities declined in this area in 1965, and heavy damage was confined to several small areas, but light or moderate skeletonizing of white birch foliage was still extensive.

Introduced Insects

A number of introduced forest insects continued to spread northward in 1965. Figs. 1 and 2 show the range limits of eight of the more important problem species, as determined by intensive and detailed surveys. These are the European pine sawfly, *Neodiprion sertifer* (Geoff.); larch casebearer, *Coleophora laricella* (Hbn.); European spruce sawfly, *Diprion hercyniae* (Htg.); introduced pine sawfly, *Diprion similis* (Htg.); European pine shoot moth, *Rhyacionia buoliana* (Schiff.); smaller European elm bark beetle, *Scolytus multistriatus* (Marsh.); birch leaf miner, *Fenusa pusilla* (Lep.); and the mountain-ash sawfly, *Pristiphora geniculata* (Htg.).

On Coniferous Trees

Damage to Scots, red, and jack pine plantings by the European pine sawfly greatly intensified in southern Ontario for the second consecutive year. Heaviest damage occurred in Bruce, Grey, Dufferin, Simcoe, York, Ontario, Durham, and Norfolk counties where numerous plantations were stripped of needles by mid-June. The discovery of the sawfly on Manitoulin Island, in two widely-separated Scots pine plantations (Fig. 1), represents a considerable advance in the spread of this sawfly that was first found around Windsor in 1939. The extension of distribution is particularly significant in view of recent predictions, based on studies of the cold hardiness of eggs (Sullivan, 1965), that the sawfly will eventually be capable of extending its range into natural stands of jack pine in northern Ontario.

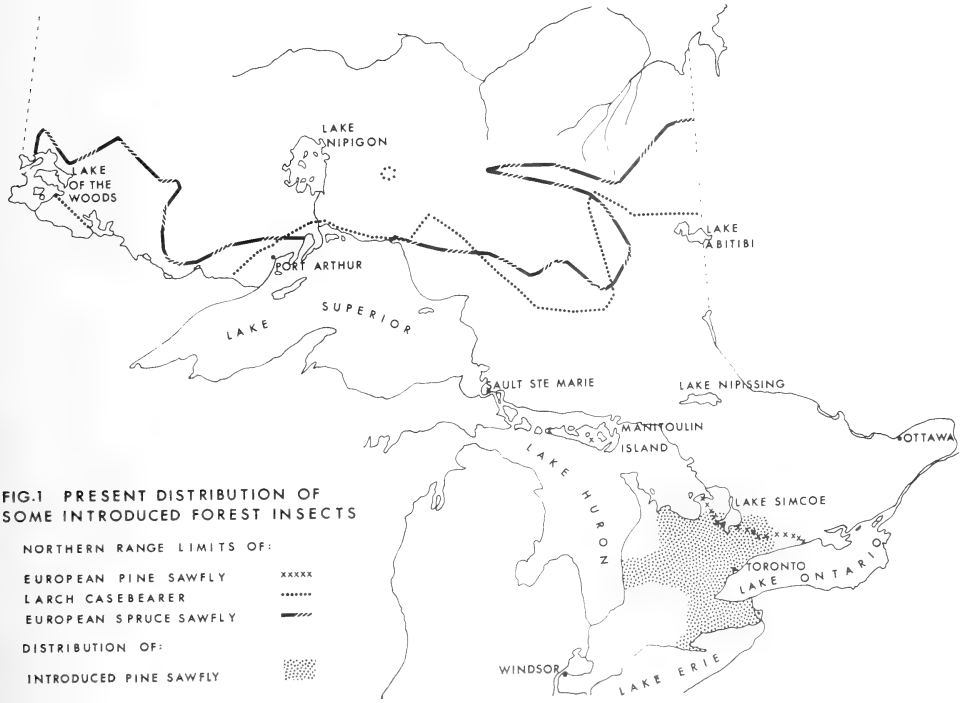

FIG.1 PRESENT DISTRIBUTION OF SOME INTRODUCED FOREST INSECTS

The larch casebearer, first found in Ontario 60 years ago, caused widespread and severe defoliation of tamarack from 1930 to 1952. During the past 13 years, it has remained at levels sufficiently low to be tolerated by forest authorities, but

it has spread northward to the limits shown in Fig. 1. Only three small pockets of heavy infestation were found in 1965, all on European larch near Orono, Newmarket, and Elmira in southern Ontario.

The European spruce sawfly, which earlier created havoc in eastern Quebec and in New Brunswick, is now found in small numbers on spruce across much of northern Ontario (Fig. 1). Generally low population levels, with occasional high numbers of larvae, have typified its occurrence for many years in northern Ontario. Populations are being carefully monitored, but so far no sign of any real threat to spruce in northern Ontario has been indicated.

Another introduced pest that has been carefully suveyed is the introduced pine sawfly in southern Ontario. Minor extensions of range have been detected over a three year period and it is now known to occur from Lake Huron, east to Cameron in Victoria County, and south to Port Burwell on the north shore of Lake Erie (Fig. 1).

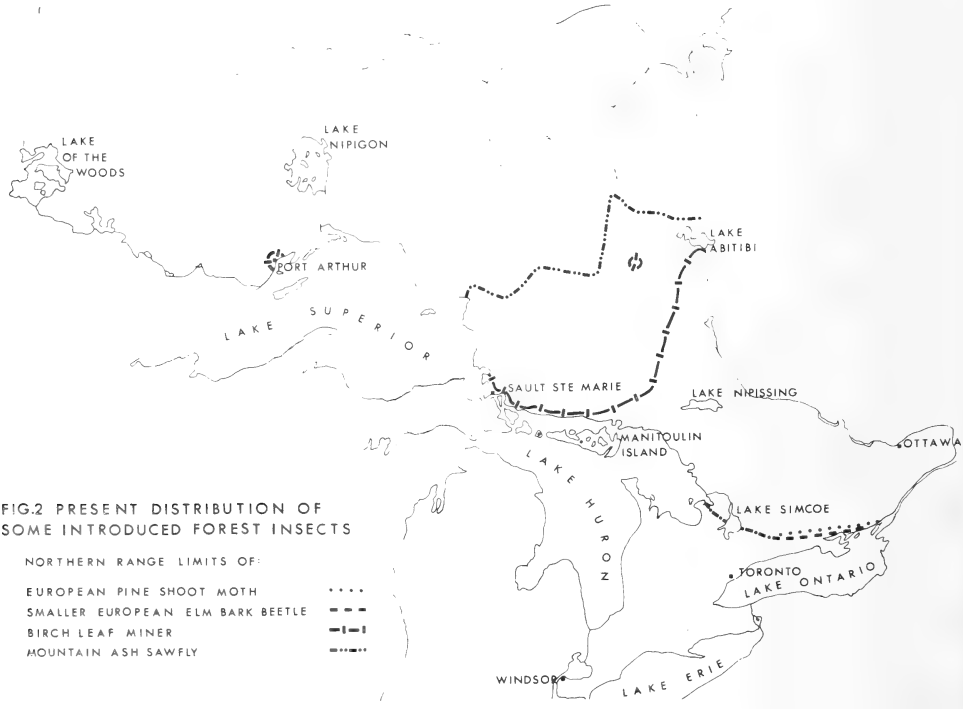

FIG.2 PRESENT DISTRIBUTION OF SOME INTRODUCED FOREST INSECTS

The northern limit of the range of the European pine shoot moth (Fig. 2) seems now to be stable at the —20°F. minimum isotherm as shown by Green (1962). In 1965 severe damage was confined largely to three areas, one in Northumberland County, a second in Mills Township on Manitoulin Island, and a third on Cockburn Island in Lake Huron. Plantations suffering light or moderate damage are still numerous, but the general lowering of population levels over the past decade has greatly enhanced the popularity of red pine in reforestation programs in southern Ontario.

On Broad-Leaved Trees

Of the two bark beetle vectors of the Dutch elm disease in southern and central Ontario, the smaller European elm bark beetle, an introduced species, is the more abundant. Owing to the high rate of elm mortality and the amount of material

in which the bark beetles may breed, extremely high numbers of beetles were again noted in 1965. This beetle now occurs along the north shore of Lake Ontario as far east as Kingston (Fig. 2).

The birch leaf miner has been a persistent problem on white birch in southern Ontario for many years. This year damage to birch foliage was more pronounced in central Ontario than ever before, and the insect shifted northward in the Cochrane and White River areas slightly beyond the range shown by Lindquist (1965), (Fig. 2).

The mountain-ash sawfly also edged northward to the extent shown in Fig. 2. South of this line few mountain-ash trees escaped attack and severe defoliation was commonplace.

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FOREIGN INSECTS THREATENING ONTARIO AGRICULTURE AND FORESTRY

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It has been said that, if early settlers in North America had realized the future significance of plant pests and diseases to the agricultural economy of the country, many of our current food production problems would not have developed. This is also true of present day international travellers as few of them seem to realize the risk involved in bringing back plant material which may be host to some serious plant pest or disease. Many of our imported problems have proved of a more devastating nature than domestic ones which may have been governed to some degree by natural control factors.

Professional entomology in Canada began with surveys for introduced plant pests and the formation of an inspection staff under the Destructive Insect and Pest Act of 1910 did not eliminate the risk of new introductions. Of necessity host plant material was shipped in a dormant state during cool weather and this coincided with a dormant or hibernating stage of their parasites. Moreover, many pests leave their hosts to hibernate and may be transported on products which have no physical relation to the host.

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During the period from 1890 to 1960, twenty-two plant pests of serious economic significance were introduced to North America. This includes only those which are a potential threat to Canadian agriculture or forestry and does not include diseases. Many of these, such as the European corn borer, Oriental fruit moth and pine shoot moth have already cost the country tremendous losses.

Others have a limited distribution within Canada or the United States and present a constant risk of spread to agricultural or forest areas of Ontario.

Japanese Beetle

Popillia japonica Newman

This insect has become a serious pest in eastern fruit-growing states south of the border and is spreading westward in spite of quarantines and containment programs. It was found at Niagara Falls, Ontario in 1940 and since then has been captured in several Ontario cities. Losses in orchards and vineyards have been severe in some states but control applications in Canada have prevented spread and establishment of large populations. Climate undoubtedly presents a limiting influence on distribution but populations great enough to cause skeletonization of all the leaves on backyard grapevines have developed on occasions where treatment has been delayed.

Research on Japanese beetle biology and behaviour under Canadian conditions has not been done, but it appears that it has an annual life cycle. Larval populations are susceptible to chlorinated hydrocarbons and in each of the last four years dieldrin, at the rate of 3 lbs. actual per acre, has been applied to approximately 400 acres of soil in infested cities in southern Ontario. Several infestations have been eradicated and the remainder are surrounded by barriers of treated soil. Approximately 1800 infested acres remain to be treated in Fort Erie, Niagara Falls, St. Catharines and Hamilton. It is also expected that new introductions may occur from time to time but with modern insecticides and continuous survey spread should be limited.

European Chafer

Amphimallon majalis (Razoumowsky)

European chafer adults were observed flying about the top of a lombardy poplar in Niagara Falls in 1959. This was the first record of the insect in Canada. Treatment was applied to soil in the vicinity but surveys were not completed until 1962. By that time approximately 40 square miles were affected, including much of the urban area of Fort Erie. Surveys in 1965 showed that spread to the westward had reached the Welland Canal but had not extended southward beyond the Welland River except for the localized area in Fort Erie.

No containment or eradication program has been put in operation because of limitations to the use of chlorinated hydrocarbons on agricultural land. The larval state is quite susceptible to dieldrin but closely cropped grass is the favoured habitat. Lawns have been effectively treated but pastures or grazing land cannot because of probable contamination of meat and milk.

Pear Sawfly

Hoplocampa brevis Klug.

This insect was first discovered in the Niagara Peninsula in 1964 and this is its only known distribution in Canada. Surveys in 1965 show that it is distributed in most pear orchards in the Niagara Peninsula.

Present spray programs appear adequate to prevent any serious outbreaks in commercial orchards and no eradication program is intended.

Cereal Leaf Beetle

Oulema melanopa (L.)

Of considerable concern to agriculturists interested in cereal production in Ontario is the presence of cereal leaf beetle along the Detroit and St. Clair Rivers in Michigan. This beetle was first discovered damaging crops in the southwestern part of the state in 1962 and has spread rapidly to the north and east. In May 1965, one adult was captured three miles west of Harrow in Ontario, but subsequent intensive surveys throughout Essex County failed to detect any more.

Adults are strong fliers and have been captured at 1000 feet in aeroplane surveys. They probably drift considerable distances during warm weather when convection currents may move them above local winds. Infested fields observed in 1964 and 1965 show that in crops of oats and barley left untreated few plants are likely to reach maturity and feeding of larvae renders the crop useless for fodder or pasture.

Alfalfa Weevil

Hypera postica (Gyllenhal)

The alfalfa weevil was discovered in North America in 1904 at Salt Lake City, Utah but it did not become a major pest in the east until relatively recently. It was first discovered in the New England States in 1952 and has spread rapidly northward to northern Vermont and New York adjacent to the Canadian border. Although no specimens have been captured in Quebec Province it is suspected that it may be present in Huntingdon or Missisquoi Counties because of its known proximity in the United States. It poses an imminent threat to Ontario in both the St. Lawrence region and the Niagara Peninsula.

Gypsy Moth

Porthetria dispar (L.)

The gypsy moth is also threatening Ontario in a similar manner. It is spreading gradually westward in New York and populations great enough to cause considerable defoliation to individual trees have been discovered north of Watertown within a few miles of the Ivy Lea international bridge. The infestation in this area has persisted in spite of concentrated efforts by federal and state authorities.

In 1964 three pupal cases were discovered during inspection of camping equipment used by a Canadian family while visiting in an infested park in the United States. These were located on the undersurface of a house trailer after its return to Brantford, but no trace of any stage of the moth was found at the premises during subsequent surveys.

The gypsy moth will attack almost any hardwood tree and has been known to cause mortality to some stands in the United States through repeated defoliation. It is unlikely to become of economic importance to our timber resources but could have a serious impact on ornamental trees and parklands.

These are a few of the more serious pests which are of immediate concern to agriculture in Ontario. Many others from foreign countries are already established in other parts of Canada or in the United States and some of these will undoubtedly spread to Ontario at some future date unless effective containment programs can be developed for their control.

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HIGHLIGHTS OF HOUSEHOLD INSECTS AND OTHER ARTHROPODS IN ONTARIO IN 1965

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Since environmental conditions in human habitations are, in general, artificially controlled and relatively stable, fluctuations in numbers of strictly household pests are usually limited to local infestations. Any major fluctuatons that may occur from year to year almost invariably involve adventitious pests that invade buildings from outdoors and whose numbers are, therefore, influenced by weather and other variables.

In Ontario, in 1965, an unusual general scarcity, amounting to almost absence, of the Clover Mite, *Bryobia praetiosa* Koch, was certainly a highlight. On the other hand, because of low temperatures and unusual precipitation during late summer and fall, reports of Millipedes and, to a lesser extent, Sowbugs were more numerous than usual in most areas. They invaded garages, basements and even upper floors of buildings. Wasps and Bees, although scarcer than usual in the Chatham area, were more frequently reported in the Ottawa Valley than in any season in memory. The severe early season drouth in the latter area may have been partly responsible. In eastern Ontario, the late summer weather conditions that favored millipedes and sowbugs apparently retarded the outdoor development of Cat Fleas, *Ctenocephalides felis* (Bouché), and Dog Fleas, *C. canis* (Curtis). In most areas the Strawberry Root Weevil, *Brachyrhinus ovatus* (L.), was noticeably scarcer than usual. The Black Carpet Beetle, *Attagenus piceus* (Olivier), usually the most frequently reported household pest in any year, was generally of normal abundance, and the House Centipede, *Scutigera coleoptrata* (L.), normally rather rare, was more numerous than usual. The Saw-toothed Grain Beetle, *Oryzaephilus surinamensis* (L.), continued to be the most common pest of stored foods.

In the Chatham area, inquiries concerning the Boxelder Bug, *Leptocoris trivittatus* (Say), were extremely scarce, compared to outbreak years, and a single inquiry on Powder-Post Beetles created somewhat of a record for this usually numerous pest. In this area, too, inquiries regarding Stored Grain Pests and Spiders were rather less numerous than usual. Ground Beetles, however, invaded buildings in large numbers.

In Ontario, generally, reports of early summer infestations of the Larder Beetle, *Dermestes lardarius* L., were numerous and usually associated with appreciable numbers of hibernating Cluster Flies, *Pollenia rudis* (Fabr.), and/or Face Flies, *Musca autumnalis* De Geer. In eastern Ontario a dirth of inquiries on these pests during the latter part of the season probably indicated poor larval establishment of the cluster fly on earthworms during the unusually dry weather in May and June.

Among the pests of more recent introduction, the Brown-banded Cockroach, *Supella supellectilium* (Serville), and the Brown Dog Tick, *Rhipicephalus sanguineus* (Latr.), are now established in most of the larger urban centres and continue to spread. The European Earwig, *Forficula auricularia* L., well established in most of southwestern Ontario, is now established and spreading in Carleton Place. The Face Fly is generally established and abundant.

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ECONOMICALLY IMPORTANT NEMATODES IN ONTARIO

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Economically the most destructive nematodes in the soils of Ontario are the root-lesion nematode *Pratylenchus penetrans* (Cobb) Filip. and Stek., the root-knot nematode *Meloidogyne hapla* Chitwood, the sugar beet cyst nematode *Heterodera schachtii* Schmidt, the bulb and stem nematode *Ditylenchus dipsaci* (Kühn) Filipjev and the pin nematode *Paratylenchus hamatus* Thorne and Allen.

Pratylenchus penetrans is the most important of the five nematodes because of its wide distribution in Ontario to-day, its wide host range in agricultural and non-agricultural crops (Townshend and Davidson, 1960) and its destructive capacity. The nematode feeds and reproduces in the cortex of roots (Mountain and Patrick, 1959; Townshend, 1963a, b). The resulting necrosis predisposes roots to infection by bacteria and fungi which are frequently more destructive to a plant than the nematode itself. *Pratylenchus penetrans* is a primary incitant in the "rusty" root problem of celery (Townshend, 1962a), in the root-rot complex of strawberry (Townshend 1962b), in the replant problem of peach (Mountain and Boyce 1958 a,b) and in the brown root-rot complex of tobacco (Mountain, 1954).

In the early 1950's *Pratylenchus neglectus* (Rensch) Chitwood and Oteifa was the primary incitant of brown root rot of burley tobacco in Essex and Kent county (Mountain, 1954). During that time *P. penetrans* was found occasionally in flue-cured tobacco in Norfolk county and it was believed then that the nematode caused little damage. Gradually *P. neglectus* declined in numbers until in the late 1950's *P. penetrans* had gained ascendancy in numbers and was the main species involved in brown root rot of both flue-cured and burley tobacco in all three counties. To-day *P. penetrans* is widespread in Ontario and occurs in great numbers whereas *P. neglectus* is found infrequently such as in raspberry in 1965.

It is believed that the hot dry weather of the late 1940's and the early 1950's favoured the development of *P. neglectus* whereas the cooler moister summers of later years have favoured the development of *P. penetrans*. In earlier studies on brown root rot of tobacco, the optimum temperature for the reproduction of *P. neglectus* was over 30°C (Mountain, 1954), while present studies show that *P. penetrans* is very active at 10°C.

Recently the sugar beet nematode *H. schachtii* has created considerable interest in Ontario. Formerly it was believed to be confined to the sugar beet-growing areas of Lambton county (Brown, 1932); however, late in 1964 *H. schachtii* was discovered in the vegetable growing areas near Hamilton and Toronto. The nematode was found wherever rhubarb was grown for the winter rhubarb industry. Red table beet, spinach and cabbage were most severely affected. In one field there was a 40% loss in red beet followed by a 10% loss in spinach. *Heterodera schachtii* may have been introduced into the Hamilton-Toronto area on rhubarb brought in by early English immigrants. In England this nematode is a serious problem. The better clones of these English varieties were occasionally selected for multiplication and distribution by propagators to meet the demands of a newly developing fresh winter rhubarb industry and were reintroduced widely into the Hamilton-Toronto area.

The northern root-knot nematode *Meloidogyne hapla* is destructive to vegetable and ornamentals in the field particularly to carrots. Southern root-knot nematodes such as *M. incognita* do not overwinter in the field in Ontario but survive readily in greenhouses where they are very harmful to tomato and cucumber.

Ditylenchus dipsaci is a problem on onion in the Lemington marsh and *Paratylenchus hamatus* on celery in the Thedford marsh and about Burlington but both only in isolated incidences.

Dagger nematodes *Xiphinema* spp. are potentially very important in Ontario because of their capacity to transmit plant viruses. *Xiphinema americanum* Cobb transmits Tobacco ringspot virus and Tomato ringspot virus (Cadman, 1963), while *X. diversicaudatum* (Micoletzky) Thorne transmits Arabis mosaic virus (Cadman, 1963). Though *X. americanum* and the viruses it transmits are found in Ontario, they rarely occur together and hence they have yet to become a problem. *Xiphinema diversicaudatum* does not occur in the field in Ontario but it is found on roses in greenhouses and the nematode is very destructive to rose.

The needle nematode *Longidorus elongatus* (deMan) Thorne and Swanger, rarely found in Ontario, was discovered on sweet corn in Essex county in 1965. Stubby lateral and feeders roots characterized the affected plants from the areas of stunted corn. Nematodes which were firmly attached were seen feeding on these roots. Only the variety Gold Cup appeared to be affected. The condition may have been aggravated by the great numbers of the root-lesion nematode *P. penetrans* in the roots.

The detection of plant parasitic nematodes and the provision of recommendations for their control requires research as well as extension specialists. These specialists could not be provided entirely by the Canada or Ontario Departments' of Agriculture. Consequently the Ontario Nematode Diagnostic and Advisory Service was established in 1965 on a fee basis. Each department of agriculture provided the necessary personnel. To-day this service provides more effective assistance to the grower than in the past.

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II. INVITATION PAPERS

ESTIMATION OF PATHWAYS OF CARBOHYDRATE METABOLISM IN INSECTS[1,2]

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Enzymatic studies on the metabolism of carbohydrates in insects have revealed the operation of the Embden-Meyerhof pathway of glycolysis and the pentose cycle as the major catabolic routes for the utilization of glucose. In addition, tracer studies utilizing labelled acetate and pyruvate provide evidence supporting the occurrence of tricarboxylic acid cycle for the metabolism of pyruvate and acetate in flies and cockroaches (Chefurka, 1965 a,b). However, information concerning the relative importance of these catabolic pathways of glucose in intact insects is scanty. Wang and his group (1958) have made limited attempts to evaluate the relative contribution of these pathways and have proposed that glucose in male cockroaches is metabolized to an extent of only 4-9% by the pentose cycle; the major catabolic route being glycolysis-tricarboxylic acid cycle.

Over the past few years, our laboratory has invested a considerable amount of effort into the problem of estimation of pathways in insects. Two approaches have been used:

(a) the radiorespirometric method which monitors the yield of $C^{14}O_2$ from variously labelled glucose molecules. The pattern of release of $C^{14}O_2$ with time permits one to make certain conclusions as to the nature of the pathways involved while the yields of $C^{14}O_2$ permit an evaluation of the extent of participation of these pathways (Cheldelin *et al.*, 1962). The method, as used in this laboratory, has already been described (Robinson and Chefurka, 1964). It also has the advantage of providing a continuous time-course record of metabolic events.

(b) the Katz and Wood method (1960) which is based on the fact that the pentose cycle randomizes the C^{14} between carbons-1, and -3 of glucose-6-phosphate or its derivative, glycogen, when glucose-2-C^{14} is metabolized. The extent of randomization may be readily determined by comparing the radioactivity of carbon-1 and carbon-3 relative to that of carbon-2 in glucose residues of hydrolized glycogen.

The data in Fig. 1 give the interval recovery of $C^{14}O_2$ from insects metabolizing specifically labelled glucose. The rapid recovery of much of glucose-3 (4)-C^{14} as $C^{14}O_2$ from both sexes of the cockroach and the milkweed bug suggests that the major pathway for breakdown of glucose is glycolysis followed by pyruvate decarboxylation. The resulting acetate is probably further metabolized by the tricarboxylic acid cycle. This is supported by the fact that the rate of $C^{14}O_2$ production from glucose-2-C^{14} was higher than that from glucose-6-C^{14}. This would

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[2]Summary of paper presented to the 102nd Annual Meeting of the Society in London, September 8, 1965.

Proc. Entomol. Soc. Ont. 96 (1965) 1966

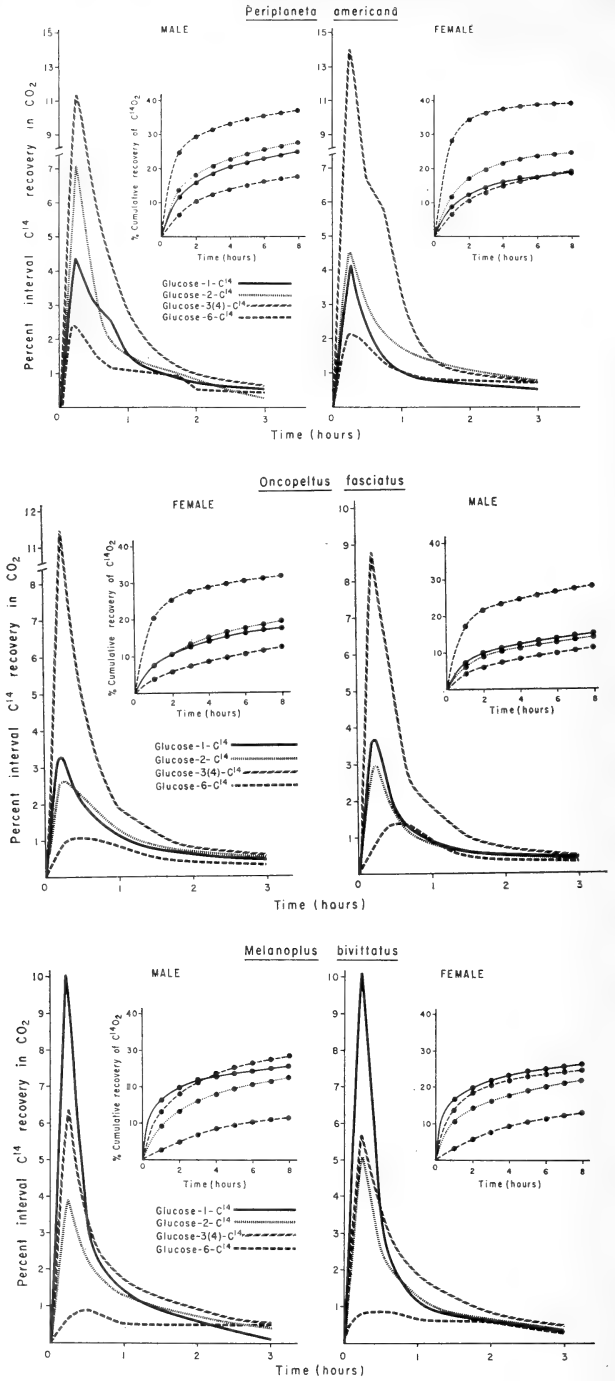

FIG. 1. Interval recovery of respired $C^{14}O_2$ rfom insects metabolizing radioactive glucose. Twenty microliters of labelled glucose (2 μC/ml) were abdominally (between the third and fourth segment on the midventral line) injected into adult insects. Five cockroaches, five grasshoppers and ten milkweed bugs of each sex were used per experiment. Each

curve is an average of at least two runs. The cockroaches were three months old, the grasshoppers about one month after the final nympal molt, while the age of the adult milkweed bugs was not controlled. Glucose-1-C^{14}, glucose-2-C^{14} and glucose-6-C^{14} was obtained from New England Nuclear Corp. while glucose-3(4)-C^{14} was produced biologically by an unpublished method kindly provided by Dr. J. F. Hogg, Queens College, New York.

be expected if one assumed that the C-2 and C-6 of glucose correspond to the carboxyl and methyl groups of acetate respectively and that the operation of tricarboxylic acid cycle would result in a preferential combustion of the carboxyl carbons in the early phases of metabolism. Acetate-1-C^{14} was more rapidly metabolized than acetate-2-C^{14} by both sexes of these three species of insects (Ela *et al.*, unpublished).

That an alternate pathway for the catabolism of glucose exists is also suggested by the preferential recovery of C-1 of glucose in CO_2 as compared with that of C-6. It can be assumed that this is due to the operation of the pentose cycle involving both glucose-6-phosphate and 6-phosphogluconate dehydrogenases. The participation of the later enzyme was inferred from the rapid and almost complete recovery of $C^{14}O_2$ from gluconate-1-C^{14} injected into both sexes of the cockroach (Ela *et al.*, unpublished). Futhermore, comparing the recovery of $C^{14}O_2$ from glucose-1-C^{14} and glucose-3(4)-C^{14} for the three species suggests that the pentose cycle plays a more prominent role in the grasshopper than in either the roach or the milkweed bug. At present, we may only speculate on the physiological significance of this apparently active pentose cycle in the grasshopper. It is worth recalling however, that the chief energy reserve in locusts and grasshoppers is fat. The pentose cycle may be providing reducing equivalents in the form of TPNH for fat synthesis.

The cumulative percentage radiochemical recoveries of $C^{14}O_2$ from glucose-1,-2,-3(4) and -6-C^{14} metabolized by these insects is given in the inserts of Fig. 1. The incomplete recovery of the administered glucose as CO_2 suggests some diversion of the carbons into other components of the cell. An analysis of some of these fractions indicates that about 27% of the glucose was incorporated into trehalose, 3% into glycogen and 18% into acid insoluble constituents at 4 hours after injection of glucose-U-C^{14}.

An estimate of the individual pathways was made by applying these yields to equations derived by Silva *et al.* (1958). Bearing in mind all the assumptions involved in these equations, an approximate estimate of the importance the two pathways in the metabolism of glucose is given in Table I.

The data in Table I suggest that in intact roaches and milkweed bugs 13 to 17% of the glucose is catabolized by the pentose cycle: the bulk of it was dissimilated by the glycolysis-tricarboxylic acid cycle. Very little difference in the activity of this pathway was noted between the sexes of the milkweed bug and grasshopper. However a striking sexual difference was noted for the cockroach where the pentose cycle was more active in the male than in the female. These calculations also confirm that the pentose cycle plays a much more prominent role in the metabolism of glucose in the grasshopper than it does in either the cockroach or milkwood bug.

Attempts were also made to detect the pentose cycle by inhibiting other pathways which may have an obscuring effect on this cycle. The data in Table II show that fluoride, fluoroacetate, and arsenite caused a substantial inhibition of $C^{14}O_2$ production from glucose-6-C^{14} without affecting the metabolism of glucose-1-C^{14}. This is in accord with their well-known inhibition of glycolysis and tricarboxylic acid cycle. More interesting is the fact that the inhibitors, at certain doses, seemed to cause a slight stimulation of the metabolism of glucose-1-C^{14}. These results suggest that the metabolism of glucose-6-C^{14} and glucose-1-C^{14} is mediated

TABLE I. Percent pentose phosphate cycle and glycolysis in insects.

Species	Sex	Percent Gp	Percent GE
Periplaneta americana	Male	16.7	83.3
	Female	2.4	97.6
Oncopeltus fasciatus	Male	13.4	86.6
	Female	16.4	83.6
Melanoplus bivittatus	Male	38.7	61.3
	Female	39.9	60.1

$Gp = \frac{(G_1 - G_6) \times 100}{(G_1 - G_6) + G_{3(4)}}$ = percentage glucose metabolized by pentose phosphate cycle

$GE = 100 - Gp$ = percentage glucose metabolized by glycolysis

G_1, G_6 and $G_{3(4)}$ = percentage cumulative yield $C^{14}O_2$ from glucose-1-C^{14}, glucose-6-C^{14} and glucose-3(4)-C^{14} respectively

All calculations were based on the assumpjtion that the RTU (Cheldelin *et al.*, 1962) was 3 hours. The justification for this value lies in the fact that no evidence of free radioactive glucose could be found in the cockroach at this time suggesting complete cabolism of glucose. Silva *et al.*, (1958) have assumed an RTU of 6 hours. Based on a RTU of 6 hours, the Gp for the cockroach would be decreased by1-2%. The appropriate percentage cumulative yields of $C^{14}O_2$ were obtained from the data in Fig. 1.

by two distinct and independent pathways. The inhibition of glucose-1-C^{14} by cyanide could result from a decreased transhydrogenase-DPNH-oxidase system; the inhibition of the respiratory chain by cyanide presumably accounts for the inhibition of $C^{14}O_2$ production from glucose-6-C^{14}. Iodo-acetate inhibited the metabolism of both glucose-1-C^{14} and glucose-6-C^{14}. This is consistent with the dependence of these pathways on key -SH enzymes (Chefurka 1957). The increase in the yield of $C^{14}O_2$ from glucose-1-C^{14} as well as glucose-6-C^{14} by male roaches treated with 2,4-dinitrophenol suggests that the catabolism of glucose-1-C^{14} is linked to the respiratory chain by perhaps the transhydrogenase system. The stimulation of glucose-6-C^{14} is probably related to the uncoupling action of dinitrophenol. This would make more phosphate acceptor available for substrate-linked phosphorylations.

The data in Table II also permit an assessment of the role of the pentose cycle in glucose metabolism by the C_6/C_1 $C^{14}O_2$ ratios first introduced by Bloom and Stetten (1953) and Bloom *et al.* (1953). Although this approach to the estimation of pathways is complicated by many variables (Wood *et al.*, 1963) it is generally believed that a C_6/C_1 $C^{14}O_2$ ratio of unity indicates the participation of only glycolysis while a ratio of less than unity suggests the presence of the oxidative portion of the pentose cycle, i.e. the oxidation of glucose-6-phosphate to pentose-5-phosphate and CO_2. The data in Table II indicates a C_6/C_1 $C^{14}O_2$ ratio of near unity for the females and considerably less than unity for the males. This suggests that the pentose cycle plays a more prominent role in the male than in the female in the dissimilation of glucose; a conclusion already established by a direct quantitation of the pathways (Tables I and III). Hence, although these early attempts at pathway estimations employing the C_6/C_1 ratios were based on premises which are no longer tenable (Wood *et al.*, 1963) the C_6/C_1 $C^{14}O_2$ ratios may serve as a useful qualitative guide to the extent of participation of the pentose cycle.

The occurrence of the pentose cycle is accentuated in the presence of inhibitors of glycolysis and/or the tricarboxylic acid cycle. Thus the effect of fluoride,

TABLE II. Effect of metabolic inhibitors and uncoupling agents on glucose metabolism

Compound Injected		Percent conversion of labelled glucose to $C^{14}O_2$ from G-6-C^{14}	G-1-C^{14}	C_6/C_1
None (female)		20.5	21.5	.95
NaCN	50 μg	8.9	16.4	.55
	100 μg	8.1	14.2	.57
NaF	400 μg	12.7	22.9	.53
	800 μg	6.8	20.4	.33
Fluoroacetate	200 μg	15.9	22.7	.70
	400 μg	10.1	19.0	.53
Iodoacetate	250 μg	9.9	13.0	.77
Arsenite	25 μg	18.2	29.8	.61
	50 μg	11.2	27.0	.41
None (male)		18.0	30.0	.60
2,4-Dinitrophenol	25 μg	51.0	61.0	.84
	50 μg	59.0	60.0	.98
	100 μg	54.0	59.0	.92

The roaches were abdominally injected as in Fig. 1, with 20 microliters of aqueous inhibitor solution except dinitrophenol which was applied topically as an acetone solution. Thirty minutes later the insects were reinjected with 20 microliters of labelled glucose solution (2 μC/ml). All values are yields of $C^{14}O_2$ at 6 hours after injection of glucose.

fluoroacetate and arsenite was to decrease the C_6/C_1 ratio to values considerably below unity. Clearly this was due more to the inhibition of catabolism of glucose-6-C^{14} than stimulation of glucose-1-C^{14}. The net result, however is that in relative terms, more glucose was metabolized by the pentose cycle without necessarily stimulating its activity.

The data in Table III suggests that the C-2 of glucose was more extensively randomized during its incorporation into glycogen in the male than the female roach. These randomized patterns of C^{14}-glycogen correspond to a contribution by the pentose cycle of about 20-22% in the male and 2-5% in the female. This estimate is in good agreement with that arrived at by the radiorespirometric method (Table I) and C_6/C_1 $C^{14}O_2$ ratios (Table II). The randomization increased in the male with time more rapidly than in the female. Thus after 6 hours injection, 81% of the radioactivity was found in C-1 and 38% in carbon-3. By contrast the percentage distribution of the radioactivity of C-1 and C-3 in the females increased by only 1 and 2% respectively. (Ela *et al.*, unpublished). In this experiment the percentage recovery was 93.0 percent suggesting that the low recovery of 60.7% in the experiment reported (Table III) could not account for the difference in the distribution of the C-1 and C-3 radioactivity between the sexes. The preponderance of radioactivity in C-1 over that of C-3 in the male suggests the participation of the following reactions in the pentose cycle catalyzed by transketolase (TK) and transaldolase (TA):

$$2(C^*\text{-}C\text{-}C\text{-}C\text{-}C) \xrightarrow{TK} (C^*\text{-}C\text{-}C^*\text{-}C\text{-}C\text{-}C\text{-}C) + (C\text{-}C\text{-}C) \xrightarrow{TA} (C^*\text{-}C\text{-}C^*\text{-}C\text{-}C\text{-}C\text{-}C) + (C\text{-}C\text{-}C\text{-}C\text{-}C) \quad (1)$$

$$(C^*\text{-}C\text{-}C\text{-}C\text{-}C) + (C\text{-}C\text{-}C\text{-}C) \xrightarrow{TK} (C^*\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C\text{-}C) + (C\text{-}C\text{-}C) \quad (2)$$

The equal distribution of the label in C-1 and C-3 in the hexose residues of glycogen isolated from females suggests that reaction (2) is either absent or relatively inactive.

This account represents a summary of work which will be reported in detail shortly. The productive collaboration of Dr. J. R. Robinson, Dr. Y. Horie, Dr. R. Ela, Mr. S. T. Bajura and Mr. H. Rode is acknowledged. Part of this summary was taken from a Ph.D. dissertation by Dr. Ela prepared in this laboratory and submitted to the Faculty of Graduate Studies, University of Western Ontario, London, Ontario. The degradations of C^{14}-glucose units of glycogen were performed by Mr. W. Hollis, Department of Biochemistry, Western Reserve University.

TABLE III. C^{14} in glucose residues of glycogen on injection of roaches with glucose-2-C^{14}

	Male		Female	
Carbon Number	% activity	% Distribution C_2=100	% activity	% Distribution C_2=100
1	19.7	31.4	3.3	4.1
2	62.5	10.0	81.5	100
3	10.6	16.9	4.1	5.0
4	.85	1.4	0.42	0.50
5	4.9	7.8	9.5	12.1
6	1.4	2.2	0.93	1.1
Recovery %	85.6	—	60.7	—

	$\frac{C_1}{C_2} = \frac{2PC}{1 + 2PC}$	$\frac{C_3}{C_2} = \frac{PC}{1 + PC}$
Female	$.041 = \frac{2PC}{1 + 2PC}$	$.050 = \frac{PC}{1 + PC}$
	PC = 2.1%	PC = 5.3%
Male	$.314 = \frac{2PC}{1 + 2PC}$	$.169 = \frac{PC}{1 + 2PC}$
	PC = 22.8%	PC = 20.3%

Twenty microliters of glucose-2-C^{14} (25 μC/ml) were injected abdominally into 10 male and 10 female 3 month-old roaches. After one hour, the roaches were anaesthetized, minced into 0.1N KOH solution and thoroughly homogenized in a glass-Teflon homogenizer (2-3 mm clearance). This was filtered through cheesecloth and after several washings of the solid residue, the combined filtrate was digested in 30% KOH for 30 minutes in a boiling water bath. The glycogen was isolated and purified by repeated precipitation with ethanol in the presence of sodium sulfate and solution in water (Hassid and Abraham, 1957) as well as by dialysis at 2° for 60 hours. It was hydrolyzed in 0.167N H_2SO_4 for 48 hours. The resulting solution was made slightly alkaline, decolorized with charcoal and deionized by passing through a cation (Rexyn 102 in the H^+ form) and anion (Rexyn RG3 in the OH^- form) exchange columns. The final effluent was reduced under vacuum to an amorphous glucose residue which was degraded with *Leuconostoc mesenteroides* (Bernstein and Wood, 1957). The above table records the percentage distribution of C^{14} activity of the carbons of glucose residues of glycogen.

$$\text{The percentage recovery} = \frac{\Sigma C^{14}_{1-6}}{\text{Total } C^{14}} \times 100$$

The percentage of glucose metabolized *via* the pentose cycle (PC) from the C-1 to C-2 and C-3 to C-2 ratios (Katz and Wood, 1960) are also recorded.

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HORMONAL CONTROL OF CARBOHYDRATE METABOLISM IN INSECTS[1]

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During the past fifteen years the field of insect biochemistry has reached a state of maturity approaching that of vertebrate biochemistry. Unfortunately insect endocrinology does not share the same happy state of affairs although much work has been done and still is being done in the field of endocrine control of growth and development. There has been almost total neglect of that area of endocrinology dealing with hormonal control of metabolism. This is indeed strange in the light of the interesting and important advances which have been made in the vertebrate field. It is even more difficult to understand when one considers that the necessary biochemical and physiological knowledge is already at hand.

The study of carbohydrate metabolism in insects has in recent years produced many interesting observations, not the least important of which is the discovery that the principal blood sugar is the disaccharide trehalose rather than glucose as

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in the vertebrates. This represents a pathway in the insect which is not found in the mammal. Trehalose is usually present in the blood in very high concentration. Candy and Kilby (1961) have shown that the synthesis of this sugar in the locust takes place mainly in the fat body which is the insect tissue generally thought to be analogous to the mammalian liver. The synthesis of trehalose involves the participation of uridinediphosphoglucose (UDPG) which in the presence of trehalose synthetase transfers the glucose moiety of UDPG to glucose-6-phosphate to yield trehalose-6-phosphate. This is dephosphorylated by a specific phosphatase, the localization of which is not known. The rather slow penetration of cell membranes by phosphorylated compounds coupled with the fact that most, if not all, of the trehalose in the haemolymph appears to be in the non-phosphorylated form favours the fat body as the site of localization of this enzyme. In general it is thought that the conditions which occur in the cell do not favour the synthesis of glycogen via phosphorylase. It has recently been shown that glycogen synthesis in the cockroach, in common with many other organisms, is by means of glycogen synthetase (Vardanis, 1963). This enzyme, like trehalose synthetase, utilizes UDPG as the donor of glucose which it transfers to existing glycogen chains.

Under normal conditions glucose is supplied to the blood of mammals as a result of glycogenolysis in liver giving rise to glucose-6-phosphate. This is dephosphorylated by glucose-6-phosphatase to yield glucose which in turn diffuses into the blood. In the insect, on the other hand, the glucose-6-phosphate is not dephosphorylated but serves as a substrate for trehalose synthesis which, as already mentioned, requires UDPG as does the glycogen synthetase reaction. Herein lies a most interesting problem in metabolic control, not only because both reactions require UDPG but because of the central position occupied by glucose-6-phosphate and glucose-1-phosphate, the latter being required for the synthesis of UDPG.

We may inquire, therefore, into the nature of this control mechanism. Why is synthesis of glycogen favoured at one time but degradation at another? Undoubtedly this may be influenced by changes in enzyme concentration, which is itself subject to regulation, substrate concentrations and metabolic feedback mechanisms. However, the possibility that there is a mechanism of hormonal control is an interesting one. The hormonal regulaton of blood sugar in higher animals by the endocrine pancreas and pituitary-adrenal mechanisms is now well established and provides an incentive to seek hormone-regulated metabolic pathways in the insect.

In view of the fact that earlier studies had shown neurosecretory cells of the pars intercerebralis of the brain and the corpora allata to be involved in moulting and metamorphosis, it is perhaps not surprising that these endocrine organs should be selected first for studies on possible mechansms of hormonal control of metabolism. L'Helias (1955) showed that removal of the corpora allata from the stick insect, *Dixippus*, resulted in a lowering of blood glucose and at the same time an increase in the tissue level of this sugar. One might infer from these results an insulin-like action for the corpora allata in which the transfer of glucose from blood to tissues is facilitated. McCarthy and Ralph (1962) have claimed an opposite function for the corpora allata in the cockroach, *Periplaneta americana* (L.). Using the same insect, Steele (1961) was unable to show any effect by the corpora allata on blood glucose and it is perhaps noteworthy that Bowers and Friedman (1963) using the cockroach, *Blaberus discoidalis* (Serville), were also unable to show any effect by corpora allata on blood glucose. The increase in blood sugar claimed by McCarthy and Ralph as being due to the injection of corpora allata extract may have another explanation. Their use of Glucostat for glucose determinations must also be considered. This is a glucose oxidase preparation used clinically for the determination of glucose. We have observed that it is contaminated

with trehalase which therefore precludes its use in the determination of insect blood sugars. Needless to say the possibility that the corpora allata regulate in some way the level of circulating glucose ought to be reinvestigated using more refined techniques than those used in the past.

The neurosecretory cells of the pars intercerebralis are usually assocated with the brain hormone which is responsible for initiating the moult. The studies by Thomsen (1952), however, show that a factor produced by these cells in *Calliphora* has general metabolic effects. If these cells are removed, glycogen accumulates in the fat body and the deposition of yolk in the eggs ceases. The interference in yolk development signifies an interruption in protein synthesis whch may be under the control of a factor produced by the neurosecretory cells. If this were so, then carbohydrate which is normally used to supply energy for the synthesis of protein might accumulate in the fat body as glycogen. An alternative explanation is that the factor contained in the neurosecretory cells is required for the utilization of glycogen and that in its absence glycogen will accumulate. Recent work by Van Handel and Lea (1965) indicates that the latter alternative may be closer to the truth. They have been able to show that removal of the neurosecretory cells in three species of *Aedes* has no effect on the utilization of glycogen or triglycerides. On the other hand, synthesis of these materials is greatly modified by the presence or absence of the neurosecretory cells. When the cells are present, there is preferential synthesis of the triglycerides where as in their absence synthesis of glycogen predominates. It will be most interesting to determine whether similar effects are found in other insects.

The effects of insulin and adrenalin on the level of blood glucose of vertebrates are well known. It is perhaps not surprising therefore, that the investigator using insect material should look for tissues or organs which are capable of modifying the concentration of sugar in the blood. We began our work shortly after trehalose had been shown to be the principal blood sugar in insects. We were therefore presented with an opportunity unavailable to the earlier workers. The initial experiments were an attempt to show that blood trehalose concentration could be altered by various gland extracts. The corpus cardiacum which was investigated because of its analogy to the crustacean sinus gland which Abramowitz *et al* (1944) had shown to contain a hyperglycaemic factor. Our assumptions proved to be correct as the extracts did indeed contain a hyperglycaemic principle (Steele, 1961).

These results have been verified for *Periplaneta* by Ralph and McCarthy (1964) and by Bowers and Friedman (1963) using *Blaberus*. Steele (1961) was unable to show any effect of cardiaca extracts on blood glucose and this result was also confirmed by Ralph and McCarthy (1964). However, Bowers and Friedman (1963) using purified trehalose in conjunction with a highly purified glucose oxidase system were able to demonstrate an increase in blood glucose following injection of cardiaca extracts into *Blaberus*.

Ralph and McCarthy (1964) have shown an increase in blood trehalose in response to brain extracts so that a neurosecretory cell origin of the active principle does appear possible. Should this prove to be the case then the corpora cardiaca would represent a storage-release organ for the hyperglycaemic hormone. In addition to the corpora cardiaca, Steele (1961) assayed nerve cord, brain, muscle and corpora allata for hyperglycaemic activity with respect to trehalose with negative results for all but the corpora cardiaca and the corpora allata. It was originally suggested that it was residual cardiaca tissue, which is impossible to remove from the allata, that was responsible for the hyperglycaemic activity demonstrated. It has been estimated that, if the greatest care is taken in removing the allata, 5% of the cardiaca tissue will remain attached but where large numbers

of glands are being removed on a production line basis 15% or more may be a realistic figure. Scharrer (1962) has in fact shown that cardiaca tissue pentrates the allata and that it is impossible to completely separate the two. Dilution studies, however, showed that the amount of active material contained in the corpora allata was considerably less than that in the corpora cardiaca (Steele, 1963b). There still remained the possibility that the hyperglycaemic activity associated with the corpora allata was due to a different material. However, evidence obtained from chromatography did not support the idea of a second material in the corpora allata. This data has been interpreted as meaning that the activity associated with the corpora allata is due to the small amount of cardiaca tissue which cannot be removed from the allata.

The most obvious source of the additional trehalose observed in the blood of cockroaches after treatment with hyperglycaemic hormone would be glycogen, the major reserves of which are found in the fat body and thoracic musculature. Steele (1963a) has shown that the hyperglycaemic hormone can invoke a profound decrease in the concentration of fat-body glycogen which bears an inverse relationship to the change in blood trehalose. Bowers and Friedman (1963) have confirmed our observation that fat-body glycogen is the principal carbohydrate reserve acted upon by the hyperglycaemic hormone. The fat body, however, is not the only tissue affected by the hormone, as the nerve cord responded in a similar manner (Steele 1963a). Of no little significance is the lack of effect of the hormone on muscle glycogen which is reminiscent of the action of glucagon in the mammal.

The studies of Sutherland and Cori (1951) on dog liver have shown that adrenalin and glucagon exert their effect by increasing the amount of active phosphorylase. This is the rate limiting step on the pathway from glycogen to glucose. It appeared likely, therefore, that the insect hormone might also exert its effect by causing a conversion of inactive phosphorylase to the active form within the fat body. Treatment of cockroach fat body *in vitro* with hyperglycaemic hormone results in appreciable increases in the amount of active phosphorylase (Steele, 1963a) thus helping explain the hyperglycaemic effect. The effect on phosphorylase by adrenalin and glucagon is apparently mediated by the nucleotide cyclic 3,5-AMP whose synthesis is stimulated by the hormones (Rall and Sutherland, 1958). Although cyclic 3-5-AMP has been reported in fly larvae (Sutherland *et al,* 1962), attempts to demonstrate an increase in the cockroach in the presence of the hyperglycaemic hormone have been unsuccessful. However, the fact that synthetic 3,5-AMP will stimulate phosphorylase activity in intact isolated fat body suggests that it may also be involved in hormonal activation of the enzyme (Steele, 1963b).

The rate-limiting enzyme on the pathway from glycogen to glucose-6-phosphate is phosphorylase. This enzyme is thought to be activated in an indirect manner by the hormone resulting in an increased synthesis of glucose-6-phosphate. It is difficult to imagine a system in which both glycogen synthesis and degradation are not in some way linked so that only one system predominates at a given time. Steele (1963a) using *Periplaneta,* obtained evidence that when glycogen synthesis is proceeding at a moderate rate there is inhibition of the phosphorylase system. There is evidence, therefore, that glycogen synthesis and degradation are integrated by an unknown mechanism which dictates that both shall not operate to oppose each other.

In a recent paper by Wiens and Gilbert (1965) evidence is presented that the hyperglycaemic hormone may have sites of action other than at phosphorylase. They found that fat body of *Leucophaea maderae* (Fabr.) treated with cardiaca

extract had a lowered R.Q. indicating increased oxidation of fat rather than glycogen which at this time is converted into trehalose. These studies point to an inhibition of glycolysis, possibly at phosphofructokinase, or an activation of the glycogen synthetase system.

It is possible that there is yet another hormone regulated mechanism controlling the utilization of glycogen. It has long been known that the brain is necessary for the completion of normal pupal development. In the silkworm, *Bombyx mori* L., Ito and Horie (1957) have shown that normal pupal development is accompanied by a decline in the glycogen reserve. If the brain is removed or a ligature is placd around the metathoracic region, pupal development does not proceed and the pupa lapses into a diapause-like state. With the onset of this condition there is no decrease in glycogen content. Superficially it would appear that the brain is necessary for the utilization of glycogen. However, if an active prothoracic gland is implanted into the abdomen, pupal development proceeds normally with the usual decrease in glycogen (Ito and Horie, 1957). Ito and Horie therefore suggest that the ecdysone produced by the prothoracic glands, in addition to its well known effects on development, also activates the glycolytic enzymes. There is, however, the possibility that the effect on glycogen utilization is an indirect result of a primary developmental action of the hormone.

There is now some evidence that the synthesis of glycogen, in addition to its utilization, may also be under hormonal control. In the silkworm, *Bombyx mori* L., it is the egg which undergoes diapause. The occurrence of diapause in the eggs is dependent upon the production of a diapause hormone by the suboesophageal ganglion of the female. Yamashita and Hasegawa (1964) have shown that ovaries which are destined to produce diapause eggs have almost 50% more glycogen than those that produce eggs which will not enter diapause. This increased ovary glycogen appears to result from the action of the diapause hormone. During pupal development there is a decline in total glycogen but at the same time the amount of glycogen in the ovaries increases. If, in those pupae which are destined to produce diapause eggs, the suboesophageal ganglia are removed the increase in ovary glycogen is severely reduced and there is an accompanying increase in the level of total blood sugars. It thus appears that one function of the diapause hormone is to facilitate the transfer of blood sugars to the ovary or to activate the glycogen synthetase system in that tissue. The ovary appears to be the only tissue affected. The role of the diapause hormone in the developing male pupa is not so evident. Removal of the suboesophageal ganglion does not result in increased blood sugars as it does in the female but, on the other hand, male pupae, which have received ovarian transplants as larvae, respond to the removal of the suboesophageal ganglion in the same manner as do female pupae.

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III. SUBMITTED PAPERS

A COMPARATIVE STUDY OF THE ALIMENTARY CANAL OF ADULT CALYPTRATE DIPTERA[1]

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Introduction

Comparative morphology is, on the whole, the most productive source of phylogenetic information and classification. Since Linnaeus (1758) classified insects upon the characters afforded by mouth parts and wings, the search for an adequate basis of classification of insects has continued. This has led to extensive comparative studies of the various organ systems of insects. Particularly, many authors have contributed much to the study of the order Orthoptera and have derived therefrom schemes to show the phylogenetic relationship among the various groups in that order (Judd, 1948).

The order Diptera, and particularly the group Calyptratae of the sub-order Cyclorrhapha, has attracted little attention with respect to comparative anatomical studies, although its classification poses many problems. No two authorities on this group of flies agree either as to the number of families that should be recognized or as to the limits of certain families that are generally recognized. This may be attributed to the fact that this group of flies is of recent origin and the different types included in it have not been segregated by the dropping out of intermediate forms (Essig, 1956).

In order to visualize the disagreement concerning the natural classification of Diptera one may consult those text-books of entomology which are generally consulted by students of entomology and note the varying number of families listed under the group Calyptratae. Comstock (1950) has divided this group into nine families, Essig (1956) arranged them into twelve families and Imms (1957) has put them into four families only. Similarly, Ross (1956) and several others have dealt with this group differently.

The present work was undertaken to elucidate some of the taxonomic differences of the group Calyptratae using the characters afforded by the internal organs, and to investigate the comparative morphology and histology of the alimentary canal and its associated organs in this group of flies. *Euxesta notata* Wied. has also been included in this investigation as it belongs to the family Otitidae, in order to compare its internal anatomy wth that of calyptrate flies. Roback (1951) has suggested, on the basis of the external characters of adults and larvae of Calyptratae, that this group must have evolved from some ancestral forms like otitids or the helomyzids of the group Acalyptratae. The family Anthomyiidae, which is considered by Roback (1951) as the most primitive of the Calyptratae, has least deviated from its ancestral forms.

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Review of the Literature

System of Classification

The literature on the group Calyptratae is large and widely scattered. However, the main points used in elucidating the taxonomic differences are here discussed, in dealing with the long history of classification of this group. The history of this classification dates back to Linnaeus (1758) who, in the 10th edition of his "Systema Naturae", divided the order Diptera into ten genera based upon the characters afforded by their mouth parts. Three of these, viz. *Conops, Musca* and *Oestrus,* when grouped together, correspond roughly to the present sub-order Cyclorrhapha. Each of these divisions contained calyptrate species. The largest genus, *Musca,* also contained species of Syrphidae. Now the Syrphidae are grouped under section Aschiza of sub-order Cyclorrhapha. Stratiomyiidae and Bombyliidae are now included in the sub-order Brachycera. Linnaeus further divided *Musca* into five different groups on characters afforded by the arista, and was thus able to separate certain calliphorids and *Musca* species in which the arista is plumose from some tachinids and anthomyiids in which it is bare.

Harris (1776), on the basis of wing venation of flies known to him, divided Linnaeus' *Musca* into five orders. Duméril (1801) divided the order Diptera into four families on characters of the mouth parts, recognizing twenty-one genera. Meigen (1803, 1826, 1838) introduced the size of the squama as a basis for separating certain genera of flies with abbreviated squama now considered as Acalyptratae. He also made use of the bend in the fourth vein to separate anthomyiid flies from other muscoid groups. Latreille (1805) first subdivided the order Diptera on the basis of habit and immature stages as well as upon adult characters. His first group was called Proboscidea, his second Eproboscidea and his third Phthiromyiae, and these were further divided into fifteen families. Fallen (1814-1820) noted the presence of oral vibrissae in Calyptratae and their usual absence in Acalyptratae. Robineau-Desvoidy (1830, 1863) may be called the first specialist on this group of flies and he used a wide range of characters of the ptilinum, head, sclerites, bristles and simple proportions and differences in venation. He established the artista as having evolved from the fourth and the terminal antennal segment of Nemocera. In his attempt to develop a natural classification he endeavoured to make use of larval habits. Meigen (1838) noticed that the transverse mesonotal suture is present in calyptrate flies.

At the end of the 19th century the discovery of the constant arrangement of the bristles within the species of this group by Mik (1878) and Osten-Sacken (1881, 1884) gave rise to chaetotaxy. The combination of characters of bristling with those previously used provided an arrangement of genera and species which is somewhat similar to that now in common usage. Mik (1878) proposed the first system for classifying bristles of the legs of this group of flies. This system was elaborated by Osten-Sacken (1903), while Grimshaw (1905) later proposed an almost similar system independently of Mik (1878), and Osten-Sacken (1881, 1884) noted that the arrangement of the bristles on the bodies of flies could be used as a means of classification and his system is used by most dipterologists at the present time. Owing to their prominence, such bristles were often mentioned by Fallen (1814-1820), Robineau-Desvoidy (1830, 1863) and others as "macrochaeta". Osten-Sacken termed the system "Chaetotaxy". He noticed that calyptrate flies have a row of bristles across the hypopleura and that the acalyptrate flies do not have such a row of bristles.

Girschner (1893) proposed for this group a new system of classification which more nearly approaches our modern concept than does any previous system. Using a wide variety of characters, he divided Calyptratae into Anthomyiiden and

Tachiniden. The Anthomyiiden correspond roughly to the super-family Muscoidea of Roback (1951) and Tachiniden correspond to the super-family Oestroidea plus the Sarcophagoidea of the same author. Girschner (1893) was the first to recognize the calliphorids as a distinct group and grouped them under the sub-family Calliphorinae, a grouping retained till recently by most European workers. Williston (1908) removed the family Cordyluridae from Girschner's Calyptratae and placed it in the Acalyptratae.

After Williston many workers such as Parker (1914), Aldrich (1916), Boyes (1956), Malloch (1917, 1919, 1923), Shannon (1923, 1924, 1926), Séguy (1923, 1928, 1937, 1941), Allen (1926), Roback (1951), Townsend (1892, 1914, 1917, 1935-1942), Zumpt (1952, 1956, 1957, 1958a, b) and Zumpt and Patterson (1953) worked on various groups within the Calyptratae as a whole and added more characteristics at different levels and published revisions of the families.

Roback (1951) coordinated the study of both adults and larvae of Calyptratae and then re-examined the present-day classification. His results and classification are based on the characters afforded by both larvae and adults, and have involved a shifting in the ranks of some groups.

Internal Anatomy

The use of internal characters has been restricted to a few cases, e.g. where Townsend (1914) has made use of internal organs. Organs such as the alimentary canal and its associated organs, the internal reproductive organs of male and female, the heart and nervous system have been used only slightly in flies. According to Walker (1922) "in any attempt to unravel the relationships of a group of organisms it is obvious that the entire structure of the body should be taken into account".

General works on the internal anatomy of adult Diptera are few, but some information is to be found in the writings of Ramdohr (1811), Loew (1841), Dufour (1844, 1851), Chun (1876), Cholodkovsky (1892, 1900, 1905), Tichomirow (1898), Pratt (1899), Patton & Cragg (1913), Miyake (1919), Cognetti de Martiis (1924), Sturtevant (1925, 1926), Adler and Theodor (1926), Roberts (1927), Kobayashi (1934), Faasch (1935), Smart (1935), Miller (1950), Mukerji and Sen-Sarma (1955), Okada (1954a, b), Megahed (1956), Snodgrass (1959) and Christophers (1960).

Among these workers Dufour (1844, 1851) did extensive work dealing with the anatomy, physiology and life cycles of Diptera as a whole. Snodgrass (1959) has dealt with the anatomy of the various stages of mosquitoes. Christophers (1960) has investigated *Aedes aegypti* (L.), the yellow fever mosquito.

The group Calyptratae has been relatively more investigated than the other groups of Diptera. However, the number of species investigated in this large group is relatively small. The first major anatomical monograph on Calyptratae was published by Lowne (1893-1895) in two volumes on *Calliphora erythrocephala* (L.) with considerable detail on physiology and development. The next outstanding work was carried out by Hewitt (1907, 1914) on the internal anatomy and life-cycle of *Musca domestica* L. In the beginning of the twentieth century descriptions of the internal organs of several species of flies were given by several others besides Hewitt, such as Berlese (1902), Holmgren (1903), Minchin (1905), Tulloch (1906), Cholodkovsky (1905), Townsend (1935-1942), Pantel (1914), Patton and Cragg (1913) and Prell (1914), but the numbers of species treated in those papers are few. Among the workers mentioned above, Prell (1915) was an

outstanding contributor, writing on the female internal sexual organs of tachinids. Recently West (1951) and Catts and Garcia (1963) investigated the internal anatomy of *Musca domestica* (L.) and *Cuterebra latifrons* (Coquillet) respectively.

Contributions to the comparative anatomy of the internal organs, viz. heart, alimentary canal and its associated organs and reproductive systems of male and female adult Diptera are very few. Among the earlier workers, reference may be made to Dufour (1851) who investigated the comparative anatomy of six European species belonging to the family Asilidae, but other than his work the publications that include descriptions of the internal anatomy of adult flies have for the most part dealt with only certain organs. Townsend (1935-1942) studied the comparative anatomy of the female reproductive system of a considerable number of muscoid flies, but his works have only a few illustrations. Okada (1954a, b) studied the comparative morphology of the internal organs of the drosophilid flies in considerable detail. Recently Hori (1960, 1961, 1962a, b) published on the comparative anatomy of the internal organs of adult Calyptratae, dealing with the male and female internal sexual organs, alimentary canal and Malphighian tubules of the adult flies. His study includes 83 species belonging to eight different families and 38 genera. The familes Calliphoridae, Sarcophagidae and the sub-family Muscidae have been treated in considerable detail, whereas Anthomyiidae, Phasiidae, Dexiidae and Tachinidae are considered to a lesser extent. There is no account of species belonging to the families Hypodermatidae, Oestridae, Cuterebridae and Glossinidae.

The histology of Diptera has been scantily studied. Among the few authors, Wigglesworth (1929) studied the histology of the alimentary canal of the tsetse fly and Graham-Smith (1930, 1934) studied the morphology and histology of the internal organs of *Calliphora erythrocephala* (L.) with special reference to the musculature. Later, Jones (1942), Dixon (1952) and Megahed (1956) contributed to the morphology and histology of the alimentary canal of *Pollenia rudis* (Fabricius), *Hylemya brassicae* (Bouché) and *Culicoides nubeculosus* Meigen respectively. Concerning the comparative histology and morphology of several of the internal organs of adult flies, one published account is that of Owsley (1946) on four species in the family Asilidae, including the dorsal vessel and related organs, the digestive tract and its associated organs and the male and female reproductive organs.

Alimentary canal

The insect alimentary canal and its associated organs are derived from two different embryonic layers of the insect embryo, the ectoderm and endoderm. The whole digestive tract, extending from mouth to anus, is made up of three regions: i) *Stomodaeum* or fore-gut, which is ectodermal in origin, ii) *Mesenteron* or mid-gut, which is endodermal in origin, iii) *Proctodaeum* or hind-gut, which is ectodermal in origin. The stomodaeum and proctodaeum are ectodermal invaginations which join the mesenteron during the early embryonic development of the insect. Being ectodermal in origin, the stomodaeum and proctodaeum contain the same basic tissue elements as the body integument. There is a sclerotized layer or "intima", which lines the lumen of the digestive tract and underneath this is a cellular layer based on the basement membrane, which in turn is surrounded by a muscular layer. The stomodaeum, mesenteron and proctodaeum are further differentiated into various organs, viz., pharynx, oesophagus, crop, proventriculus, anterior ventriculus, posterior ventriculus, anterior intestine, rectal valve, posterior intestine, rectal sac and rectum.

The terms used by different authors from time to time to describe these organs are quite varied, as shown in Table I, with a few exceptions such as "pharynx" and "oesophagus" which are generally used by authors. Graham-Smith (1934) has divided the oesophagus into three regions, the pre-ganglionic oesophagus, the ganglionic oesophagus and the post-ganglionic oesophagus. The "crop" has been described as panse (Dufour, 1851) and sucking stomach (Minchin, 1905; Tulloch, 1906). The "proventriculus" has been designated as gésier (Dufour, 1851), stomach (Minchin, 1905) and cardia (Jones, 1942). The "anterior ventriculus" has been designated as chyle stomach (Lowne 1890-1895), thoracic intestine (Minchin, 1905), ventriculus (Hewitt, 1914; Graham-Smith, 1934; Townsend, 1935-1942; Catts, 1963), thoracic ventriculus (Dixon, 1952; Hori, 1962a), anterior segment (Wigglesworth, 1929) and stomach (Patton and Cragg, 1913; Matheson, 1950; West, 1951). The "posterior ventriculus" has also been further differentiated into "coil" (Minchin, 1905), "helix" (Lowne, 1890-1895), "helicoid region" (Graham-Smith, 1934; Dixon, 1952; Hori, 1962a) and "loops and turns" (West, 1951).

The proctodaeum or hind-gut, which commences from the point of origin of the Malphigian tubules, consists of the anterior intestine and posterior intestine. They are separated internally by an internal invagination, the rectal valve. These two regions are further divided into colon, ileum, rectal sac and rectum (Snodgrass, 1935). The proctodaeum of the group Calyptratae has been dfferentiated into distal intestine and rectum by Lowne (1890-1895), Hewitt (1914), Matheson (1950) and West (1951), and has also been described as mesenteron by Lowne (1890-1895) and Graham-Smith (1934). Minchin (1905), in dealing with the anatomy of the alimentary canal of the tsetse fly, described the region between the points of origin of the Malphigian tubules and the rectal sac as being composed of two regions: the ileum, which lies posteriorly to the point of origin of the Malpighian tubules, and the colon, the succeeding thicker portion towards the rectal sac. He did not notice the rectal valve which was reported by Lowne (1890-1895). Subsequent workers such as Tulloch (1906), Brain (1913), Hewitt (1914), Wigglesworth (1929) and others also have failed to observe this organ, but Patton and Cragg (1913), Graham-Smith (1934), Townsend (1934-1942), Dixon (1952) and Hori (1962a) have described its presence. The posterior intestine has been called "rectum" by most authors. Graham-Smith (1934) has divided the posterior intestine into three distinct regions: (i) the first part of the rectum, the portion immediately behind the rectal valve, (ii) the rectal pouch, the swollen portion of the rectum and (iii) the anal portion of the rectum, which is the narrow tube behind the rectal pouch. The first part of the rectum (Graham-Smith, 1934) has also been called the anterior rectum (Townsend, 1934-1942) and posterior intestine (Dixon, 1952). The rectal pouch (Graham-Smith, 1934), has been referred to as the rectal cavity (Hewitt, 1907, 1914). The rectal pouch bears four conspicuous structures which project into the lumen of the rectal pouch and which have been called boutons charnus (Dufour, 1851), rectal papillae (Lowne, 1890-1895; Graham-Smith, 1934) and rectal glands (Minchin, 1905; Tulloch, 1906; Hewitt, 1914).

The rectal papillae of insects were first discovered by Swammerdam (1669) and later Ramdohr (1811) reported the presence of these organs in calyptrate flies. The number of rectal papillae among Diptera varies from none to six. They are absent in *Clunio* (Chironomidae) (Okada, 1936, 1954b) and *Clinocera* (Empididae) (Engel, 1924). There are two in Cecidomyiidae and most Chironomidae (Okada, 1936, 1954b), *Phlebotomus* (Psychodidae) (Adler and Theodor, 1926), *Culicoides* (Ceratopogonidae) (Megahed, 1956), *Oestrus* and *Hypoderma* (Oestridae) (Engel, 1924). There are three in some of the Mycetophilidae

(Okada, 1936, 1954b) and in *Dolichopus* (Dolichopodidae) (Dufour, 1851). There are four in many other Diptera such as Bombyliidae, Cyrtidae, Therevidae, Scenopinidae (Dufour, 1851) and most cyclorrhaphous Diptera (Dufour, 1851; Engel, 1924; Falcoz, 1926; Graham-Smith, 1934; Kobayashi, 1934; Maki, 1935; Okada, 1936, 1954a, b; Jones, 1942; Owsley, 1946; Dixon, 1952; Hori, 1962a). There are five in *Senex* and *Dasypogon* (Asilidae) (Dufour, 1851), *Oncodes* (Cyrtidae,), *Tipula* (Tipulidae) (Engel, 1924) and *Cryptochaetum grandicorne* Rondani (Drosophilidae) (Okada, 1954b). Hori (1962a) considered the rectal pouch as representing three types based on the arrangements of the rectal papillae: (a) the bilateral type, where there are two rectal papillae placed on one side of the rectal pouch, (b) the cruciate type A, where the papillae are placed opposite each other at the middle part of the rectal pouch and (c) the cruciate type B, in which four papillae are arranged in a cruciate form at the anterior end of the rectal pouch. He pointed out, however, that their arrangement was not always stable. In certain cases sexual dimorphism has also been reported regarding the number and arrangements of the rectal papillae inside the rectal pouch in some species. Chun (1876), Engel (1924) and Okada (1936, 1954a, b) have reported that the males of families Culicidae, Simuliidae, Tabanidae, Rhagionidae and the genus *Atherix* have four rectal papillae, whereas females have six. Hori (1962a) reported sexual dimorphism in the arrangement of the rectal papillae inside the rectal pouch of flies in the genera *Ophyra, Pyrellia, Stomoxys* and *Lyperosia,* where the males have a cruciate type, while the females have a bilateral type of arrangement. The primitive number of rectal papillae in insects is considered to be six by Engel (1924) and Palm (1949).

Material and Methods

During the summer of 1961, flies belonging to the Calyptratae were collected in the vicinity of London, Ontario by following the technique of Judd (1953). The specimens captured in the trap (Fig. I) were anaesthetized with the aerosol insecticide "Slug-a-Bug" manufactured by Shulton Fine Chemicals Division, New York and Toronto, under Registration No. 5817 P.C.P. Act. The spray contains 0.25% Pyrethrins and 1.25% technical Piperonyl Butoxide as active ingredients.

The flies in the trap were transferred to cyanide bottles and subsequently were identified by using suitable keys. In most cases the specimens were identified and checked using the collection in the Department of Zoology, University of Western Ontario made by Judd (1953). In certain cases the help of dipterologists was sought to remove doubts in the identification. This was accomplished in two ways, either by requesting them to send identified specimens or to provide pictorial keys of certain groups with which they were particularly acquainted.

Those flies which could not be obtained by trapping, either because of their absence or rarity, were made available from laboratories in Canada, U.S.A. and Liberia. Some laboratory-bred specimens were also used.

The following flies belonging to ten families were selected for investigation:

Hypodermatidae	:	*Hypoderma lineatum* (deVilliers)
Oestridae	:	*Cephenemyia apicata* Bennett and Sabrosky
Cuterebridae	:	*Cuterebra latifrons* (Coquillet)
Larvaevoridae (Tachinidae)	:	*Bessa harveyi* (Townsend)
Sarcophagidae	:	*Sarcophaga haemorrhoidalis* Fallen

Calliphoridae	:	*Calliphora vicina* Robineau-Desvoidy
		Pollenia rudis (Fabricius)
		Phormia regina (Meigen)
Muscidae	:	*Musca domestica* Linnaeus
Anthomyiidae	:	*Muscina stabulans* (Fallen)
Glossinidae	:	*Glossina palpalis* (Robineau-Desvoidy)
Otitidae	:	*Euxesta notata* (Wied.)

Euxesta notata, although it belongs to the Acalyptratae, was included in order to investigate the structural features of the alimentary canal and its associated organs.

Before fixation a small incision was made in the abdomen of each identified specimen with a fine pair of scissors, to puncture the hard integumental coating which surrounds the insect's body, in order to provide an inlet for the fixative into the body cavity. This process ensures quick penetration of the fixatives into the internal organs and a proper fixation. Otherwise the cuticle offers a good deal of resistance to the penetration of the fixatives and tends to produce artifacts. The fixatives employed were Kazal's fluid, aqueous Bouin's fluid and Pempel's fluid. After a period of about 12-15 hours the flies were removed from the fixative and washed and preserved in 70% ethyl alcohol. The specimens fixed in Bouin's fluid and Kazal's fluid remained soft enough to permit good dissection for anatomical details.

Because of the size and limited number of specimens, the conventional methods of dissection were modified. Instead of pinning the insects into the wax-lined dissecting dish they were tucked into the wax (Fig. 2). The tucking of the specimens was performed by melting the central part of the wax of the dissecting dish by placing a hot scalpel on it. Then the fly, which had just been blotted with a filter paper, was picked up with forceps and placed carefully on the molten wax with its dorsal surface upwards. The process is quite simple and is very useful, as it provides a rigid packing of the wax from three different sides and holds the specimen firmly in its original position throughout the dissection.

For species collected locally both fresh and fixed specimens were used in the investigation of gross anatomical details. For species available only in preserved form, investigations were made only on such preserved material. The dissections were performed under a binocular microscope in insect saline. In certain cases the vital staining technique was used in order to dissect minute transparent organs, which are quite indistinct in a freshly killed specimen. Mainly Janus green B and neutral red stains were used in the above mentioned insect saline.

Permanent whole mounts of the alimentary canal and its associated organs stained in borax carmine were also prepared, in order to examine their structural details and their association with other organs. Mounts of alimentary canals, treated with 10% KOH and incubated at 36°C for about four hours were also prepared. They were used for examination of the intima lining the stomodaeum and proctodaeum, as well as the spines of the intima, the position of the rectal valve and the peritrophic membrane.

Histological studies were carried out by making serial sections ranging from 3 to 10 microns in thickness from tissue impregnated with wax at 55°C. The wax used was a mixture of Parawax (Imperial Esso Product) and Fisher tissuemat in 1:1 ratio. Before embedding, the organs were stained in alcoholic eosin, while the process of dehydration was proceeding. Stained materials are easier than

unstained materials to handle in the final stage of block preparation for small organs, viz., cardia, rectal valve, and can easily be oriented in their proper planes in the block.

The sections were stained with standard haematoxylin modified by Harris and counterstained with Bowie's eosin. After dehydration and cleaning the sections were permanently mounted in Canada balsam or piccolyte.

Photomicrographs of whole mounts and sections were made by using 35 mm film ADOX DOKU Pan with the help of a reflex camera. The outlines of some drawings were made with the help of a camera lucida or Rayoscope and the details were filled in by hand.

Observations

Anatomy

Although there are some individual variations in parts of the alimentary canal in each group of flies, there is a basic plan which is present in all muscoid flies.

The relative positions of the different parts of the alimentary canal are shown in Fig. 3. Beginning at the posterior margin of the fulcrum (F) of the mouth parts, the muscular pharynx (P) extends through the head capsule to the oesophagus (O). The oesophagus curves before going beneath the brain (B). Passing through the neck and extending into the thorax, it gives an offshoot, the crop (Cr), and a small tubule which connects with the cardia (Ca). The pharynx (P), the oesophagus (O) and the tubule to the cardia (Ca) are parts of the stomodaeum or fore-gut, which arises as an invagination of the embryonic ectoderm.

The cardia (Ca) is a button-or bean-shaped structure and is situated at the anterior end of the thorax beneath the huge flight muscles. From the posterior margin of the cardia (Ca), the anterior ventriculus (AV) takes its origin and extends the whole length of the thorax, running backwards in a straight line. Following the anterior ventriculus is the posterior ventriculus (PV) which is highly coiled and consists of numerous loops and turns and ends at the point of origin of the Malpighian tubules (OMT). The cardia (Ca), anterior ventriculus (AV) and posterior ventriculus (PV) constitute the mesenteron or mid-gut, which is derived from embryonic entoderm.

At the point where mesenteron joins the proctodaeum or hind-gut are located the Malpighian tubules (MT). These are four in number, arranged in two pairs, each pair uniting to form a common duct which enters the alimentary canal. The remaining parts of the alimentary canal constitute the proctodaeum. The anterior intestine (AI) is the first part of the proctodaeum and ends in a bulbous swelling, the rectal valve (RV). Following this is the posterior intestine (PI) which dilates into a bladder-like structure, the rectum (R), which opens to the outside by the anus (A). The rectal sac (RS) contains four finger-like structures, the rectal papillae (RP), projecting into the lumen. The anterior intestine (AI), rectal valve (RV), posterior intestine (PI), rectal sac (RS), rectal papillae (RP) and rectum (R) constitute the proctodaeum, which is ectodermal in origin.

The anterior part of the salivary system is the salivary pump (SP) which is situated ventrally at the anterior end of the fulcrum (F). The pump gives way to a duct, the common duct of the salivary gland (CDG). This duct turns directly caudad and, passing ventrally to both the oesophagus (O) and the brain (B), enters the thoracic cavity. In the thoracic region the duct divides to form the two salivary glands (SG) which extend backward into the abdomen. In the abdomen they make turns and coils and reach the rectal sac (RS). The gland is thus a coiled tube as long or longer than the body of the fly.

The anatomy of the alimentary canal of species studied in the present investigation is shown as follows:

Fig. 4 — *Euxesta notata*

Fig. 5 — *Bessa harveyi*

Fig. 6 — *Pollenia rudis*

Fig. 7 — *Calliphora vicina*

Fig. 8 — *Sarcophaga haemorrhoidalis*

Fig. 9 — *Phormia regina*

Fig. 10 — *Musca domestica*

Fig. 11 — *Glossina palpalis*

Fig. 12 — *Muscina stabulans*

Fig. 13 — *Cuterebra latifrons*

Fig. 14 — *Cephenemyia apicata*

Fig. 15 — *Hypoderma lineatum*

Euxesta notata (Fig. 4), which belongs to Acalyptratae, has been included in order to compare the alimentary canal of this species with that of the Calyptrate Muscoidea.

The anterior part of the alimentary canal in all the muscoid flies under present investigation is a muscular pharynx (P) which is situated at the posterior margin of the fulcrum (F). In feeding forms, the pharynx (P) is well developed in comparison to non-feeding forms like *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons*. The pharynx (P) narrows into the oesophagus (O) and extends backward through the brain (B). After emerging from the brain (B), it dilates gradually and extends backward below the ventriculus and above the thoraco-abdominal ganglion (TAG) to form the crop (Cr). The crop is a distensible bilobed sac, which occupies the antero-ventral region of the abdomen. When the crop is fully distended with food the lobes disappear and the crop becomes almost spherical in shape. The crop is absent in *Hypoderma lineatum* and *Cephenemyia apicata*. The oesophagus (O) gives off a small tube to the cardia (Ca), by which the food is conducted to the ventriculus.

The cardia (Ca), which has been variously named by different authors (Table I), is situated at the anterior end of the ventriculus. It is an inverted mushroom-shaped structure whose stem is formed by a tube, which is the continuation of the oesophagus (O). Among non-feeding forms it is very short e.g. *Hypoderma lineatum* and *Cephenemyia apicata,* as indicated by the indices of this organ, which give the ratio between the length and the width (Table II).

The ventriculus commences from the posterior end of the cardia (Ca) and ends at the point of origin of the Malpighian tubules (OMT). Internally, it is also separated from the proctodaeum by the pyloric valve. From its point of origin the ventriculus takes a straight course posteriorly over the crop duct (CD) and under the well-developed flight muscles. At its anterior end it shows a corrugated surface which is not very prominent in *Hypoderma lineatum* and *Cephenemyia apicata*. The ventriculus narrows as it passes into the abdomen, curves dorsally and proceeds in the median line over the crop and below the aorta. When the crop is fully distended the whole ventriculus, along with the proctodaeum, is

lifted up and presses against the tergites. After reaching the abdomen the ventriculus is coiled in a helicoid manner except in non-feeding forms and in *Glossina palpalis*. This has created some confusion as regards the use of terminologies in describing the different parts of the ventriculus by previous authors from time to time (Table I). The degree and the pattern of coiling followed by the ventriculus inside the abdominal cavity is fairly consistent in different species and even in families, as has been pointed out by Graham-Smith (1934). Hori (1962a) has stated that in calyptrate Muscoidea the primitive forms have relatively less coiling as compared to more advanced ones. Okada (1954a), in studying the comparative morphology of drosophilid flies, stated that several of the primitive systematic groups have fewer coils than those of more advanced groups. Histologically the ventriculus can be divided into two regions, the anterior ventriculus (AV) and the posterior ventriculus (PV), except in *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons*. On the other hand *Glossina palpalis* shows one more region which is characterized by giant cells (GCS).

The proctodaeum, which constitutes the rest of the alimentary canal, starts at the posterior part of the pyloric valve, and can be divided into five regions. In the past its parts have been named variously by different authors (Table I). The first part, the anterior intestine (AI), is a narrow tube. The second part is the rectal valve (RV), a bulbous mass situated at the posterior end of the anterior intestine and containing a valve. The third part is the posterior intestine (PI) which lies between the rectal valve and the rectal sac (RS). The fourth part is the rectal sac (RS), an enlarged pouch, which contains four rectal papillae (RP). These are cone-shaped structures projecting into the lumen of the rectal sac (RS). The fifth part is the rectum (R), which is a small tube-like structure opening to the outside of the body by the anus. Curiously enough, the proctodaeum in all non-feeding forms, namely *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons,* is well developed as shown in Figs. 13, 14 and 15.

In order to compare the alimentary canals and to indicate the size variation in the different species under present investigation, the lengths of the alimentary canal, as a whole, as well as of its different parts, were measured and compared by using various indices as shown in Tables II, III, IV, and VII.

When the average lengths of the alimentary canals were plotted against the average body length for each species (Fig. 16) a linear correlation was found and proved significant at the 5% level ($r = 0.58$).

The index of the alimentary canal is the length of the alimentary canal divided by the body length, and was calculated as shown in Table IV. The index increases in the following sequence, the flies, on this basis, being in three groups:

A—non-feeding flies with short alimentary canal; B—flies with canal of intermediate length; and C—flies with long canal:

A : *Hypoderma lineatum*
Cephenemyia apicata
Cuterebra latifrons

B : *Bessa harveyi*
Euxesta notata
Pollenia rudis
Muscina stabulans
Sarcophaga haemorrhoidalis

C : *Phormia regina*
Calliphora vicina
Glossina palpalis
Musca domestica

The indices (ratio of their length to the total body length in each species) were calculated for the stomodaeum, for the mesenteron and for the proctodaeum, the interspecific variances being 0.028, 0.4335 and 0.0303, for stomodaeum, mesenteron and proctodaeum respectively. To ascertain whether the variance value of the mesenteron is significant, within the species, all data were statistically analysed by applying the analysis of variance test and it was found that the value is highly significant at the 5% level as tabulated in Table V. The indices of the mesenteron follow the same sequence as the indices of the alimentary canal.

The comparative proportion of the three sections, viz., stomodaeum, mesenteron and proctodaeum, of the alimentary canal of this group of flies, when calculated in percentage, indicated that the mesenteron constitutes the largest proportion in all the flies under investigation (Table VI), ranging from 48.7 to 74.07, while the stomodaeum and proctodaeum form the rest of the alimentary canal, in which the stomodaeum comprises 9.03 to 21.56 and the proctodaeum constitutes from 12.13 to 39.49, as shown in the histogram (Fig. 17).

The salivary glands have been termed lingual glands in *Calliphora erythrocephala* by Kraepelin (1883). Lowne (1890-1895) and Graham-Smith (1934) described them as lingual salivary glands in the same species. Hewitt (1914), dealing with the alimentary canal of *Musca domestica,* called them lingual glands, and Matheson (1950) and West (1951) mentioned them as salivary glands. Tulloch (1906) referred to them as salivary glands in *Stomoxys.* Townsend (1934-1942), dealing with Diptera in general, called them lingual salivary glands. However, Snodgrass (1935) states that co-called "salivary glands", opening at the base of the hypopharynx, would be better called labial glands. Jones (1942), in describing the histology of the digestive tract of the cluster fly, *Pollenia rudis,* called these organs labial salivary glands. Dixon (1952) has called them salivary glands.

The function of these glands has not been fully investigated although their cytology has been extensively investigated because of the significance of polytene chromosomes in genetics, but whether their characteristics are related to the functioning of the glands is not known (Ross, 1939). The occurrence of amylase has been reported in *Calliphora* (Wigglesworth, 1931).

As a matter of convenience in the present investigation, these glands are called salivary glands (Fig. 3). They are long, paired, tubular structures of uniform width, with swollen tips. The paired structures run along the side of the cardia (Ca), flanking either side of the anterior ventriculus (AV) in the thoracic region. After entering the abdominal cavity each gland takes the ventral route and extends as far as the end of the crop (Cr). The glands are highly coiled in the region of the thorax and it appears that the total length of each gland would be more than the body length of the flies, although the lengths of the salivary glands (SG) could not be measured because of the fixed state of the specimens.

The surface of the gland is smooth in all species studied except in *Musca domestica* and *Muscina stabulans* where it is corrugated due to the convexity of the external surface of the cells. These glands were not found in the few specimens of *Hypoderma lineatum* and *Cephenemyia apicata* studied although Catts and Garcia (1963) report them in the latter. The two ducts unite beneath the oesophagus (O) to form a common salivary duct (CDG), which terminates in a

bulbous mass, the salivary pump (SP). The salivary pump is situated beneath the fulcrum (F). Just before the ducts unite in the neck region, the cells of the gland have a spiral thickening, presumably marking the change from gland to duct.

Histology

In describing the comparative histology of the alimentary canals only that of *Muscina stabulans* is described in detail and the others are compared with *Muscina stabulans* to indicate structural differences.

I. Salivary glands

The glandular tubule consists of a single layer of cuboidal to columnar cells (Fig. 19-C), with approximately 6 to 8 cells in the cross-section. Each cell contains a vesicular, deep-staining, spherical nucleus (N) in its centre. The inner margin of the cells surrounding the lumen of the tubule is lined wth a thin intima (I). In some cases, such as *Muscina stabulans* (Fig. 19) and *Musca domestica,* the outer margin of a cell bulges outwards giving the tubule a beaded appearance. In the rest of the flies investigated the gland has a smooth outer surface which rests on the basement membrane (B).

In all the flies investigated the basic cellular details are the same, with a few variations. For example, the cells in *Calliphora vicina* (Fig. 20) are short columnar, with dense nuclei situated at the periphery of the cells towards the lumen. In *Sarcophaga haemorrhoidalis* (Fig. 21) the cells are tall columnar with rounded vesicular nuclei situated in the centre of the cells. The cells of *Euxesta notata* (Fig. 18) are typically cuboidal. Other variations are listed in Table IX.

II. Stomodaeum

The histology of the stomodaeum is exemplified by that of the oesophagus (Fig. 3-0) and the crop (Cr), since all the flies studied have the same cellular details with very little variation in relation to development of the muscular layer, except in the crop.

The oesophagus (Fig. 22) consists of small irregular epithelial cells (E) with minute nuclei (N). The inner margin of the cells is covered by a thick intimal layer (I). The outer ends of the cells are covered by a basement membrane which is surrounded by a band of circular muscle (CM). No longitudinal layers of muscles could be observed. The arrangement of tissues described above is the same in all the flies, except in the layer of circular muscles which in some cases is more fully developed in comparison to *Muscina stabulans* (Fig. 22), e.g., *Sarcophaga haemorrhoidalis* (Fig. 23).

The crop epithelium (Fig. 24-E) consists of long irregular cells projecting into the lumen of the crop in a folded manner, with rounded vesicular nuclei. When the crop is fully distended the epithelial cells become reduced in size and become flattened. The inner margin of the cells is lined by the thin intimal layer (I). The musculature consists of muscle bands which branch and anastomose over the outer surface of the crop.

III. Mesenteron

The histological details of the mesenteron are here described in the four sections of the mesenteron; the cardia (Fig 3-Ca), anterior ventriculus (AV), posterior ventriculus (PV) and the point of origin of the Malpighian tubules (OMT).

Although the morphology and size of the cardia (Ca) varies considerably in this group of flies, as is evident from the figures (Fig. 25 to 38) and Table X, the basic histological elements are the same in most cases.

The histology of the cardia (Ca) is best studied in its sagittal section. The central core of the cardia in *Muscina stabulans* (Fig. 26) consists of a plug-like peritrophic press (PP), which is an inverted mushroom-shaped structure whose stem is a hollow tube, the cardial oesophagus (CO). On either side of the plug is a group of large columnar cells, with deep staining cytoplasm, containing large spherical nuclei and based on the basement membrane (B). These cells are secretory in nature and the free borders of the cells are actively engaged in secretion (Sr), which produces the peritrophic membrane (PM) as the secretion rolls along a passage bounded by the peritrophic press (PP) and the external walls of the anterior ventriculus (AV). These secretory cells are not well developed in the non-feeding *Cephenemyia apicata* (Fig. 47) and *Cuterebra latifrons* (Fig. 48) and are absent in *Hypoderma lineatum* (Fig. 45).

The posterior space, which lies between the plug and the external wall of the anterior ventriculus (AV), opens into the anterior ventriculus in the front of the neck (NE). The plug has a flange, which projects into the cardial cavity (CV) and is reflected dorsally to produce an arch, which encircles the secretory cells (SC). The curvature of the arch fits into the contour of the secretory cells. The flange looks like two horns projecting into the cardial cavity (CV). The intima (I) of the flange is quite thin. The epithelium (E) consists of pale-staining cells which are cuboidal near the secretory cells, and columnar near the opening of the cardial oesophagus (CO). A distinct basement membrane could not be seen. In the region of the tip of the flange the bases of the cells intermesh.

The musculature of the cardia consists of widely separated longitudinal muscle fibers (LM) and a packed layer of circular muscles (CM) near the junction of the plug.

The anterior ventriculus (AV) of *Muscina stabulans* (Figs. 49, 50) consists of tall columnar epithelial cells (E) throughout its length. The height of the cells varies considerably according to the physiological state of the fly. The epithelial cells are bounded by a basement membrane (B) and surrounded by well-developed layers of internal circular muscles (CM) and external longitudinal muscles (LM). The inner ends of the cells show profuse vacuolization. The secretion is quite evident in this region of the gut. Large globules are freed from the tips of the cells into the lumen. In the region where active secretion is going on epithelial cells (E) may produce spherical globules bulging out from the inner margin of the cells into the lumen. During active secretion the globules are found not only at the ends of the cells, but also free in the lumen of the mesenteron as deep-staining spherical particles. Due to active secretion the epithelial cells (E) become much more attenuated and are replaced by small regenerative cells (Re) next to the muscles. These are small spherical cells with large rounded nuclei and very little cytoplasm (Fig. 50-Re). There is no histological differentiation in the anterior and posterior ventriculus in *Hypoderma lineatum* (Fig. 53), *Cephenemyia apicata* and *Cuterebra latifrons*. In these species the epithelial layer consists of a degenerate type of columnar cell (Fig. 53-E) with scanty non-granular cytoplasm and pycnotic nuclei (N). The margin of the cells is collapsed and shrunken. The nucleus in a cell in *Cephenemyia apicata* and *Cuterebra latifrons* is small, rounded and vesicular. In *Glossina palpalis,* in the posterior ventriculus just beyond its anterior end, the epithelium is differentiated into a region of giant cells (Fig. 52-Gc). The cells are large columnar with deep-staining cytoplasm and contain spherical nuclei. The size of a cell and of the nucleus of a cell is 93 mμ and 11 mμ respectively. The details of the size of the nuclei in the cells in several species are listed in Table XI.

Throughout the length of the posterior ventriculus of *Muscina stabulans* (Fig. 51), short columnar to cuboidal cells are present. They are marked by the presence of a border and are dark-staining cells with granular cytoplasm. The circular and longitudinal muscles are present but are very poorly developed. Some comparative micro-anatomical details are listed in Table XII.

The pyloric valve of *Muscina stabulans* (Fig. 54-PVa) is formed by folds of epithelial cells of the posterior ventriculus which is the part of the mesenteron extending backwards into the proctodaeum. Behind the valve the common duct of the Malpighian tubules (MT) opens into the gut. The musculature of the region is not well differentiated. However, circular muscle bands (CM) are present. This valve also demarcates the point of junction of mesenteron and proctodaeum, as the anterior part of the anterior intestine joins the mesenteron beneath the point of origin of the Malpighian tubules. This arrangement of tissues is present in all the flies investigated.

IV. Proctodaeum

The anterior intestine and the posterior intestine are tubular in cross-section and the epithelial lining is thrown into longitudinal folds (Fig. 79) which may become reduced if the lumen is distended. The epithelial cells are cuboidal (C), with spherical vesicular nuclei (N) situated in the centre of the cells. The histology of the anterior intestine, which is close to the point of origin of the Malpighian tubules, is quite similar in structural details to the posterior intestine. Internally, the cells are lined by a sclerotized covering, the intima (Fig. 79-I) which is armed with backwardly-directed spines. These spines are absent in *Hypoderma lineatum* (Fig. 80) and *Cephenemyia apicata* and poorly developed in *Cuterebra latifrons* in comparison to those in the feeding forms. The size of the spines increases with the approach to the rectal valve (Fig. 58-RV). The cells are on a basement membrane and a thin layer of circular muscle (CM) surrounds them. The layer of circular muscle increases in thickness towards the rectal valve (RV). It attains the maximum thickness near the anterior region of the rectal valve (RV), which coincides with the increasing size of the spines found in the posterior region of the anterior intestine in feeding forms.

The position, size and shape of the rectal valve (RV) is quite characteristic and it varies in shape, size and position in different species as is evident from the whole mounts of these organs (Figs. 57—78). Looking at the shape of the rectal valve (RV) of *Phormia regina* (Fig. 69), *Pollenia rudis* (Fig. 70), and *Calliphora vicina* (Fig. 71), which belong to the family Calliphoridae, it is apparent that there are striking similarities in the morphology of the rectal valve (RV) in these species.

The rectal valve (Fig. 58-RV) is well developed in all the flies under present investigation, except that it is absent in *Hypoderma lineatum*. In comparison to the pyloric valve (Fig. 54-PVa), the rectal valve (RV) is much better developed in all the flies investigated. It is situated between the anterior and posterior intestine. The epithelium, which invaginates into the lumen and forms the valvular structure, is the continuation of the epithelium of the anterior intestine (AI) rather than of the posterior intestine (PI). The inner border of the cells is covered with small spines (S). The base of the rectal valve receives a few muscle bands from the wall of the anterior intestine.

In order to examine the extent to which the peritrophic membrane persists in the proctodaeum as a tube and to see where it is broken up into small fragments, whole mounts of the proctodaeum (Fig. 59) were prepared after treating it with 10% KOH in order to dissolve the soft tissues. It was observed that the peritrophic membrane (Fig. 59-PM) remains as a tube till it reaches the spinous region situated at the anterior part of the rectal valve (RV). After that, in the posterior

intestine (PI), the tubular form is no longer present and the membrane comes out from the rectal valve as broken pieces (Fig. 60-BM) which are seen in the region of the posterior intestine (PI) just below the rectal valve (RV). Similar conditions were also observed in other feeding forms where the peritrophic membrane (PM) is produced by the secretory cells. However, in *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons* no membrane was traceable.

The posterior intestine (PI) in *Muscina stabulans* (Fig. 79) has the same histological composition as that of the anterior intestine (AI) and is situated between the rectal valve and the rectal sac. The circular muscles (CM) are less developed and the backwardly-directed spines are reduced in size.

The rectal sac (Fig. 3-RS) is an inverted flask-shaped structure capable of great distention and contains four rectal papillae projecting into the lumen of the sac. The epithelium (Fig. 81-E) consists of flat cells with small nuclei and is lined with a spineless intima (I). These cells resemble closely the crop epithelial cells of *Muscina stabulans* (Fig. 24). In the contracted condition the epithelial cells (E) of the rectal sac of *Muscina stabulans* (Fig. 81) are thrown into a great many intricate folds but in the distended sac the cells become flattened. The basement membrane could not be seen. The muscular coat consists of two layers, the inner longitudinal muscles (LM) and outer circular muscles (CM). The arrangement of the muscle bundles in the circular layer is peculiar. They are horse-shoe-shaped and the edges of one band are joined to those of the next (Fig. 81). In the distended sac these bands flatten (Fig. 83).

Each rectal papilla is composed of two regions, a central medullary region and an outer cortical region. The base of a rectal papilla is embedded in the wall of the rectal pouch. The medulla chiefly consists of tracheae (Fig. 84-Tr), which are continuations of the tracheal membranes of the haemocoele. The tracheae run along the axes of the medullary region, branching profusely into small tracheoles entering the intercellular spaces.

The cortical cells are tall columnar, with big spherical, condensed nuclei situated towards their periphery. The cells are covered by a thick intima (I) which is armed with small spines (Fig. 81-S). No intima could be observed in the case of *Hypoderma lineatum* (Figs. 82, 84) where the surface of a rectal papilla, which is smooth in other flies, is crooked and wavy. An intima is present in all the other flies under present investigation, even in *Cuterebra latifrons* (Fig. 85) and *Cephenemyia apicata* which also are non-feeding forms. In *Hypoderma lineatum* small cytoplasmic projections (Fig. 84-PR) extend from the margin of the columnar cells of the cortical region which face the lumen of the rectal sac. These cytoplasmic projections create a fuzzy appearance on the marginal surface of the cells.

Other histological details of the papillae are the same throughout the flies except for some variations which are shown in Table XIV.

V. Malpighian Tubules

The Malpighian tubules (Fig. 3-MT) are excretory in function and are almost universally present in insects, and have been generally regarded as ectodermal in origin, but Henson (1944) believes that the Malpighian tubules originate from an undifferentiated zone of cells between mesenteron and proctodaeum. The primitive number of tubules is considered to be two by Pantel (1914) and six by Wheeler (1893). Okada (1936) has supported Wheeler's statement with his studies on the digestive system of Nematocera. The number of the tubules is variable in different orders of insects, ranging from 2 to 200 (Imms, 1957). In

Diptera it varies from 2 to 6, and there are cases such as *Culex, Aedes,* and *Psychoda* where the reported number is five (Dufour, 1851; Graber, 1889; Wheeler, 1893; Christophers, 1960).

In the present work, no attempt has been made either to measure the length of the tubules or to describe the intricate, but apparently constant, pattern of the coiling of these tubules, which has been thoroughly investigated by Hori (1962 b). In this work only the histology of these tubules has been described in some detail.

The four tubules unite in pairs to form two common ducts just before opening into the alimentary canal. In some Diptera, the four tubules enter the alimentary canal separately, viz. Syrphidae (Maki, 1935) and Pupipara (Falcoz, 1926; Roberts, 1927). The opening of the Malpighian tubule is situated anterior to the pyloric valve at the point of junction of the mesenteron and proctodaeum.

A Malpighian tubule of *Muscina stabulans* (Fig. 86-MT) consists of irregular epithelial cells (C) varying from 1 to 2 cells in a cross-section, except in the region of the common duct where the number may be as many as 12. The free surface of the epithelial cells facing the lumen of the tubule has a distinct striated border (SB), and the other surface of the cell is covered by the basement membrane (B). In *Hypoderma lineatum* (Fig. 87) the border is twice as wide as in other flies and the nuclei are very large. In other flies the histological details are the same as in *Muscina stabulans* except for some variations shown in Table XV.

Discussion and Conclusions

Anatomy and Histology

The salivary glands are of two types as shown by their external morphology, one in which the outer surface has a beaded appearance as in *Musca domestica* (Fig. 10) and *Muscina stabulans* (Fig. 12) and the other which has a smooth outer surface, including all the rest of these flies. The histology of these organs in different flies shows three kinds of cells: cuboidal, short columnar and tall columnar. Typical cuboidal cells are seen in *Euxesta notata* (Fig. 18), *Muscina stabulans* (Fig. 19) and *Musca domestica.* In *Muscina stabulans* and *Musca domestica* these cells show a slight variation, where the outer surface of the cells bulges, giving the cells a characteristic appearance. This type of structure has been reported by Dixon (1952). The presence of low columnar cells in *Calliphora vicina* (Fig. 20) and tall columnar in *Sarcophaga haemorrhoidalis* (Fig. 21) is reported here for the first time.

Histological elements of the stomodaeum in all the flies are as observed by Graham-Smith (1934) in *Calliphora erythrocephala* L. However, no such structure as the tracheal thread was observed in the sclerotized area of intimal tissue (Fig. 23-I). This thread has been reported as covering the internal lining of the lumen by Cholodkovsky (1900) in the oesophagus of *Laphria* and by Owsley (1946) in the family Asilidae.

The crop, which functions in various ways in different Diptera acts, according to Wigglesworth (1929), as a temporary reservoir for food in all the feeding forms. In feeding flies the remains of ingested food particles were observed in the serial sections of the crop and it was also noticed that the degree of distention varies in different individuals according to the amount of food present in them. In *Hypoderma lineatum* (Fig. 15) and *Cephenemyia apicata* (Fig. 14) the crop is absent, but it is present in *Cuterebra latifrons* (Fig. 13), whose feeding habit has not been recorded. This observation of food accumulation agrees with the reports of Graham-Smith (1934) in *Calliphora erythrocephala* L. and of Wigglesworth (1929) in *Glossina palpalis.* Curiously enough, Patton and Cragg (1913), working

with *Tabanus,* which is a bloodsucker and thrives on vertebrate blood meals, never found fresh blood in the crop, even when flies were killed while feeding. Owsley (1946) also noticed the absence of food in the crop of Asilidae but he observed in different individuals varying degrees of expansion of the crop.

The external morphology of the cardia (Fig. 25-Ca) varies considerably in the different species under investigation. However, the histology is the same in all cases, except in *Hypoderma lineatum* (Figs. 45, 46) where secretory cells are absent. In *Cuterebra latifrons* (Fig. 48) and *Cephenemyia apicata* (Fig. 47) they are very poorly developed. The histological details of the cardia indicate that this highly specialized structure plays more than one role, as suggested by previous workers. Giles (1906), after describing the structure of the proventriculus (cardia of present investigation) in *Stomoxys calcitrans,* stated that it functions as a valve. Hewitt (1907, 1914), contributing to the anatomy of *Musca domestica,* suggested a dual function, first as valve and then as pump. Patton and Cragg (1913) remarked that in *Philasmatomyia* it acts as a valve. Wigglesworth (1929), describing the digestion of *Glossina palpalis,* proposed the hypothesis that the cardia acts as a sphincter. This idea was confirmed by Graham-Smith (1934) in *Calliphora erythrocephala.* It is suggested by the present work on the comparative histology of this organ, that it plays at least two important roles, proposed by Wigglesworth (1929). First it acts as a sphincter, which controls the passage of the food and second, it produces the peritrophic membrane (PM). These conclusions are reached because of the presence of sphincter muscles (SM) in the cardial oesophagus (Fig. 26-CO) and of secretory cells (Sc) which are responsible for the production of the peritrophic membrane (PM) with the assistance of the peritrophic press (PP) in feeding forms. This idea is further substantiated by the fact that in non-feeding forms, particularly in *Hypoderma lineatum* (Fig. 15), these secretory cells are absent or are very poorly developed, e.g., *Cephenemyia apicata* (Fig. 14) and *Cuterebra latifrons* (Fig. 13), in comparison to feeding forms of this group. The histological investigations do not support the statement of Lowne (1890-1895) that the cardia is a gizzard, because the cellular elements constituting the cardia are derived from part of the ventriculus which is endodermal in origin, whereas a gizzard is a structure which is the posterior part of the stomodaeum and thus ectodermal in origin. Thus these two structures are not homologous. Perhaps the presence of spinous structures in the cardial oesophagus (Co) led Lowne to believe that this structure is a gizzard.

The peritrophic membrane (Fig. 26-PM) is a chitinous sheath hanging in the form of a tubular membrane along the length of the mesenteron. Where it is destroyed has been a matter of speculation. In adult flies of this group it does not protrude through the anus as a tube, as it does in some dipterous larvae (Abedi and Brown, 1961; Waterhouse, 1953).

Various suggestions have been made to explain the break-up of the membrane and it is believed by most workers that it is broken in the hind-gut. In adult *Calliphora erythrocephala,* Graham-Smith (1934) suggested that it is broken by the rectal valve and the churning movement of the rectal papillae which are also covered by spines. The hind-gut wall, which may carry backwardly directed spines, may also act mechanically to tear the membrane and press it backwards (Engel, 1924; Hoare, 1931). Waterhouse (1953) reported the general occurrence of the peritrophic membrane in Cyclorrhapha, but the present findings indicate that a peritrophic membrane is not present in *Hypoderma lineatum* (Fig. 46), *Cephenemyia apicata* and *Cuterebra latifrons* which are members of the non-feeding group of calyptrate Muscoidea. Waterhouse's observations do not include flies in the families Hypodermatidae and Cuterebridae.

The histology of the anterior ventriculus (Fig. 49) and the posterior ventriculus (Fig. 51) indicates that the anterior ventriculus is secretory and the posterior is absorptive. This conclusion is based upon the presence of long columnar cells with streaming cytoplasmic secretions of granules extending from the epithelial cells present in the anterior ventriculus, except in *Hypoderma lineatum* (Fig. 53), *Cephenemyia apicata* and *Cuterebra latifrons,* where there is no distinction between the anterior ventriculus and the posterior ventriculus. This type of secretion has also been reported in *Glossina palpalis* by Wigglesworth (1929) and Graham-Smith (1934) in *Calliphora erythrocephala.* Owsley (1945) describes the same type of secretion in dealing with the comparative anatomy of the family Asilidae.

Below the base of the secretory cells are situated small cells with minute nuclei, the regenerative cells (Fig. 50-Re), which are considered to act in replacing the older secretory cells, although they have not been observed in mitosis (Day and Waterhouse, 1953). In the present investigation these regenerative cells show mitotic divisions in the cells (Fig. 50) and various phases of cell division are visible.

The presence of a striated border in the posterior ventriculus (Fig. 51) in all the feeding forms and its general absence in the non-feeding forms makes it possible to conclude that this portion is absorptive in function, as the borders are regarded as a device to increase the surface area.

The existence of a pyloric valve (Fig. 54-PVa) in this group of flies has not been reported by previous workers. Wigglesworth (1929), dealing with the histology of *Glossina palpalis,* did not mention the presence of this organ. After making an extensive study of the alimentary canal of *Calliphora erythrocephala,* Graham-Smith (1934) failed to report the existence of this organ. The present investigation indicates the presence of a pyloric valve in all the flies at the junction of the mid-gut and the hind-gut just before the origin of the Malpighian tubules (Fig. 3-OMT). The presence of a similar structure at the same position has been reported by Owsley (1945) in Asilidae. Its probable function is to stop backflow into the mesenteron.

The histological studies of the anterior intestine agree in some details with the description by Graham-Smith (1934) of *Calliphora erythrocephela,* and in other details with the reports of Dixon (1952) on *Hylemya brassicae* (Bouché). However, neither of these authors comments on the increase in size of the spines (S) and circular muscles (CM) with the approach to the rectal valve (Fig. 58-RV). This increase is quite evident in all the flies which feed in the adult stage. This coincidence of increase in the spines as well as in thickness of muscular layer suggests that the destruction of the peritrophic membrane may take place in this region by these sharp, strong spines (Fig. 56-S) with the help of the strong muscles (Fig. 55-CM), which surround them. They might assist the spines in crushing the peritrophic membrane. To investigate further the fate of the tubular membrane, whole mounts of the proctodaeum were prepared after dissolving all the tissue elements by treatment with 10% KOH. It was noted that the tubular membrane (Fig. 59-PM) exists intact up to the spinous region which is situated at the anterior end of the rectal valve (Fig. 58-RV). The membrane is clearly visible through the internal lining of the anterior intestine (Fig. 59-AI) of the proctodaeum, but in the posterior intestine (PI) the tubular form could not be seen, while traces of broken membrane were observed (Fig. 60-BM). This idea is supported by the absence of spines in this region in non-feeding forms which produce no peritrophic membrane.

The rectal valve (Fig. 58-RV) is situated between the anterior intestine (AI) and posterior intestine (PI). The histological details of this organ agree with descriptions by Graham-Smith (1934) and Dixon (1952). The rectal valve is

absent in *Hypoderma lineatum*. Wigglesworth (1929) did not record its presence while describing the alimentary canal of *Glossina palpalis*. However, the present investigation shows that there is a rectal valve (Figs. 73, 74-RV) in *Glossina palpalis*. Graham-Smith's (1934) suggestion about the function of the rectal valve as pulling and breaking up the peritrophic membrane receives no support from the present investigation because the membrane is already broken in the anterior region of the rectal valve. Graham-Smith's (1934) diagrams, illustrating the various strokes of the rectal valve in action, can be duplicated in a series of oblique sections, i.e., not cut longitudinally. His other suggestion that the valve controls the flow of the material is well supported by the present investigation.

The histology of the rectal sac is similar in cellular details to that described by Dixon (1952) in *Hylemya brassicae* and by Owsley (1946) in Asilidae, except in the arrangement of circular muscles, which Dixon (1952) has described as closely-packed bundles. In the present investigation it is seen that they are arranged in horse-shoe-shaped bands which allow for expansion of the sac.

The rectal sac (Fig. 81) contains four conical organs, the rectal papillae, whose histological details agree with the findings of Dixon (1952) and Graham-Smith (1934). Similar structures have also been reported in Asilidae by Owsley (1946). While the morphology and histology of these organs is the same throughout most of this group, it is observed that it is different in *Hypoderma lineatum* (Figs. 82, 84) where the surface of the papillae is crooked, no intimal covering can be observed, and the margin of the cortical cells produces cytoplasmic projections into the lumen. These observations suggest a functional adaptation, which is to increase the surface area of the rectal papillae and thus to help water conservation in non-feeding forms. These findings support the hypothesis of Wigglesworth (1934) that the role of these organs is water conservation.

The histology of the rectum agrees *in toto* with the description of Dixon (1952) and the present findings indicate no variation in all the flies studied.

The histology of the Malpighian tubules is the same in all the flies studied and agrees with the description by previous workers such as Graham-Smith (1934) and Dixon (1952), except that in non-feeding forms the brush borders are more highly developed (Fig. 87) than in the rest of the group.

Phylogeny and Classification

In the present investigation the length of the alimentary canal of this group of flies shows a linear correlation (Fig. 16) when plotted against body length of the corresponding flies. It was observed that the alimentary canal indices (Table IV), which show the ratio of the body length to the total length of the alimentary canal, are lowest in *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons,* ranging from 1.41 to 1.60, and largest in *Musca domestica* (4.58), and in *Calliphora vicina, Glossina palpalis* and *Phormia regina,* ranging from 3.13 to 4.56. The indices of *Euxesta notata, Bessa harveyi, Muscina stabulans* and *Pollenia rudis* fall between these two extremes, ranging from 2.22 to 2.91. The indices of the mesenteron follow almost the same pattern. This contradicts the statement of Hori (1962 a) that the indices of the alimentary canal are largest in the advanced systematic groups, for in *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons,* which belong to the super-family Oestroidea (Roback, 1951) and are considered to be the most advanced group in the calyptrate series, the indices are smallest. However, Hori's (1962 a) observations include no members of this group. The present observations suggest that there are two extremes in indices even in the advanced group, one with the largest in the feeding forms and one with the smallest in non-feeding forms such as *Hypoderma lineatum, Cephenemyia apicata* and *Cuterebra latifrons*. The remainder fall between these two extremes.

Okada (1954 a), after investigating the comparative morphology of drosophilid flies, suggested that the members belonging to lower systematic groups have usually a smaller number of coils than those of advanced groups. Hori (1962 a) reached the same conclusion after investigating the comparative morphology of 82 species of calyptrate Muscoidea. But Graham-Smith (1934), with the help of diagrams, compared the coiling of the alimentary canals of *Musca domestica, Fannia canicularis* and a species of *Sarcophaga* and indicted that *Sarcophaga,* having a reduced number of coils, therefore belongs to a higher taxonomic group. The present investigation suggests that the theory of two extremes can also be applied in this case, where *Hypoderma lineatum* (Fig. 15), *Cuterebra latifrons* (Fig. 13) and *Cephenemyia apicata* (Fig. 13) form a series with a small number of coils and others, including *Calliphora vicina* (Fig. 7) and *Musca domestica* (Fig. 10), a series with a larger number of coils.

Hori (1962 a) noted the relative position of the rectal valve in all the species which he studied and reached the conclusion that it tends to approach the rectal sac in advanced families, and claimed that the rectal valve in a single genus or in allied groups has the same relative position. The first part of his statement is not supported by the present investigation, as the rectal valve in *Cephenemyia apicata* is far removed from the rectal sac, i.e., 5.8 mm., and is absent in *Hypoderma lineatum* (Fig. 15). The second part of Hori's statement gets some support as far as morphology of the rectal valve is concerned, as there is a characteristic shape in each group of flies under investigation.

Hori's (1962 a) idea of the rectal valve approaching the rectal sac probably originated in his investigations by his findings in specimens of Tachinidae, which certainly belongs to an advanced group of calyptrate Muscoidea, but is primitive when compared with the members of families Cuterebridae, Oestridae and Hypodermatidae, where the rectal valve is far removed from the rectal sac or even absent.

The primitiveness of Tachinidae also gets support from the observations of the anatomy of *Euxesta notata,* which belongs to the family Otitidae, where the rectal valve is situated close to the rectal sac. According to Roback (1951) the calyptrate Muscoidea must have originated from an ancestral otitid- or helomyzid-like form of Acalyptratae, and the family Anthomyiidae of calyptrate Muscoidea has least deviated from its ancestral stock.

With the supposition that the rectal valve being close to the rectal sac is a primitive condition and the separation of it from the sac is an advanced condition, the distances of the rectal valve from the rectal sac in each case were plotted to show a phylogenetic relationship within the groups of these flies (Fig. 88).

It is to be noted that this scheme coincides with Roback's (1951) proposal, except with regards to the families Cuterebridae and Hypodermatidae, which he has put together in one family Oestridae, as sub-families. According to the present studies it is indicated that *Hypoderma lineatum* and *Cephenemyia apicata* are closely related, when various indices are arranged in increasing sequence, but *Cuterebra latifrons* oscillates between various groups. This agrees with Bennett's (1955) suggestion where he considers the family Cuterebridae as a whole as a primitive family. The lack of rectal valve in *Hypoderma lineatum* indicates that Hypodermatidae is a valid systematic group.

A key to families of Oestroidea based upon the alimentary canal is as follows:

A. Rectal valve close to rectal sac
——————Tachinidae

AA. Rectal valve far removed from the rectal sac

B. Crop and rectal valve present
——————Cuterebridae

BB. Crop absent

C. Rectal valve present
——————Oestridae

CC. Rectal valve absent
——————Hypodermatidae

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NOTE — TABLE I ON PAGE 54

TABLE II. Index of Cardia. Ratio of Length to Width of Cardia.

Number of Specimens Dissected	Species	Average	Range
5	*Euxesta notata*	1.72	1.66 - 1.78
3	*Bessa harveyi*	1.25	
5	*Musca domestica*	1.89	1.54 - 2.08
3	*Muscina stabulans*	2.56	2.50 - 2.70
3	*Pollenia rudis*	1.46	1.33 - 1.66
3	*Calliphora vicina*	1.84	1.76 - 1.88
3	*Glossina palpalis*	1.85	
3	*Phormia regina*	1.60	1.42 - 1.76
3	*Sarcophaga haemorrhoidalis*	1.70	1.66 - 1.75
2	*Hypoderma lineatum*	.60	
2	*Cephenemyia apicata*	.82	
3	*Cuterebra latifrons*	1.66	

TABLE I

Table Showing Different Terminologies used by the Following Authors in Describing The Alimentary Canal of Calyptrate Muscoidea : Diptera

The three different regions of the Alimentary canal of insects	Stomodaeum (Fore-gut)								Mesenteron (Mid-gut)					Proctodaeum (Hind-gut)				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Insects Snodgrass, R.E. (1935)	Pharynx *	Oesophagus *				Crop *		Proventriculus	Mesenteron					Anterior intestine		Posterior intestine		
														Ileum	Colon		Rectal sac *	Rectum *
Diptera Townsend, C.H.T. (1934-42)	Pharynx	Oesophagus				Crop		Proventriculus	Ventriculus	Duodenum				Colon	Rectal valve	Anterior Rectum	Rectal pouch	Posterior Rectum
Calliphora erythrocephala (Meig) Lowne, B.T. (1893-95)		Oesophagus				Crop	Crop-duct *	Proventriculus	Chyle Stomach	Proximal intestine				Distal intestine	Rectal valve		Rectum	
Glossina palpalis (R-D) Minchin, E.A. (1905)	Pharynx	Oesophagus						Stomach	Thoracic intestine	Abdominal intestine				Ileum			Rectum	
Stomoxys (Linn) Tulloch, F.M.G. (1906)		Oesophagus					Duct of Sucking Stomach	Proventriculus					Origin of the Malpighian tubules	Lower intestine			Rectum	
Musca domestica (Linn) Patton, W.S. Cragg, F.W. (1913)	Pharynx	Oesophagus				Crop		Proventriculus	Stomach	Proximal intestine		Distal intestine					Rectum	
Stomoxys calcitrans (Linn) Brain, C.K. (1913)	Pharynx	Oesophagus				Sucking Stomach		Proventriculus	Intestine			Narrow Lower intestine		Proctodaeum			Rectum	
Musca domestica (Linn) Hewitt, C.G. (1914)		Oesophagus				Crop		Proventriculus	Ventriculus	Proximal intestine				Distal intestine			Rectum	
Glossina palpalis (R-D) Wigglesworth, V.B. (1929)		Oesophagus						Proventriculus	Anterior segment	Middle & posterior segment				Hind-gut			Rectum	
Calliphora erythrocephala (Meig) Graham-Smith, G.S. (1934)			Preganglionic Oesophagus	Ganglionic Oesophagus	Post-ganglionic Oesophagus	Crop	Crop-duct	Proventriculus	Ventriculus	Abdominal ventriculus	Heliciod region	Post-Heliciod region		Hind-gut	Rectal valve	1st part of the Rectum	Rectal pouch	Anal portion of the Rect
Pollenia rudis (Fabricius) Jones, David T. (1942)	Pharynx	Oesophagus				Crop		* Cardia	* Anterior Ventriculus	* Posterior ventriculus							Posterior intestine	
Musca domestica (Linn) Matheson (1950) and West (1951)	Pharynx	Oesophagus				Crop		Proventriculus	Stomach	Proximal intestine				Distal intestine	Rectal valve		Rectum	
Hylemya brassicae (Bouché) Dixon, S.E. (1951)	Pharynx	Oesophagus				Crop	Crop-duct	Proventriculus	Thoracic Ventriculus	Abdominal ventriculus	Heliciod region	Post-Heliciod region		* Anterior intestine	* Rectal valve	* Posterior intestine	Rectal pouch	Anal Rectum
Cuterebra latifrons (Coquillet) Catts, E.P. (1963)		Oesophagus							Ventriculus					Anterior intestine			Rectum	

* Terms used in the present article

NOTE — TABLE II ON PAGE 53

TABLE III. Length of the Parts of the Alimentary Canal: (mm.)

Species	Number	Body length		Length of Stomodaeum		Length of Mesenteron		Length of Proctodaeum		Total length of Alimentary Canal	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Euxesta notata	5	5.40	5.00- 6.00	2.94	2.70-3.00	8.40	8.00- 9.00	2.30	2.00-2.50	13.64	13.00-14.50
Bessa harveyi	5	6.00	—	1.5	—	7.60	7.00- 9.00	4.20	4.00-4.50	13.30	12.50-14.50
Musca domestica	5	7.80	7.00- 9.00	3.34	2.70-4.00	24.80	22.00-27.00	7.60	7.00-9.00	35.74	31.00-40.00
Muscina stabulans	5	7.80	7.00- 9.00	2.80	2.50-3.00	15.20	14.00-18.00	4.70	4.00-5.00	22.70	20.50-25.50
Pollenia rudis	5	8.20	7.00- 9.00	2.45	2.40-2.50	12.00	11.00-13.00	3.80	3.50-4.00	18.30	16.80-20.00
Calliphora vicina	5	9.20	8.00-10.00	2.86	2.30-3.50	22.00	21.00-23.00	6.40	6.00-7.00	31.26	30.50-32.50
Glossina palpalis	5	9.40	9.00-10.00	2.80	2.50-3.00	20.00	19.00-21.00	8.20	7.50-9.00	31.00	29.00-33.00
Phormia regina	5	9.80	9.00-11.00	2.30	2.00-2.50	21.20	20.00-23.00	7.20	7.00-7.50	31.50	29.50-31.50
Sarcophaga haemorrhoidalis	5	10.00	7.00-13.00	4.70	4.50-5.00	14.40	14.00-16.00	5.40	5.00-6.00	24.50	23.50-27.00
Hypoderma lineatum	5	13.80	12.00-15.00	2.30	2.00-2.50	9.50	9.00-10.00	7.70	7.00-8.00	19.50	18.50-20.50
Cephenemyia apicata	3	15.33	15.00-16.00	2.33	2.00-2.50	13.67	13.00-15.00	7.67	7.00-8.00	23.67	22.50-25.00
Cuterebra latifrons	5	17.20	17.00-18.00	3.8	3.00-4.00	20.40	19.00-21.00	3.24	3.00-4.00	27.54	25.50-29.50

TABLE IV. Indices Showing the Comparative Lengths of the Parts of the Alimentary Canal (mm.)

Species	Number	Body Length		Index Stomodaeum		Index Mesenteron		Index Proctodaeum		Index Alimentary Canal	
		Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Euxesta notata	5	5.4	5-6	0.54	0.50-0.60	1.56	1.50-1.60	0.43	0.40-0.50	2.53	2.41-2.64
Bessa harveyi	5	6.0	—	0.25	—	1.27	1.17-1.50	0.71	0.67-0.75	2.22	2.08-2.42
Musca domestica	5	7.8	7-9	0.43	0.38-0.50	3.12	3.0 -3.57	0.98	0.88-1.00	4.58	4.37-5.0
Muscina stabulans	5	7.8	7-9	0.36	0.31-0.43	1.95	1.44-2.25	0.60	0.50-0.63	2.91	2.28-3.19
Pollenia rudis	5	8.2	7-9	0.31	0.28-0.36	1.49	1.38-1.57	0.46	0.44-0.50	2.24	2.10-2.43
Calliphora vicina	5	9.2	8-10	0.31	0.29-0.44	2.39	2.21-2.88	0.70	0.60-0.75	3.40	3.05-3.91
Glossina palpalis	5	9.4	9-10	0.30	0.28-0.33	2.13	2.10-2.22	0.87	0.83-0.90	3.29	3.22-3.39
Phormia regina	5	9.8	9-11	0.32	0.20-0.28	2.16	1.82-2.44	0.73	0.64-0.83	3.13	2.68-3.50
Sarcophaga haemorrhoidalis	5	10.0	7-13	0.47	0.36-0.64	1.44	1.17-2.0	0.54	0.46-0.71	2.45	2.04-3.35
Hypoderma lineatum	5	13.8	12-15	0.17	0.15-0.18	0.69	0.60-0.83	0.56	0.57-0.67	1.41	1.23-1.67
Cephenemyia apicata		15.33	15-16	0.15	0.13-0.17	0.89	0.81-1.00	0.50	0.47-0.53	1.54	1.47-1.67
Cuterebra latifrons	5	17.2	17-18	0.22	0.18-0.25	1.19	1.12-1.24	0.19	0.18-0.22	1.60	1.50-1.66

TABLE V. Analysis of Variance of Indices of the Parts of Alimentary Canals

Variation Source	S.S.	d.f.	M.S.S.	F	F Total
Embryonic regions	12.65	2	6.325	44.542*	3.44
Species	2.71	11	.246	1.732†	
Error	3.13	22	.142		
Total	18.49	35	6.713	46.274	

* Highly significant between
Stomodaeum
Mesenteron
Proctodaeum

† not significant between flies

TABLE VI. Comparative Proportion of the Three Sections of the Alimentary Canal in Percentage

Species	Number	% Stomodaeum		% Mesenteron		% Proctodaeum	
		Average	Range	Average	Range	Average	Range
Euxesta notata	5	21.56%	20.45-23.08%	61.58%	60.60-62.70%	16.86%	15.38-18.94%
Bessa harveyi	5	11.28%	10.34-12.00%	57.14%	53.85-62. 7%	31.58%	27.59-34.61%
Musca domestica	5	9.35%	8.52-10.81%	69.93%	67.50-71.43%	21.26%	20.00-22.50%
Muscina stabulans	5	12.33%	9.80-14.63%	66.96%	63.64-70.59%	20.71%	17.39-22.73%
Pollenia rudis	5	13.85%	12.82-14.70%	65.43%	64.71-66.67%	20.72%	20.00-21.74%
Calliphoria vicina	5	9.15%	7.35- 9.68%	70.38%	67.74-73.48%	20.47%	18.46-22.95%
Glossina palpalis	5	9.03%	8.47- 9.84%	64.52%	63.64-65.57%	26.45%	24.95-27.27%
Phormia regina	5	7.49%	6.35- 8.47%	69.06%	67.80-70.77%	23.45%	21.54-24.59%
Sarcophaga haemorrhoidalis	5	19.18%	18.52-20.41%	58.78%	57.14-59.57%	22.04%	21.28-22.92%
Hypoderma lineatum	5	11.79%	10.00-13.51%	48.72%	47.37-50.00%	39.49%	37.84-42.10%
Cephenemyia apicata	3	9.85%	8.00-11.11%	57.75%	55.32-60.00%	32.40%	31.11-34.04%
Cuterebra latifrons	5	13.80%	11.32-15.25%	74.07%	71.19-75.47%	12.13%	10.71-13.56%

TABLE VII. Ratio of Length to Width of Rectal Papillae

Number of Specimens Dissected	Species	Average	Range
5	*Euxesta notata*	3.11	—
3	*Bessa harveyi*	2.25	—
5	*Musca domestica*	2.31	2.25 - 2.45
3	*Muscina stabulans*	2.67	2.50 - 2.77
3	*Pollenia rudis*	1.36	—
3	*Calliphora vicina*	1.8	—
3	*Glossina palpalis*	2.72	—
3	*Phormia regina*	2.25	—
3	*Sarcophaga raemorrhoidalis*	1.94	1.76 - 2.17
2	*Hypoderma lineatum*	1.68	1.6 - 1.75
2	*Cephenemyia apicata*	1.13	—
5	*Cuterebra latifrons*	2.00	—

TABLE VIII. The Distance of Rectal Valve from Rectal Sac (in mm.)

Hypoderma lineatum	—	*Sarcophaga haemorrhoidalis*	1.1
Euxesta notata	.08	*Cuterebra latifrons*	1.52
Bessa harveyi	.14	*Muscina stabulans*	1.63
Pollenia rudis	.43	*Phormia regina*	2.08
Calliphora vicina	.44	*Glossina palpalis*	2.84
Musca domestica	1.5	*Cephenemyia apicata*	5.46

TABLE IX. Number of Cells in a Cross-section and Dimensions in Microns of the Cells of Salivary Glands of Calyptrate Muscoidea

Species	Number of Cells	Length of Cells	Diameter of Nucleus
Euxesta notata	4	11	7
Bessa harveyi	4	19	11
Musca domestica	6	26	11
Muscina stabulans	6	26	11
Pollenia rudis	8	19	11
Calliphora vicina	6 to 8	19	11
Glossina palpalis	6 to 8	11	7
Phormia regina	6 to 8	26	11
Sarcophaga haemorrhoidalis	10 to 15	37	19
Hypoderma lineatum	x	x	x
Cephenemyia apicata	x	x	x
Cuterebra latifrons	6	11	7

TABLE X. Measurements of the Width of the Cardia of Calyptrate Muscoidea in Microns

Species	Width of the Cardia	Species	Width of the Cardia
Euxesta notata	176	*Glossina palpalis*	832
Bessa harveyi	272	*Phormia regina*	560
Musca domestica	480	*Sarcophaga haemorrhoidalis*	448
Muscina stabulans	432	*Hypoderma lineatum*	192
Pollenia rudis	400	*Cephenemyia apicata*	208
Calliphora vicina	400	*Cuterebra latifrons*	720

TABLE XI. Measurements (microns) of Cells of Anterior Ventriculus (AV) of Calyptrate Muscoidea

Species	Length of the cells	Diameter of the nucleus
Euxesta notata	37	7
Bessa harveyi	56	7
Musca domestica	75	19
Muscina stabulans	67	11
Pollenia rudis	56	15
Calliphora vicina	56	11
Glossina palpalis	75	11
Phormia regina	63	11
Sarcophaga haemorrhoidalis	56	15
Hypoderma lineatum	18	4
Cephenemyia apicata	20	4
Cuterebra latifrons	26	4

TABLE XII. Measurements (microns) of Cells in the Posterior Ventriculus (PV) of Calyptrate Muscoidea

Species	Length of the Cells	Diameter of the nucleus	Height of the border
Euxesta notata	19	7	4
Bessa harveyi	37	19	11
Musca domestica	34	19	4
Muscina stabulans	37	15	4
Pollenia rudis	30	11	7
Calliphora vicina	45	11	4
Glossina palpalis	30	11	4
Phormia regina	30	11	7
Sarcophaga haemorrhoidalis	26	11	4
Hypoderma lineatum	x	x	x
Cephenemyia apicata	x	x	x
Cuterebra latifrons	x	x	x

x: Indicates that there is no distinction between the cells of anterior ventriculus (AV) and posterior ventriculus (PV)

TABLE XIII. Length (microns) of the Spines and the Thickness of the Circular Muscles in Anterior Intestine of Calyptrate Muscoidea

Species	Spine	Circular Muscules
Euxesta notata	18	11
Bessa harveyi	22	11
Musca domestica	30	37
Muscina stabulans	44	26
Pollenia rudis	30	19
Calliphora vicina	37	37
Glossina palpalis	26	19
Phormia regina	26	19
Sarcophaga haemorrhoidalis	56	44
Hypoderma lineatum	x	4
Cephenemyia apicata	x	4
Cuterebra latifrons	7	19

TABLE XIV. Measurements (microns) of the Rectal Papilla of Calyptrate Muscoidea

Species	Length of Papilla	Length of Cell	Diameter of Nucleus
Euxesta notata	168	30	11
Bessa harveyi	400	37	11
Musca domestica	437	56	11
Muscina stabulans	437	56	11
Pollenia rudis	353	56	11
Calliphora vicina	720	26	11
Glossina palpalis	437	44	15
Phormia regina	380	37	15
Sarcophaga haemorrhoidalis	560	81	15
Hypoderma lineatum	720	63	11
Cephenemyia apicata	720	75	19
Cuterebra latifrons	720	75	15

TABLE XV. Number of the Cells in a Cross-Section and their Measurements (microns) in Malpighian Tubules of Calyptrate Muscoidea

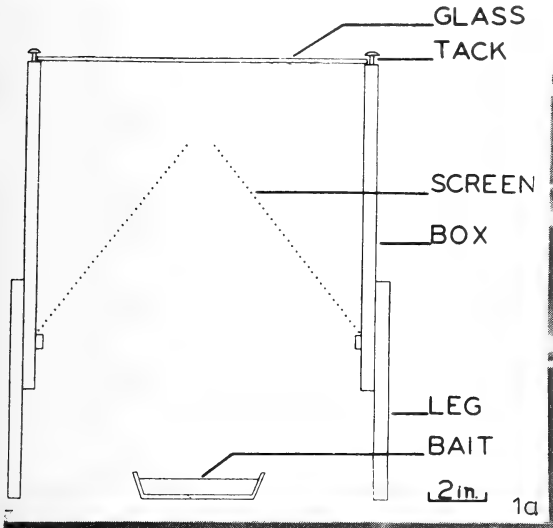
Species	Number of cells	Length of the cell	Diameter of the Nucleus	Height of border
Euxesta notata	2	11	7	2
Bessa harveyi	2	19	15	4
Musca domestica	2	19	15	4
Muscina stabulans	2	37	19	4
Pollenia rudis	2	56	26	4
Calliphora vicina	2	56	26	6
Glossina palpalis	2	37	7	4
Phormia regina	2	18	7	4
Sarcophaga haemorrhoidalis	3	26	14	4
Hypoderma lineatum	3	63	37	27
Cephenemyia apicata	2	37	18	27
Cuterebra latifrons	2	37	18	27

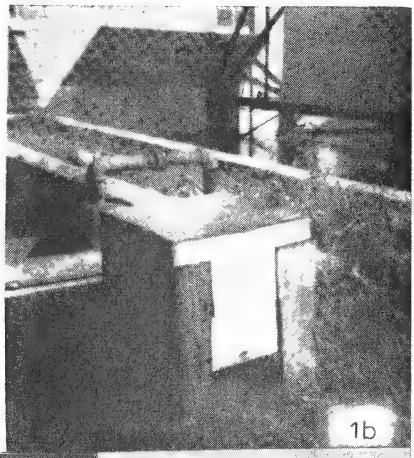
LEGEND FOR FIGURES ON ANATOMY (FIGS. 3 - 15)

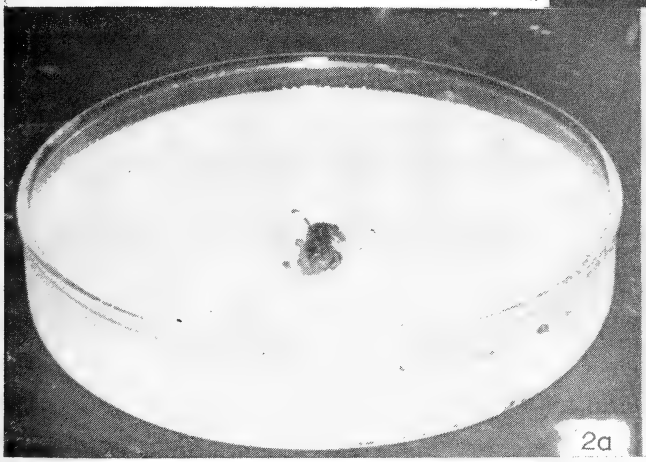
A—anus; AI—anterior intestine; An—antenna; AN—antennary nerve; Ar—arista; AV—anterior ventriculus; B—brain; Ca—cardia; CD—crop duct; CDG—common duct of salivary gland; Cr—crop; E—eye; F—fulcrum; GCS—giant cell section; L—labella; MT—Malpighian tubule; O—oesophagus; OMT—origin of Malpighian tubules; P—pharynx; PI—posterior intestine; PV—posterior ventriculus; R—rectum; RP—rectal papilla; RS—rectal sac; RV—rectal valve; SG—salivary gland; SP—salivary pump; TAG—thoraco-abdominal ganglion; VN—ventral nerve.

LEGEND FOR FIGURES ON HISTOLOGY (FIGS. 18-87)

AI—anterior intestine; AV—anterior ventriculus; B—basement membrane; BM—broken peritrophic membrane; C—cell; Ca—cardia; CD—crop duct; Cr—crop; CM—circular muscle; CO—cardial oesophagus; CV—cardial cavity; E—epithelial cells; GC—giant cells; I—intima; LM—longitudinal muscle; MB—muscle band; MT—Malpighian tubule; N—nucleus; NE—neck of ventriculus; O—oesophagus; OMT—origin of Malpighian tubules; PI—posterior intestine; PM—peritrophic membrane; PP—peritrophic press; Pr—projection of cell of rectal papilla; PV—posterior ventriculus; PVa—pyloric valve; Re—regenerative cells; RP—rectal papilla; RS—rectal sac; RV—rectal valve; S—spine; SB—striated border; Sc—secretory cells; SM—sphincter muscle; Sr—secretion; Tr—trachea.







FIGS. 1, 2. Fig. 1a. Section of fly trap. Fig. 1b. Trap in position. Fig. 2a. Dissecting dish with fly tucked in wax. Fig. 2b. Fly in wax.

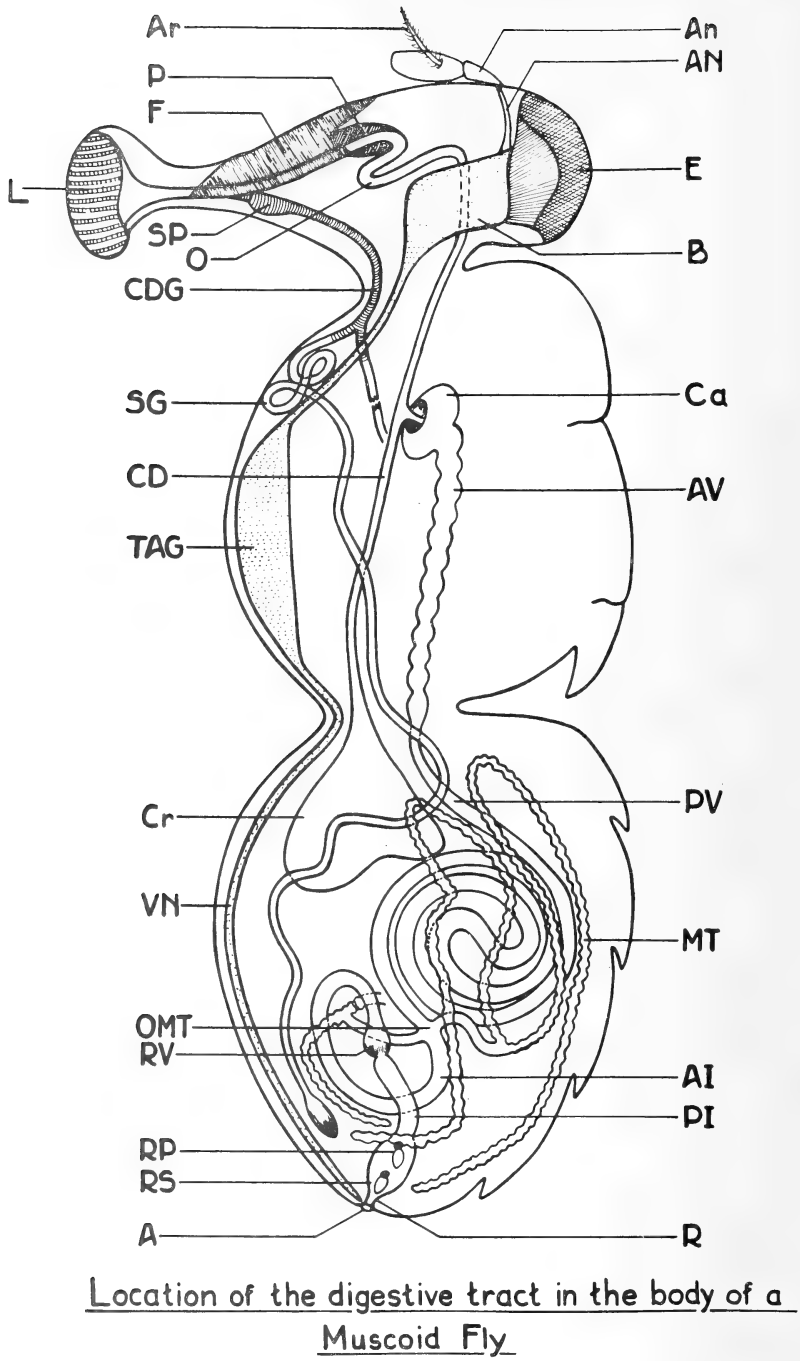
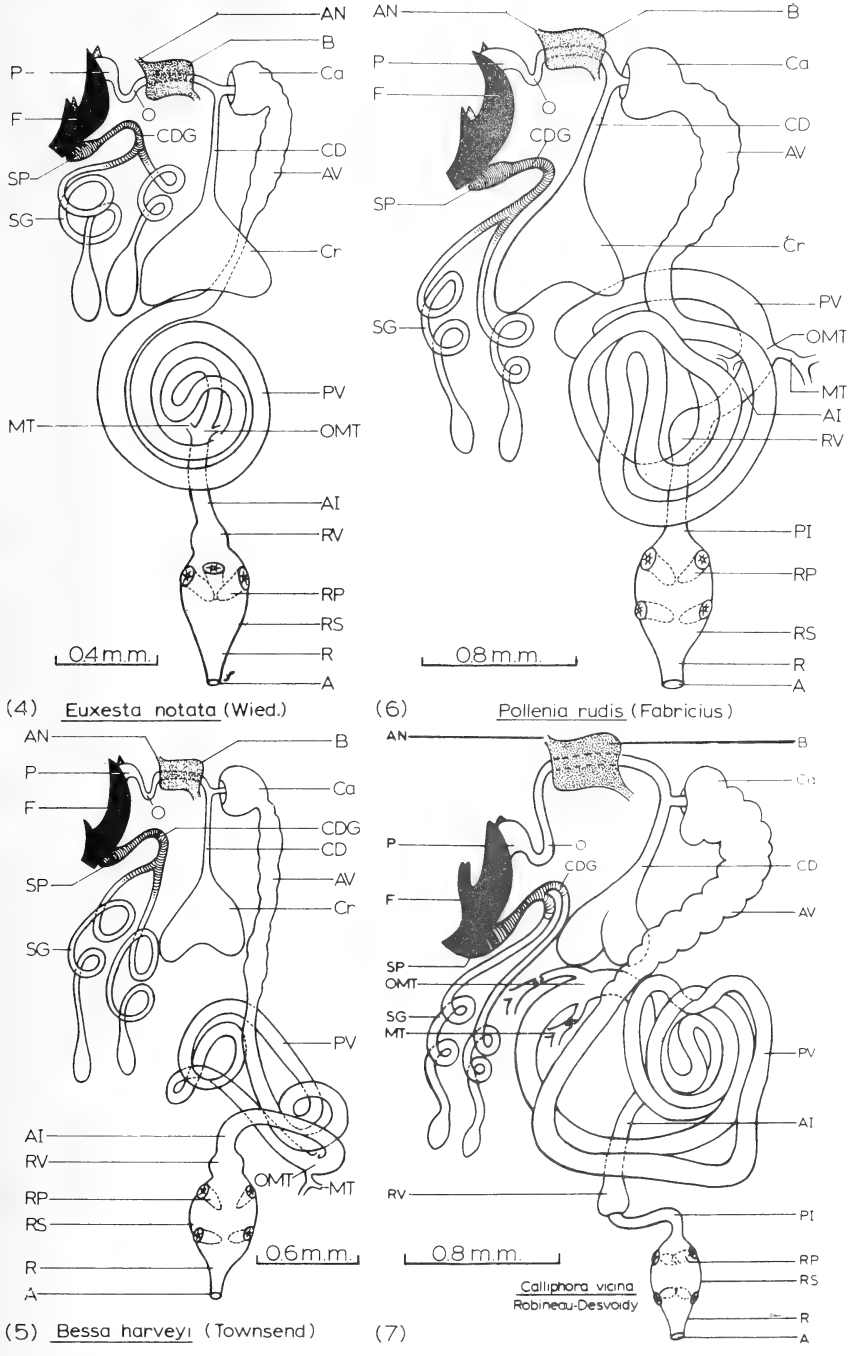
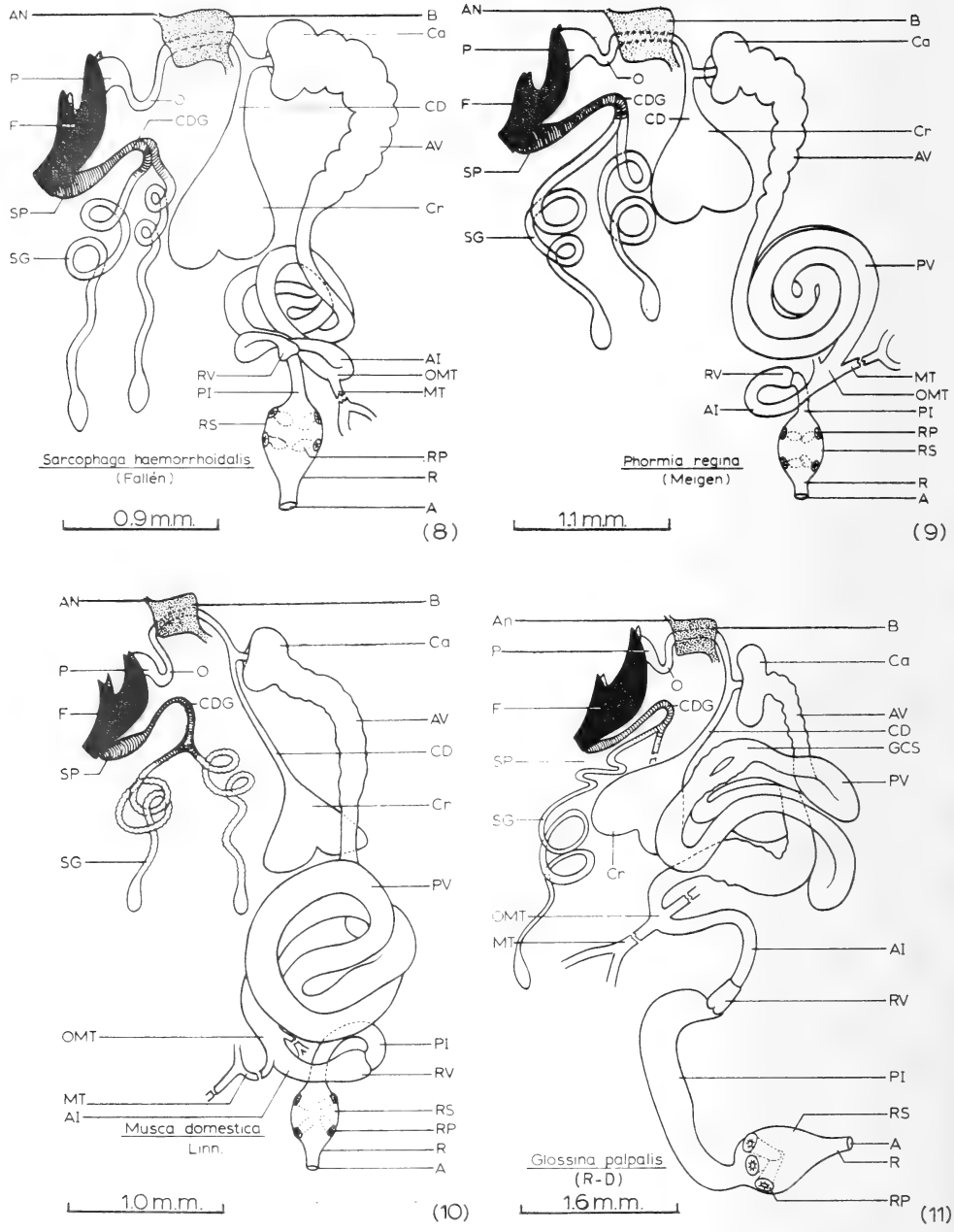


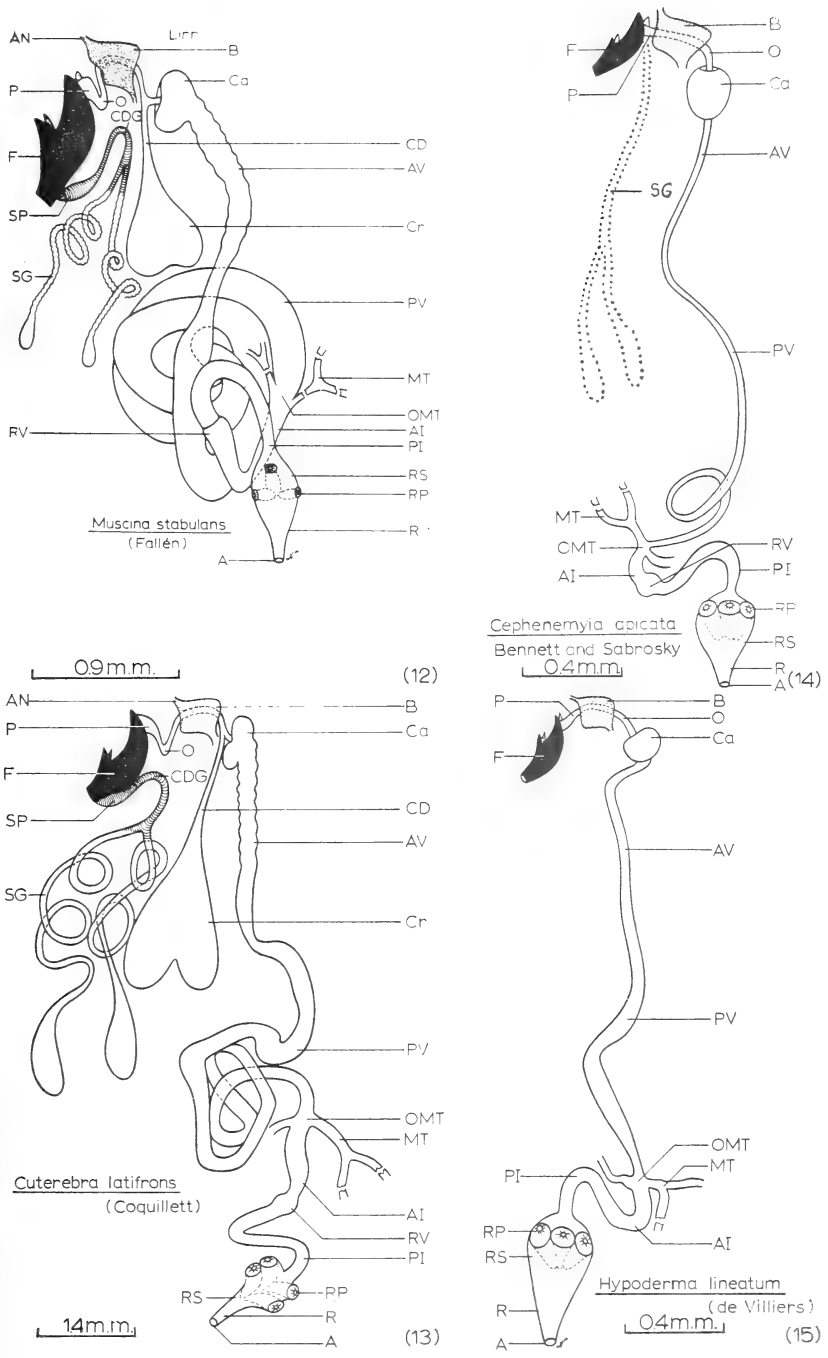
FIG. 3. Location of the alimentary canal in the body of a muscoid fly.



FIGS. 4-7. Anatomy of alimentary canal. Fig. 4. *Euxesta notata*. Fig. 5 *Bessa harveyi*. Fig. 6. *Pollenia rudis*. Fig. 7. *Calliphora vicina*.



FIGS. 8-11. Anatomy of alimentary canal. Fig. 8. *Sarcophaga haemorrhoidalis.* Fig. 9. *Phormia regina.* Fig. 10. *Musca domestica.* Fig. 11. *Glossina palpalis*



FIGS. 12-15. Anatomy of alimentary canal. Fig. 12. *Muscina stabulans*. Fig. 13. *Cuterebra latifrons*. Fig. 14. *Cephenemyia apicata*. Fig. 15. *Hypoderma lineatum*.

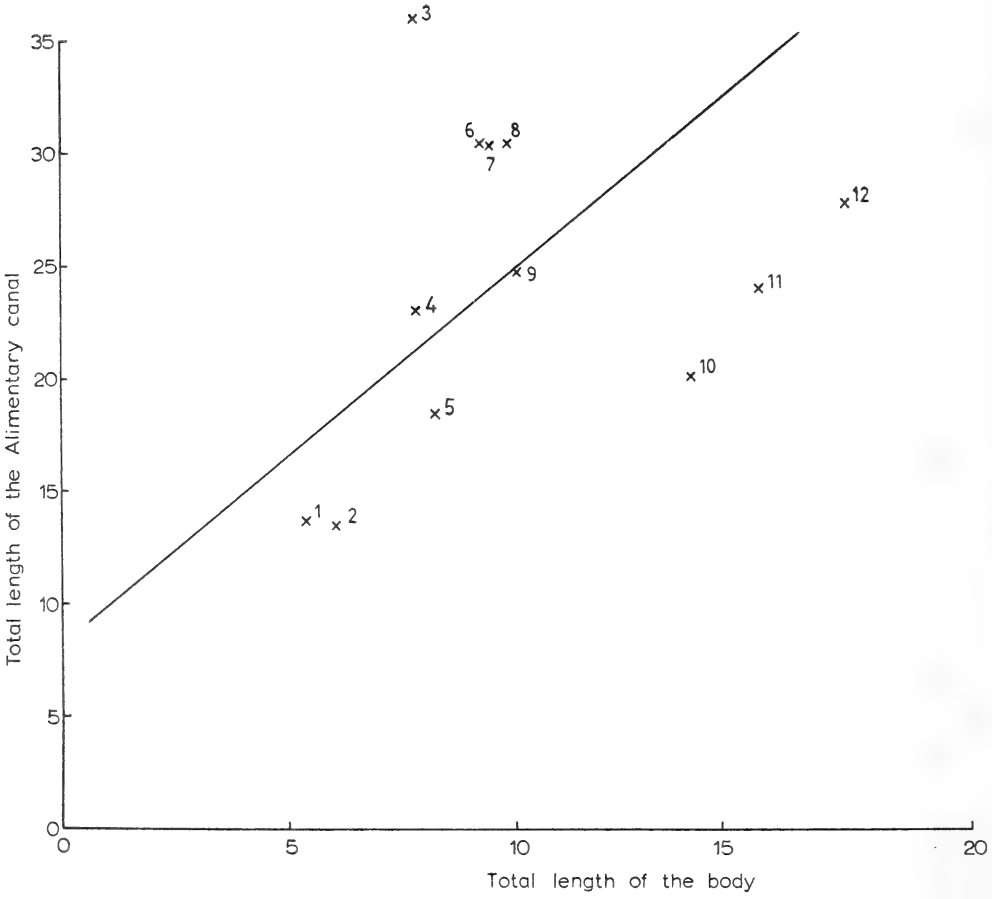


FIG. 16. Relationship of body length to total length of alimentary canal. 1—*Euxesta notata;* 2—*Bessa harveyi;* 3—*Musca domestica;* 4—*Muscina stabulans;* 5—*Pollenia rudis;* 6—*Calliphora vicina;* 7—*Glossina palpalis;* 8—*Phormia regina;* 9—*Sarcophaga haemorrhoidalis;* 10—*Hypoderma lineatum;* 11—*Cephenemyia apicata;* 12—*Cuterebra latifrons.*

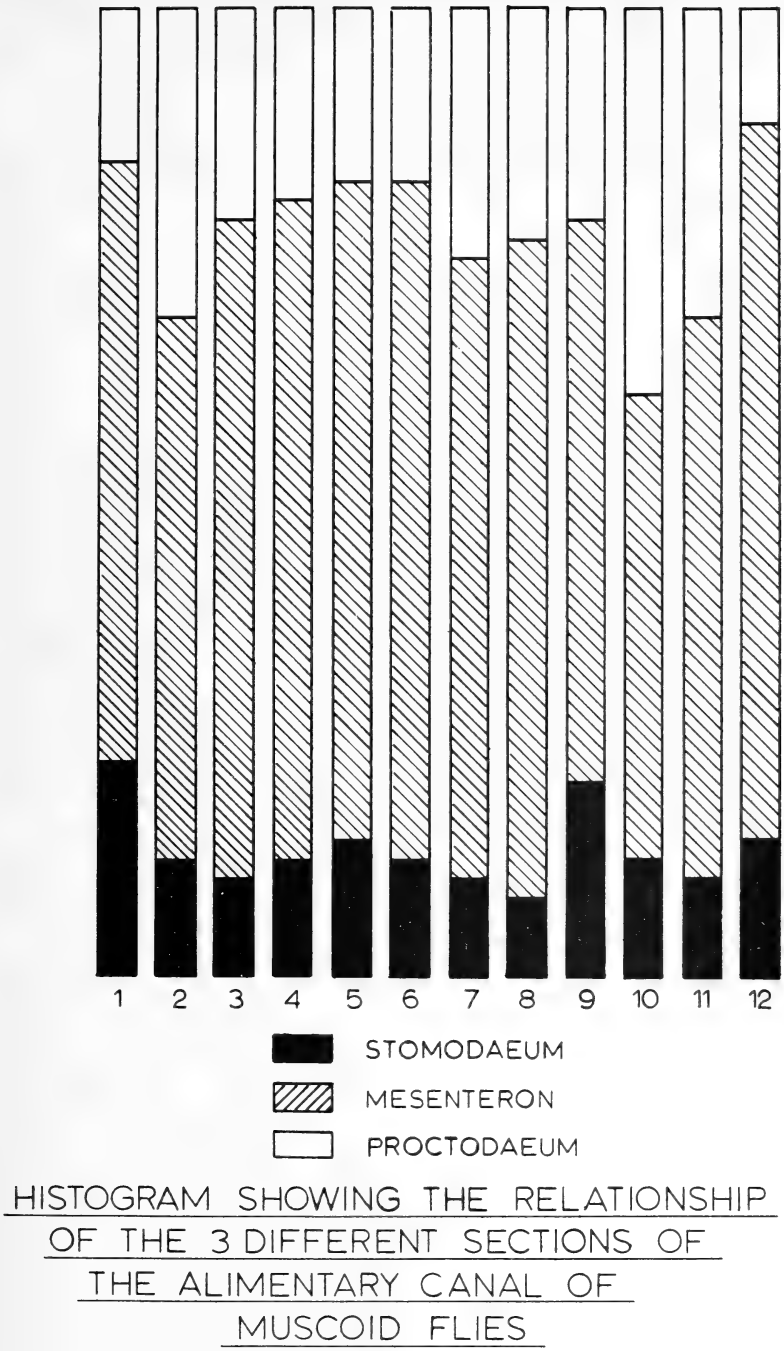
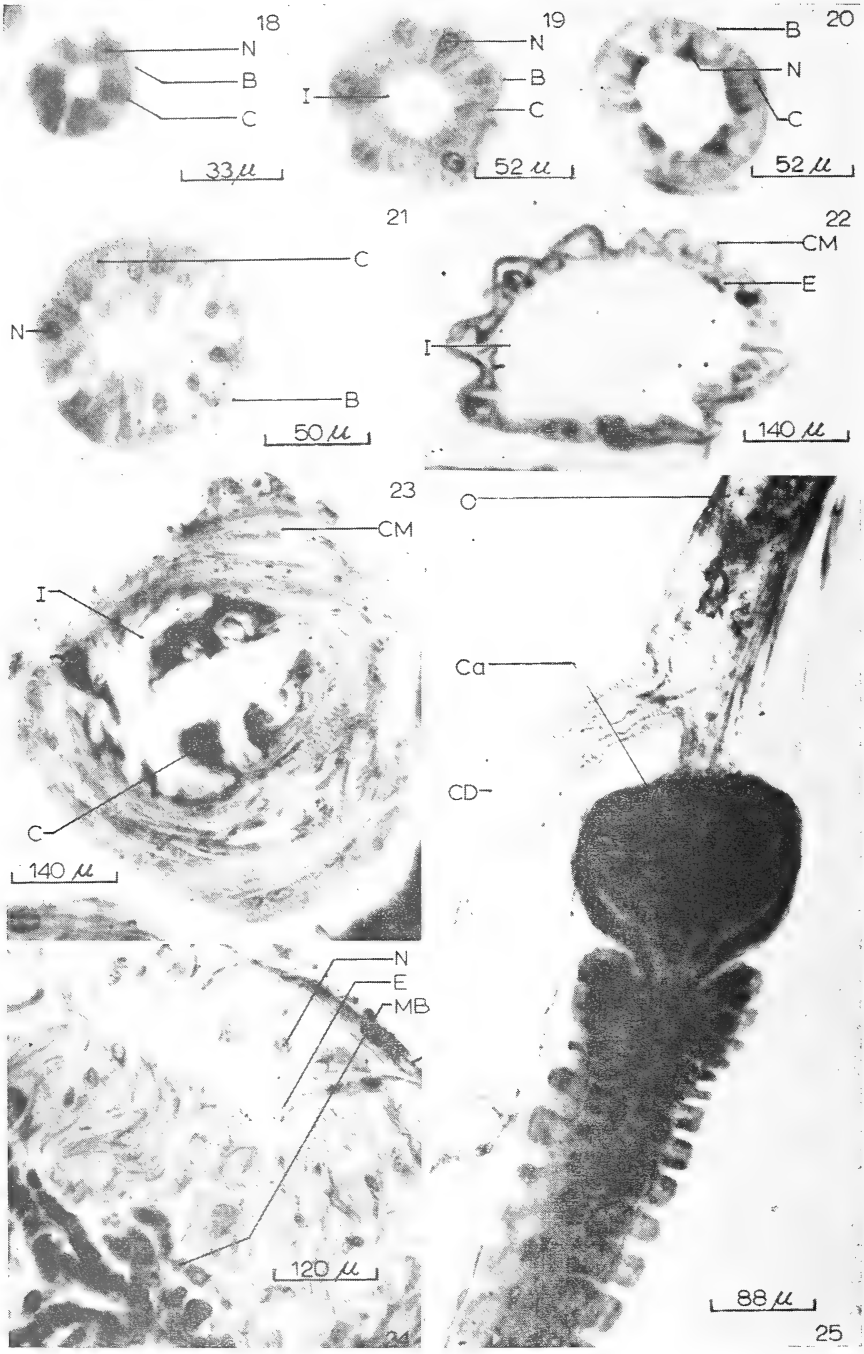
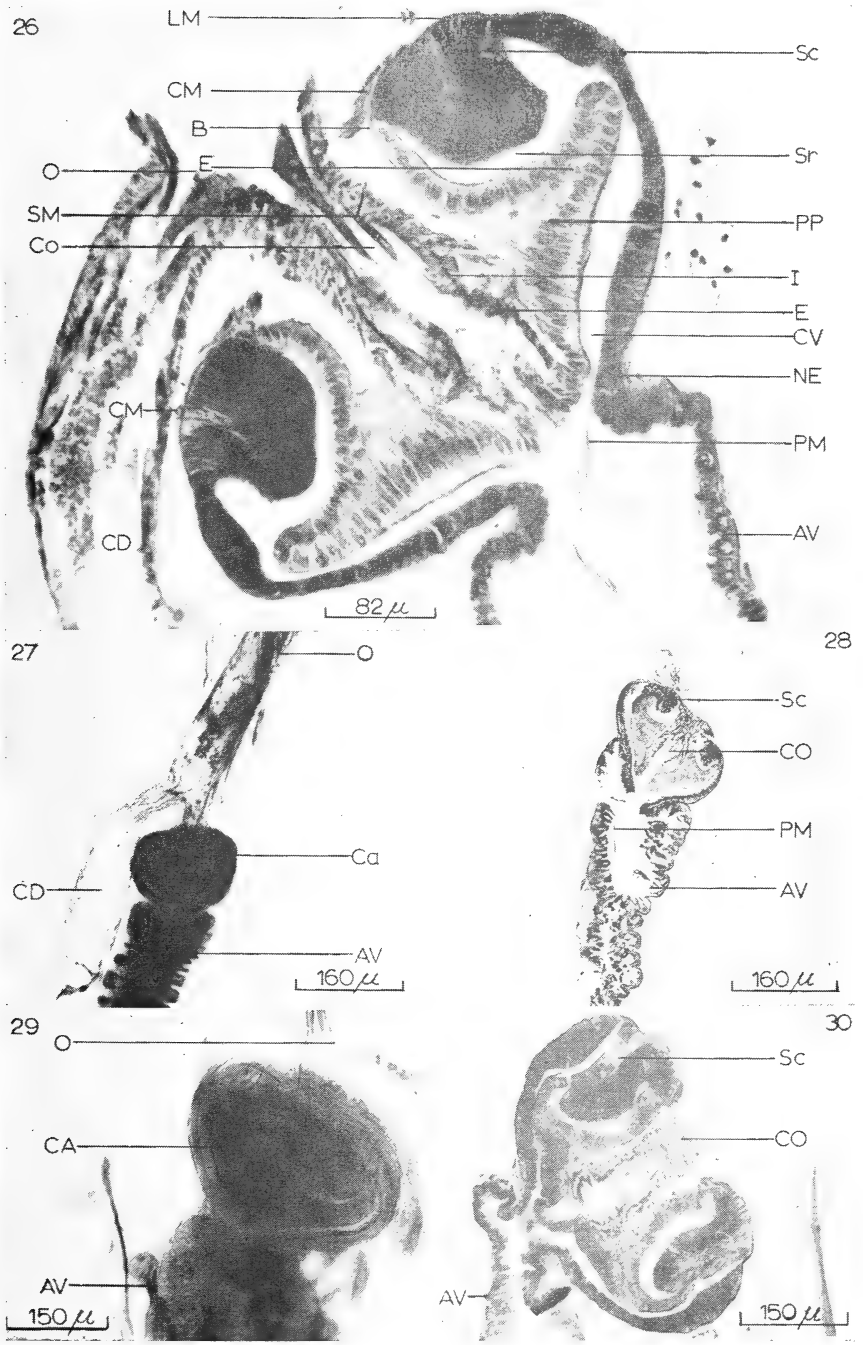


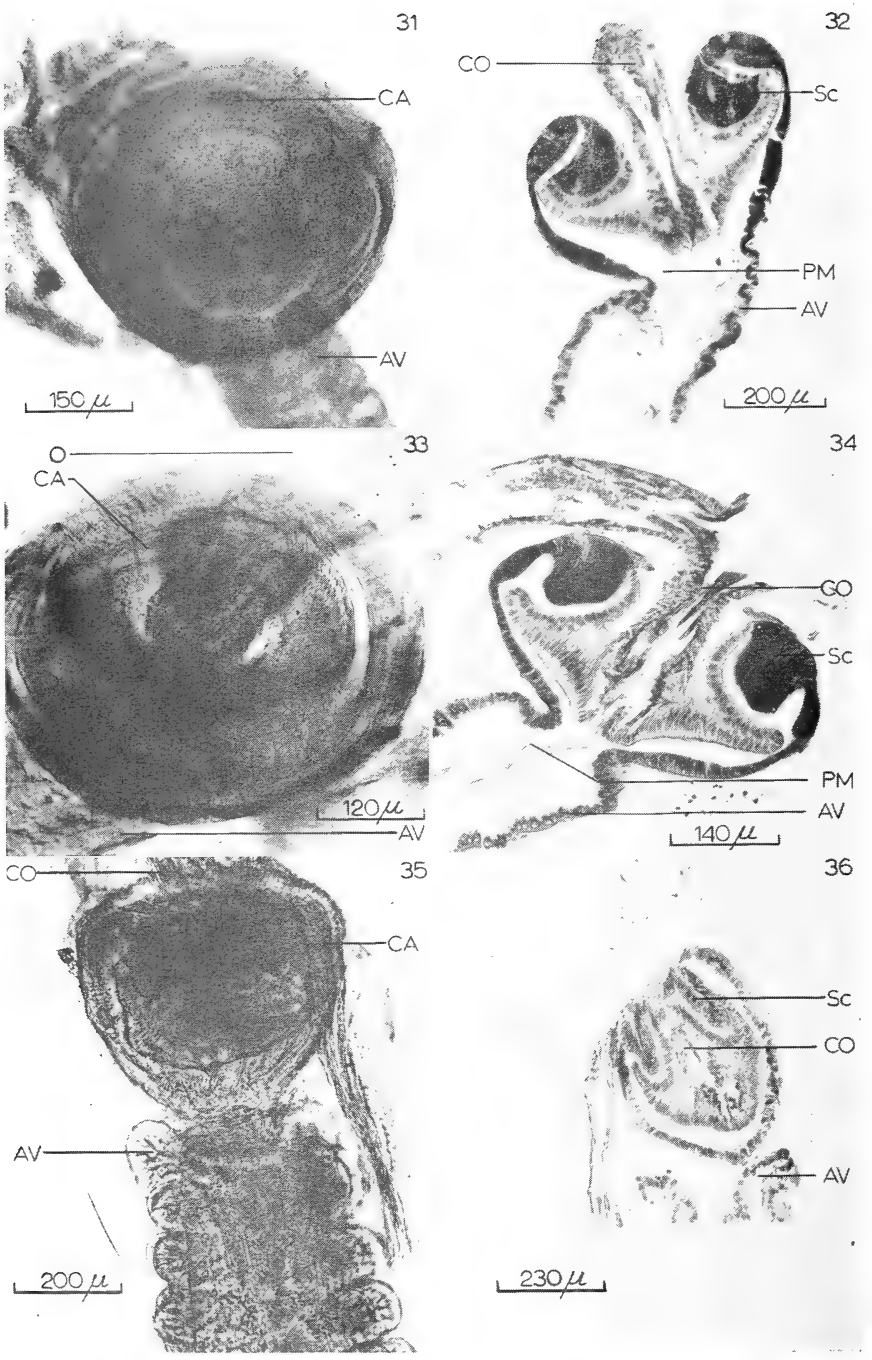
FIG. 17. Histogram showing relative length of the three parts of the alimentary canal of flies (numbering as in Fig. 16).



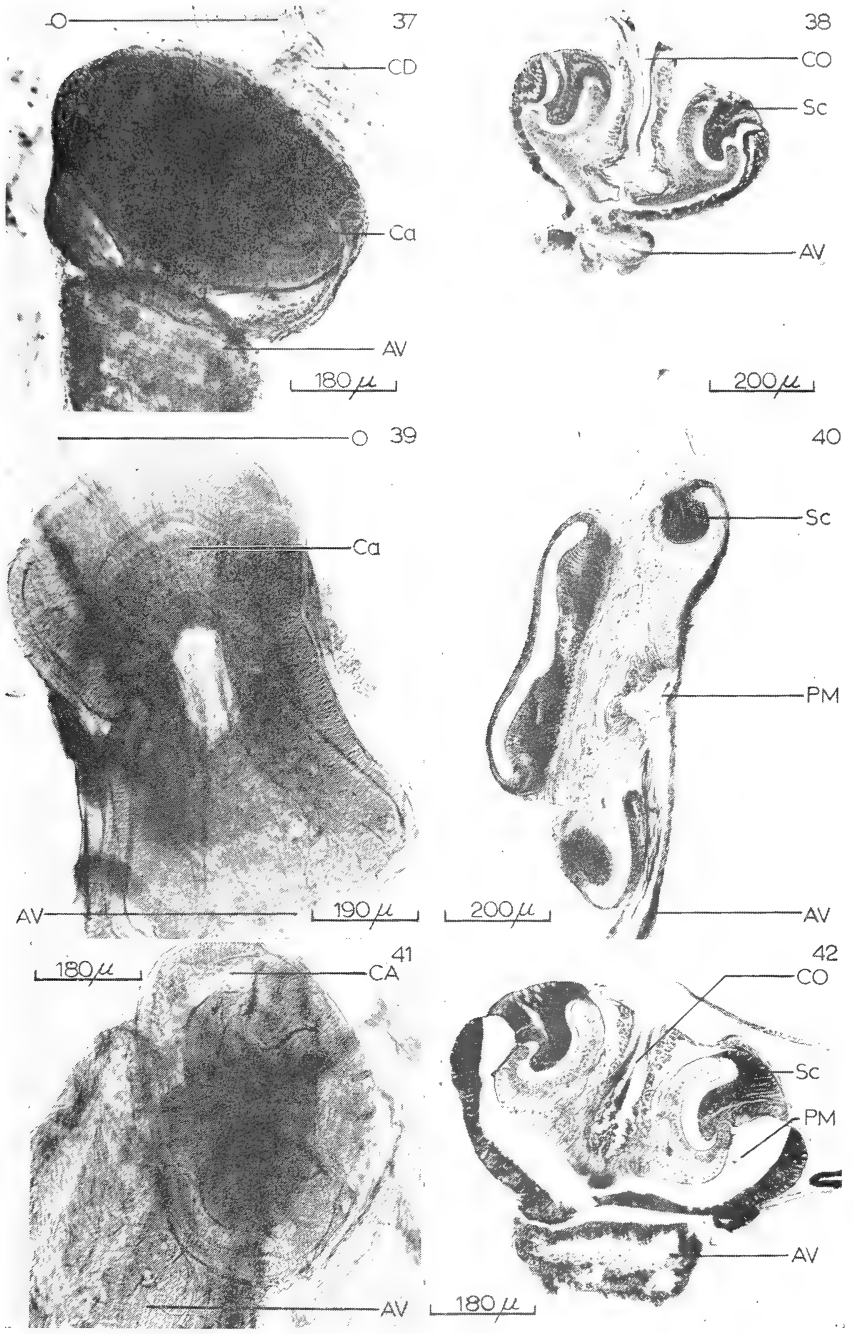
FIGS. 18-25. Photomicrographs of histological preparations. Fig. 18. Transverse section of salivary gland, *Euxesta notata*. Fig. 19. Transverse section of salivary gland, *Muscina stabulans*. Fig. 20. Transverse section of salivary gland, *Calliphora vicina*. Fig. 21. Transverse section of salivary gland, *Sarcophaga haemorrhoidalis*. Fig. 22. Transverse section of oesophagus, *Muscina stabulans*. Fig. 23. Transverse section of oesophagus, *Sarcophaga haemorrhoidalis*. Fig. 24. Transverse section of wall of crop, *Muscina stabulans*. Fig. 25. Whole mount of cardia, *Euxesta notata*.



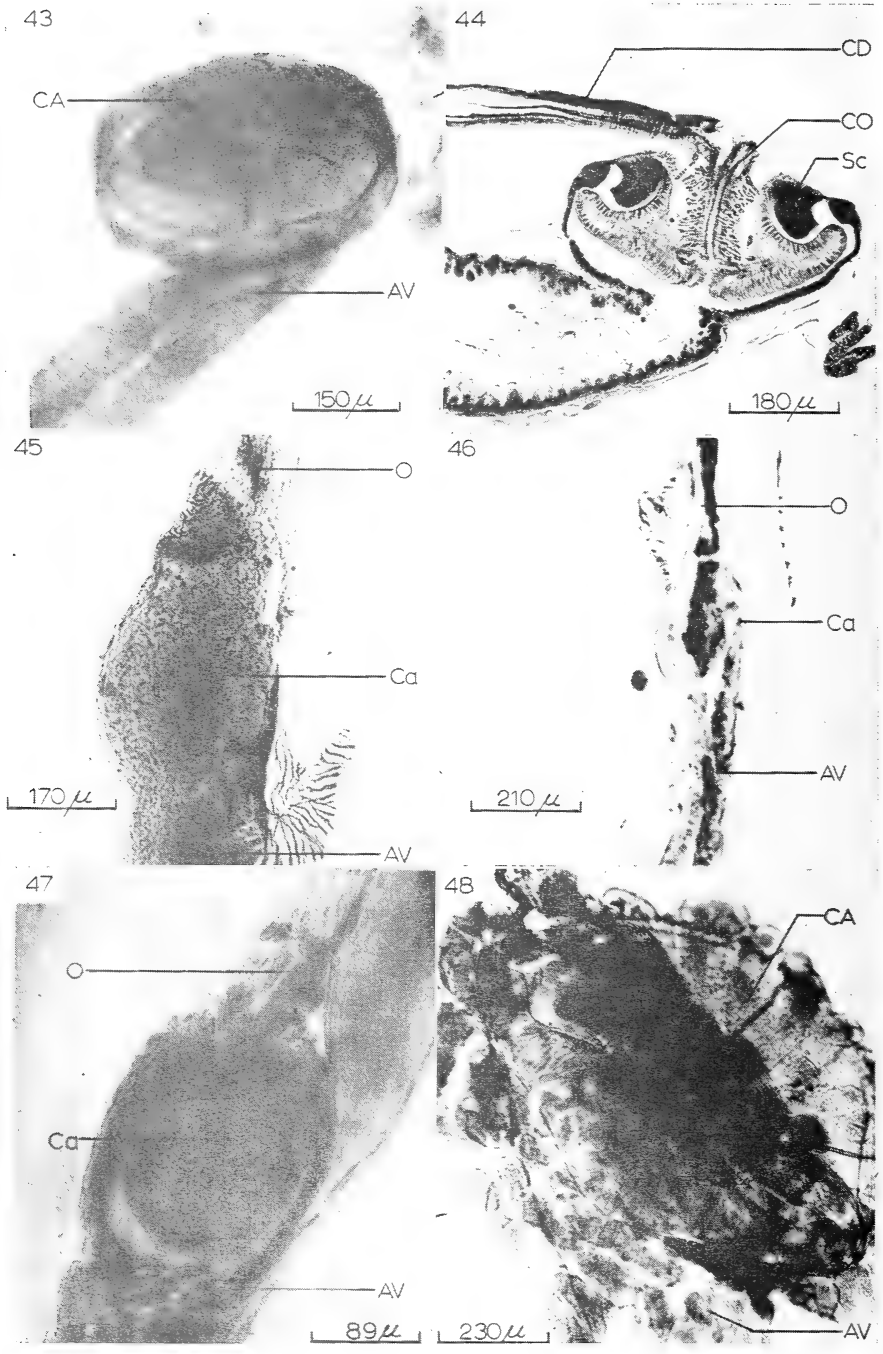
FIGS. 26-30. Photomicrographs of histological preparations. Fig. 26. Sagittal section of cardia, *Muscina stabulans*. Fig. 27. Whole mount of cardia, *Euxesta notata*. Fig. 28. Sagittal section of cardia, *Euxesta notata*. Fig. 29. Whole mount of cardia, *Bessa harveyi*. Fig. 30. Sagittal section of cardia, *Bessa harveyi*.



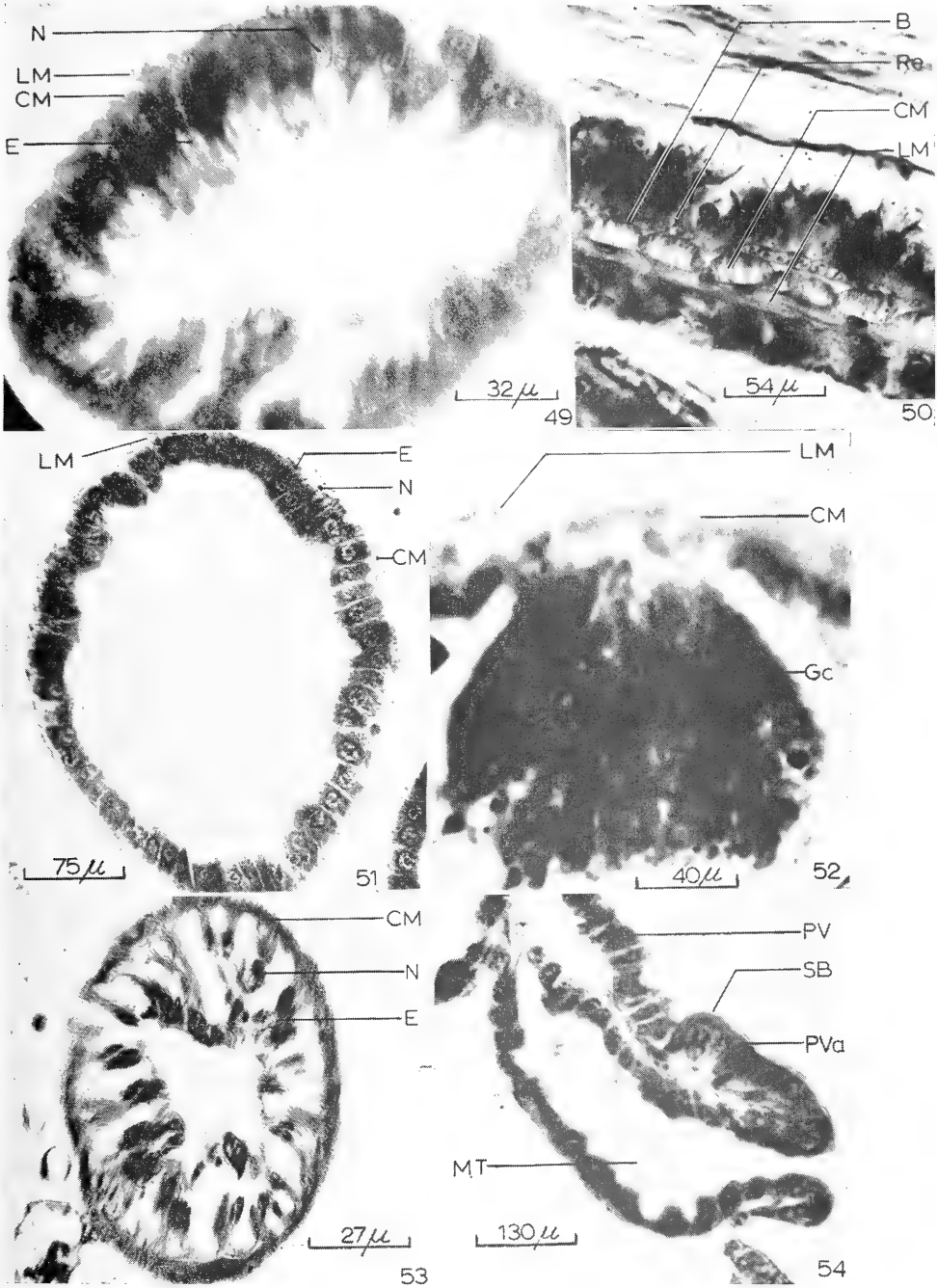
FIGS. 31-36. Photomicrographs of histological preparations. Fig. 31. Whole mount of cardia, *Musca domestica*. Fig. 32. Sagittal section of cardia, *Musca domestica*. Fig. 33, Whole mount of cardia, *Muscina stabulans*. Fig. 34. Sagittal section of cardia, *Muscina stabulans*. Fig. 35. Whole mount of cardia, *Pollenia rudis*. Fig. 36. Sagittal section of cardia, *Pollenia rudis*.



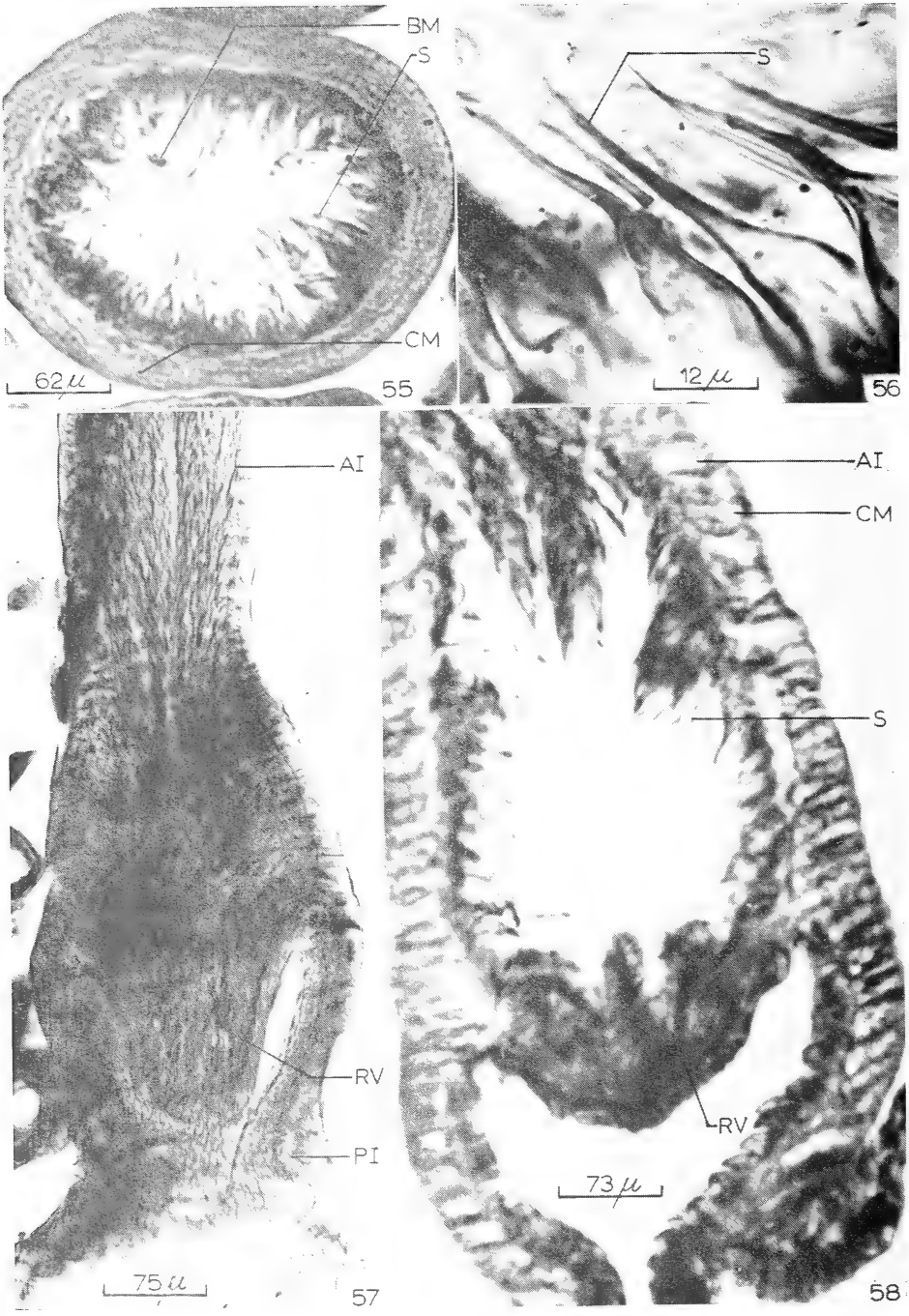
FIGS. 37-42. Photomicrographs of histological preparations. Fig. 37. Whole mount of cardia, *Calliphora vicina*. Fig. 38. Sagittal section of cardia, *Calliphora vicina*. Fig. 39. Whole mount of cardia, *Glossina palpalis*. Fig. 40. Sagittal section of cardia, *Glossina palpalis*. Fig. 41. Whole mount of cardia, *Phormia regina*. Fig. 42. Sagittal section of cardia, *Phormia regina*.



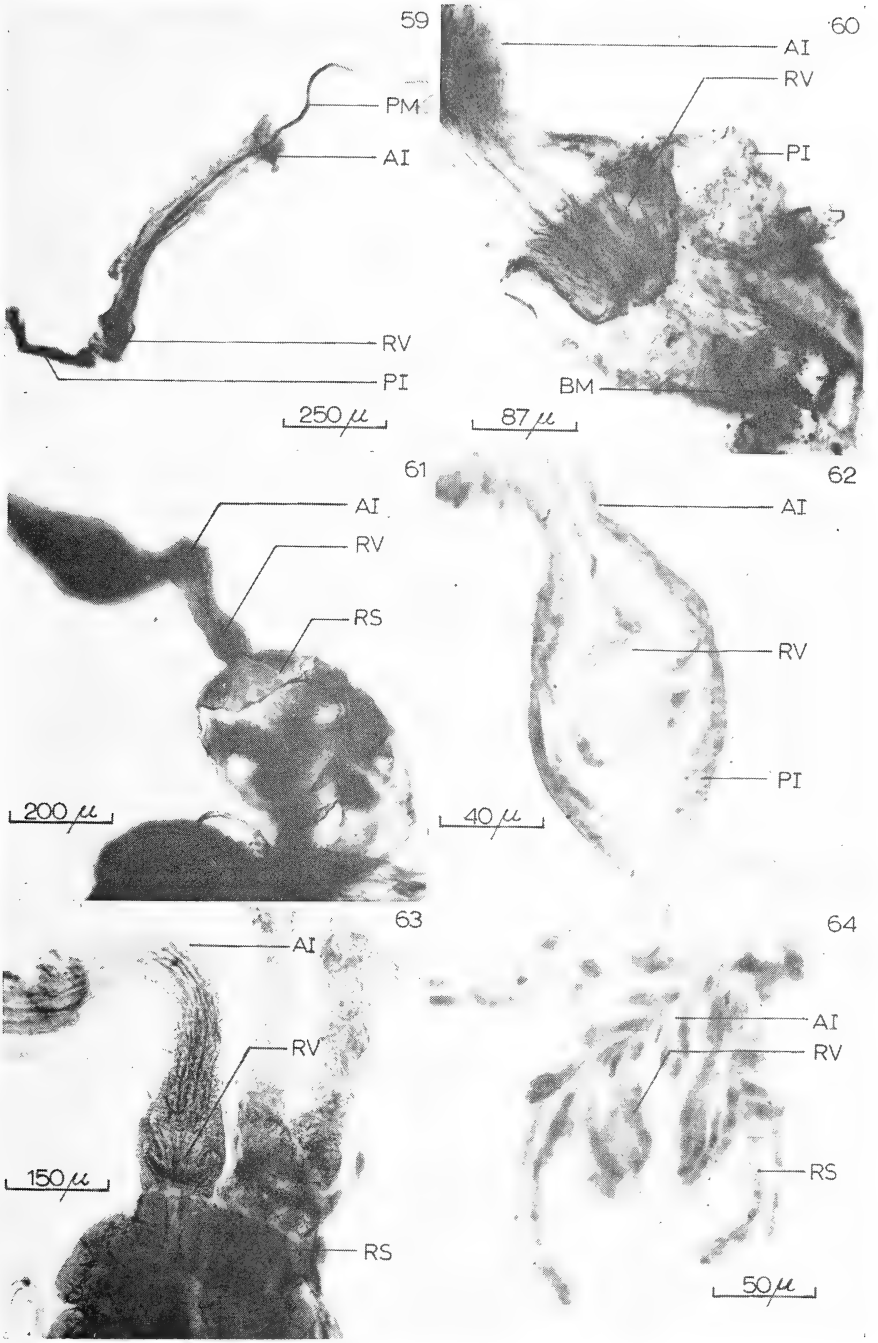
FIGS. 43-48. Photomicrographs of histological preparations. Fig. 43. Whole mount of cardia, *Sarcophaga haemorrhoidalis*. Fig. 44. Sagittal section of cardia, *Sarcophaga haemorrhoidalis*. Fig. 45. Whole mount of cardia, *Hypoderma lineatum*. Fig. 46. Sagittal section of cardia, *Hypoderma lineatum*. Fig. 47. Whole mount of cardia, *Cephenemyia apicata*. Fig. 48. Whole mount of cardia, *Cuterebra latifrons*.



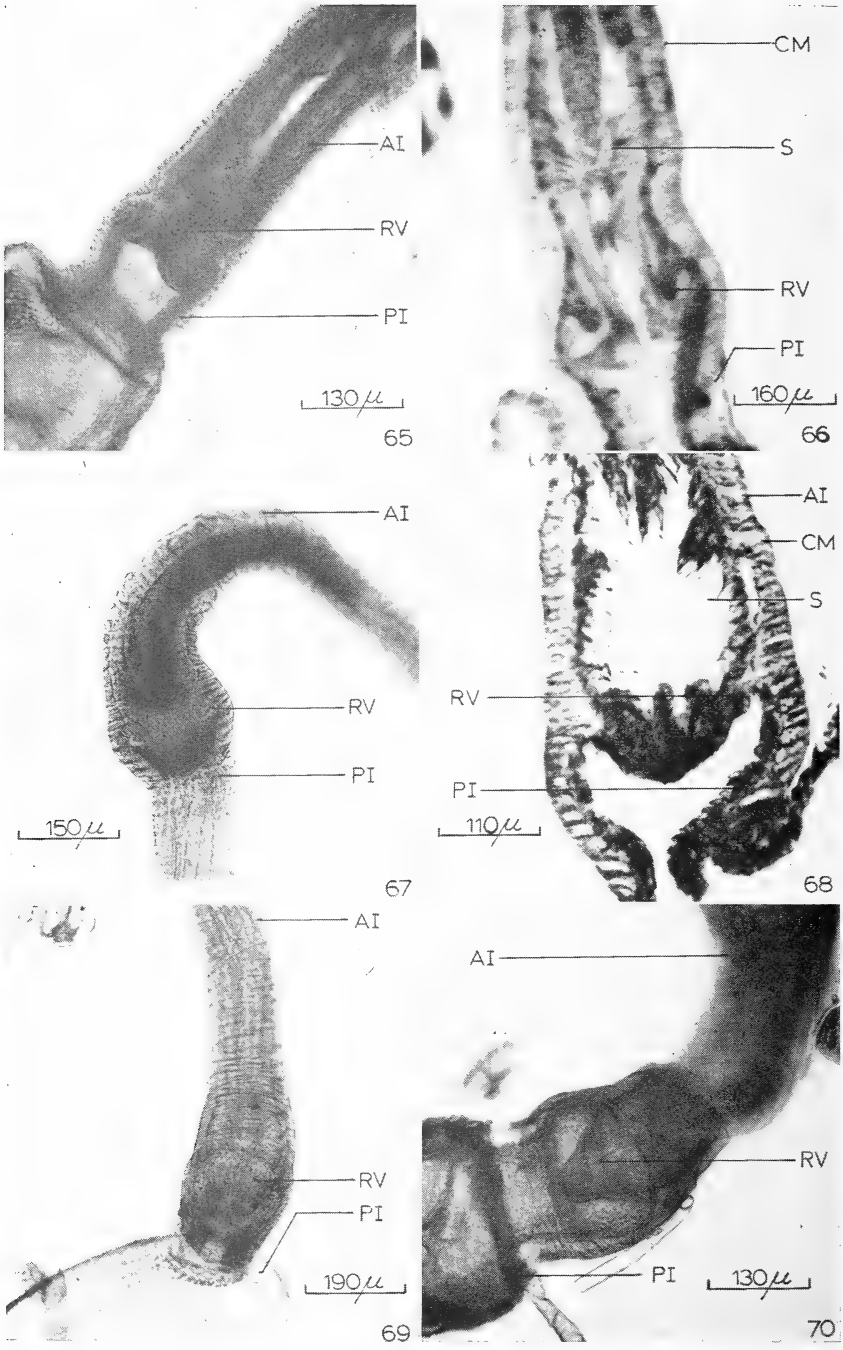
FIGS. 49-54. Photomicrographs of histological preparations. Fig. 49. Transverse section of anterior ventriculus, *Muscina stabulans*. Fig. 50. Transverse section of anterior ventriculus, showing regenerative cells, *Muscina stabulans*. Fig. 51. Transverse section of posterior ventriculus, *Muscina stabulans*. Fig. 52. Transverse section of ventriculus, showing giant cells, *Glossina palpalis*. Fig. 53. Transverse section of anterior ventriculus, *Hypoderma lineatum*. Fig. 54. Longitudinal section of pyloric valve, *Muscina stabulans*.



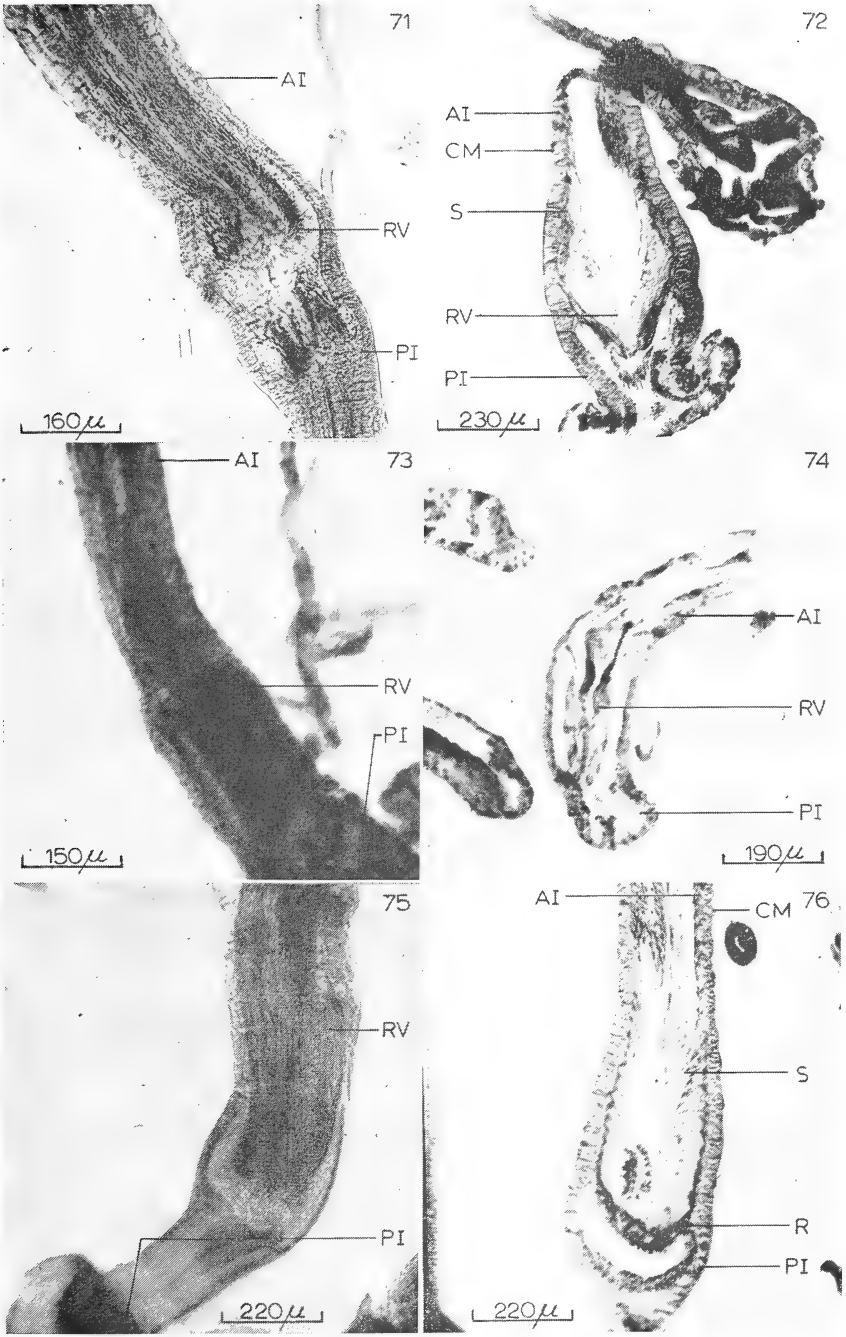
FIGS. 55-58. Photomicrographs of histological preparations. Fig. 55. Transverse section of anterior intestine, *Muscina stabulans*. Fig. 56. Spines in anterior intestine, *Muscina stabulans*. Fig. 57. Whole mount of rectal valve, *Cuterebra latifrons*. Fig. 58. Longitudinal section of rectal valve, *Muscina stabulans*.



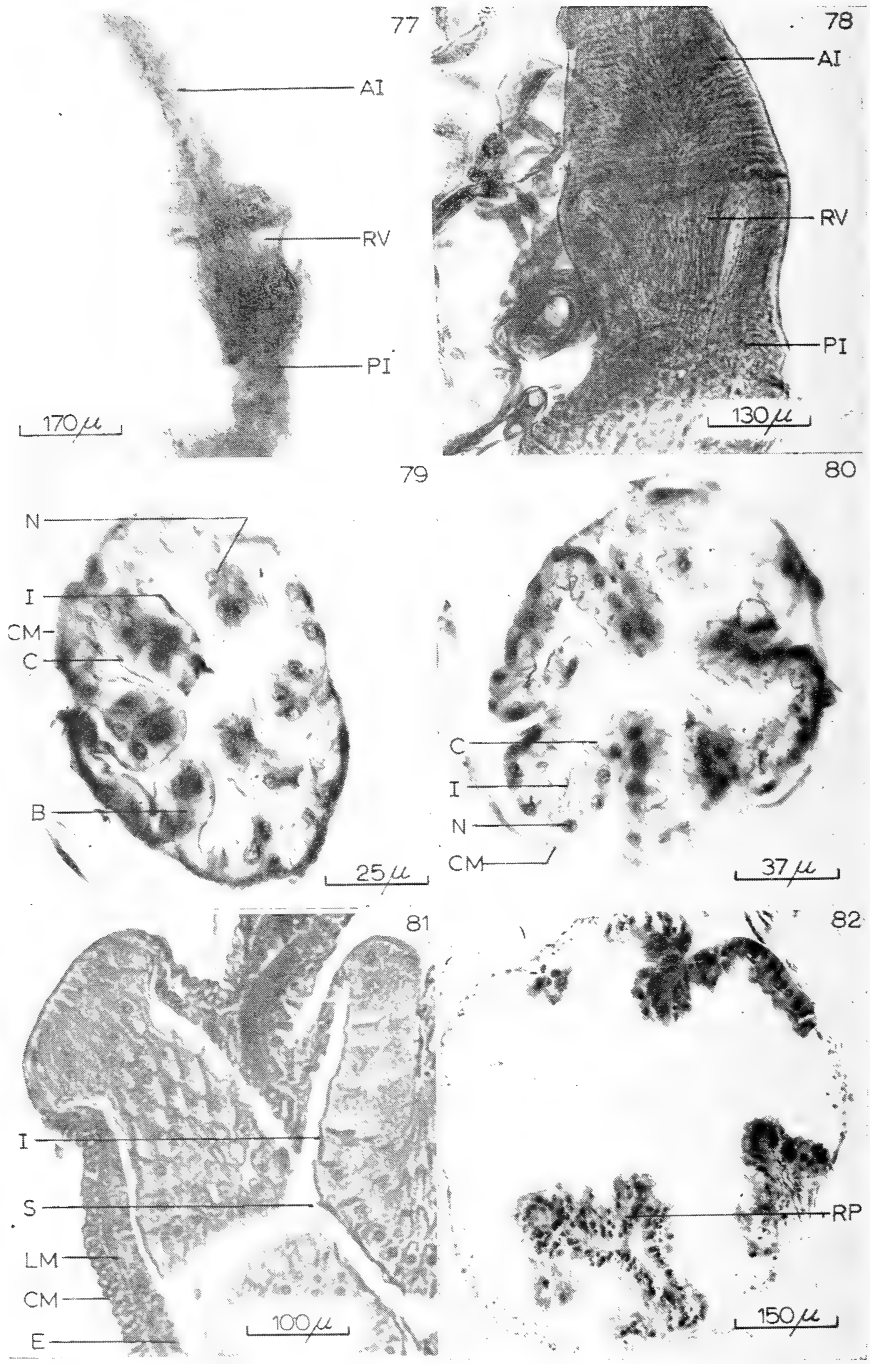
FIGS. 59-64. Photomicrographs of histological preparations. Fig. 59. Whole mount of cuticular lining of proctodaeum and peritrophic membrane, *Muscina stabulans*. Fig. 60. Whole mount of rectal valve, showing broken peritrophic membrane, *Muscina stabulans*. Fig. 61. Whole mount of rectal valve, *Euxesta notata*. Fig. 62. Longitudinal section of rectal valve, *Bessa harveyi*. Fig. 64. Longitudinal section of rectal valve, *Bessa harveyi*.



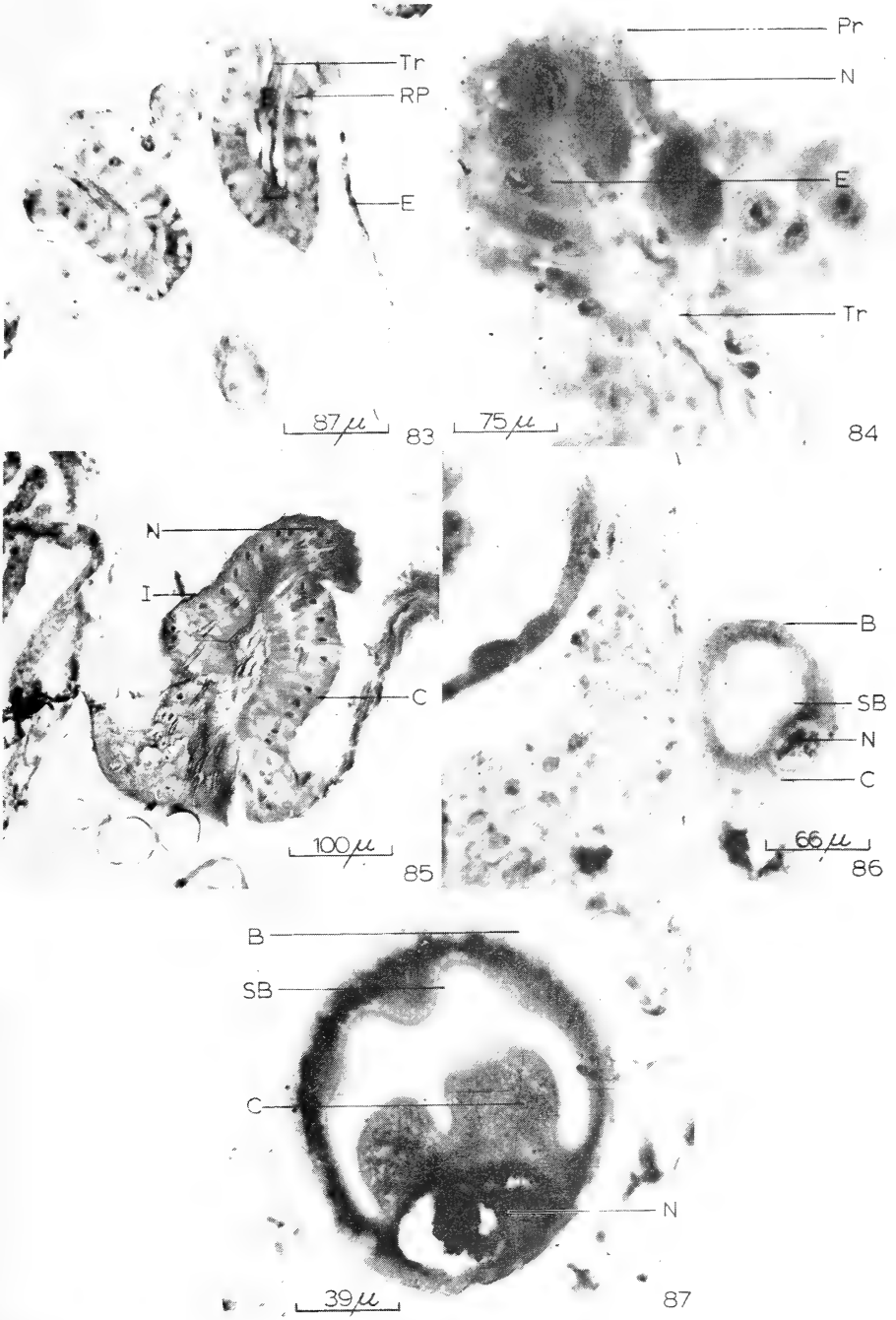
FIGS. 65-70. Photomicrographs of histological preparations. Fig. 65. Whole mount of rectal valve, *Musca domestica*. Fig. 66. Longitudinal section of rectal valve, *Musca domestica*. Fig. 67. Whole mount of rectal valve, *Muscina stabulans*. Fig. 68. Longitudinal section of rectal valve, *Muscina stabulans*. Fig. 69. Whole mount of rectal valve, *Phormia regina*. Fig. 70. Whole mount of rectal valve, *Pollenia rudis*.



FIGS. 71-76. Photomicrographs of histological preparations. Fig. 71. Whole mount of rectal valve, *Calliphora vicina*. Fig. 72. Longitudinal section of rectal valve, *Calliphora vicina*. Fig. 73. Whole mount of rectal valve, *Glossina palpalis*. Fig. 74. Longitudinal section of rectal valve, *Glossina palpalis*. Fig. 75. Whole mount of rectal valve, *Sarcophaga haemorrhoidalis*. Fig. 76. Longitudinal section of rectal valve, *Sarcophaga haemorrhoidalis*.



FIGS. 77-82. Photomicrographs of histological preparations. Fig. 77. Whole mount of rectal valve, *Cephenemyia apicata*. Fig. 78. Whole mount of rectal valve, *Cuterebra latifrons*. Fig. 79. Transverse section of posterior intestine, *Muscina stabulans*. Fig. 80. Transverse section of posterior intestine, *Hypoderma lineatum*. Fig. 81. Longitudinal section of rectal sac, *Muscina stabulans*. Fig. 82. Transverse section of rectal sac, *Hypoderma lineatum*.



FIGS. 83-87. Photomicrographs of histological preparations. Fig. 83. Longitudinal section of rectal sac (distended), *Muscina stabulans*. Fig. 84. Longitudinal section of rectal papilla, *Hypoderma lineatum*. Fig. 85. Longitudinal section of rectal papilla, *Cuterebra latifrons*. Fig. 86. Transverse section of Malpighian tubule, *Muscina stabulans*. Fig. 87. Transverse section of Malpighian tubule, *Hypoderma lineatum*.

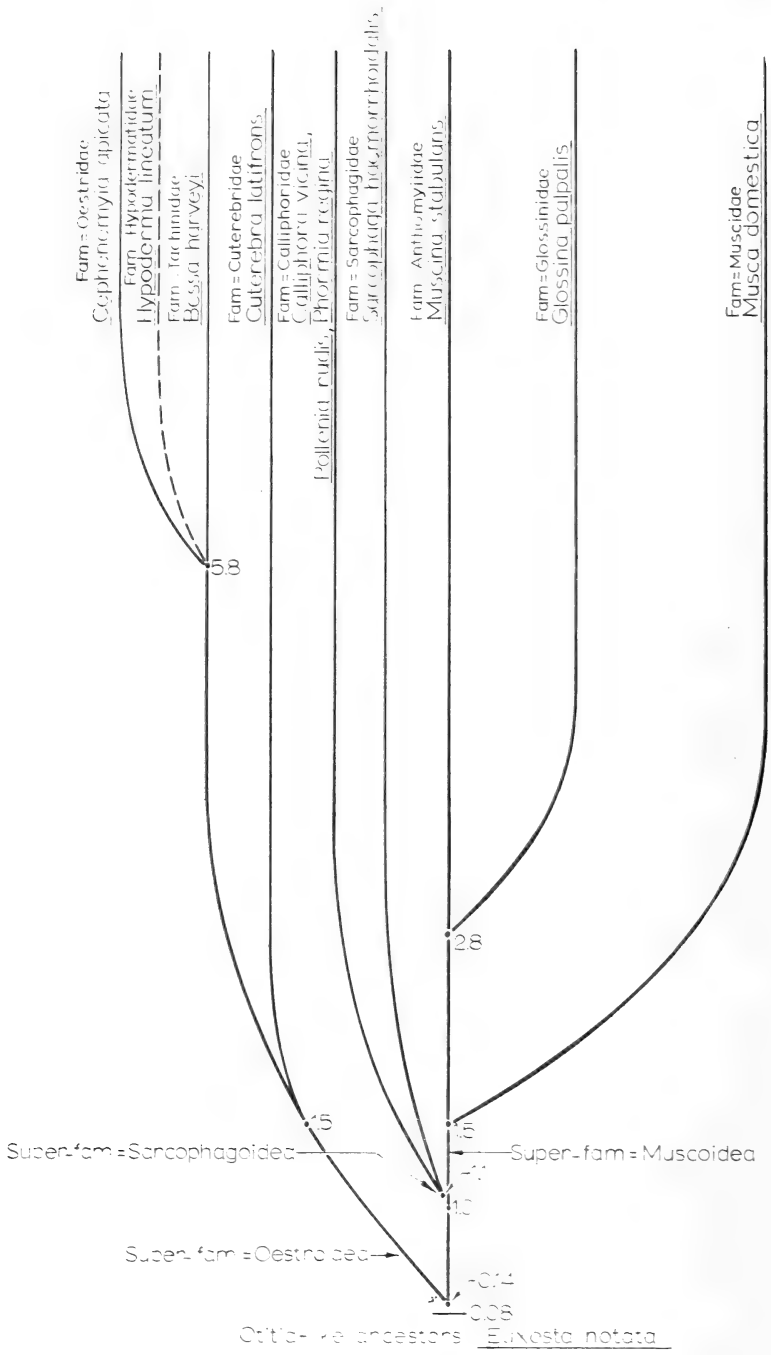


FIG. 88. Phylogenetic tree of calyptrate Muscoidea based upon morphology and distance of rectal valve from rectal sac. (mm.).

SOME METHODS OF REARING AND COLLECTING BLACK FLIES (DIPTERA : SIMULIIDAE)[1]

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The procurement and appropriate preservation of an adequate series of specimens is important in taxonomic studies of black flies. Often more than one stage is necessary for identification, especially among sibling species, and rearing adults from pupae, larvae or even eggs may be essential. In addition, the ability to rear the immature stages in the laboratory is important to a study of their biology. In this paper some of the techniques that have proved helpful to us are described. The first section presents new modifications to laboratory trough-rearing methods that have permitted greater success in rearing larvae, while suggestions advanced in the remaining parts deal with the obtaining of eggs from adults, the collection of immature stages, the rearing of large numbers of pupae and the preservation of larvae and adults.

Rearing Larvae in Artificial Streams

Introduction

Several techniques have been devised for the laboratory rearing of black-fly larvae from eggs or first instars to maturity. Doby, *et al.*, (1959) have reviewed these methods, all of which use an artificial current of water, and have classified them into two groups, those in which an unchanged quantity of water is recirculated in a closed system, and those in which the water is continually renewed. These authors presented several refinements to the method, introduced by Puri (1925) and modified by Smart (1934), of creating a water current in a container with a rising stream of air bubbles from a source of compressed air. Hocking and Pickering (1954) also explored variations in this method, and Odintsov (1960) described a portable device for aerating larvae in the field and during transportation. Fredeen (1959a) introduced additional methods of inducing a current in a cylindrical container, by shaking horizontally the platform on which the container was fastened, and by rotating the container itself. In the former, the larvae attached themselves to the side of the container and the water moved past them, while in the latter both the container and the water moved and a stationary central rod with attached plates, suspended from above, served as a support for the larvae. Wright (1957) directed a flow of water through an inclined trough in which egg masses were placed. The water was collected below and recirculated by an electric pump. Hall and Harrod (1963) added a reservoir above the trough and were thus able to vary the volume of flow.

Apparently only two authors have reported methods using continuously renewed water (Thomas, 1946; Hartley, 1955). These authors used a source of natural water pumped from a nearby lake, and directed it through a wooden trough

[1]Contribution of Department of Biology, McMaster University, Hamilton, Canada.

(Thomas) or over the side of a bottle (Hartley). The yield of adults was not given, but neither reported a high mortality of larvae. Dalmat (1955), using Thomas' method, obtained five adults from 300 eggs of *S. metallicum* Bellardi.

It is impossible to compare properly the success of these different methods because different species were used. In general, however, species that were found in warm, relatively slow streams were the most easily reared. Fredeen (1959a) reported a maximum of 42 adults of *S. vittatum* Zett. per 100 first instars, while Smart (1934) had 10% success and Hall and Harrod (1963) about 20% success in rearing *S. ornatum* Mg. Some species were more difficult to rear; Fredeen (1959a) obtained a maximum of less than three adults per 100 first instars of *S. articum* Mall., and Wright (1957) gleaned only eight pupae from approximately 10,000 eggs of *S. damnosum* Theobold, in spite of his efforts to replace the water every two days with fresh river water.

Several of the methods of rearing adults from eggs or young larvae have been used at McMaster University, Hamilton. An apparatus, set up in a cool constant temperature room and involving troughs, recirculation pumps, adjustable-flow head tanks, and temperature-controlled water (Davies, unpublished notes)[1] gave promise of success, but for the inconstancy of electric power. The apparatus below is derived from this earlier model but uses a continually renewed supply of tap water, rendered suitable by a carbon-sand filter, and thus avoids reliance on electric power for water flow.

Description of the apparatus

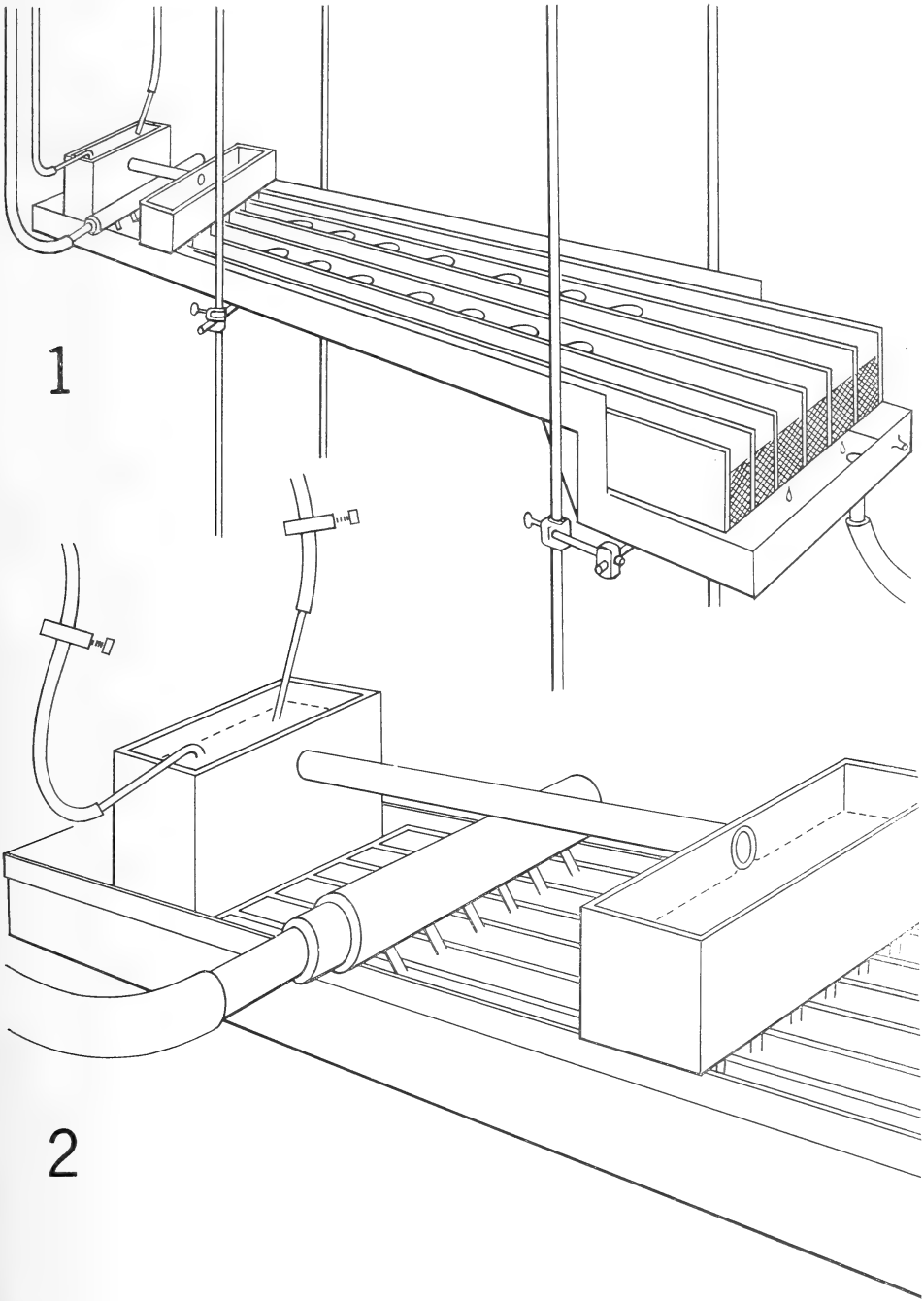
The apparatus consisted of four interconnected components; a filter, a tank serving as a reservoir for filtered water, troughs containing the larvae, and an apparatus for dispensing a dilute suspension of yeast to the troughs.

The tank for filtering the tap water was a vertical rectangular chamber (5 X 2 X 2 ft) with ⅓-inch thick acrylic plastic walls, and contained about 12 ft^3 of activated granular carbon[2], suitable for dechlorination, held in place by sand and gravel above and below. Tap water carried from city mains to the laboratory in galvanized iron pipes, entered the bottom of the tank and passed up through the carbon core. Air, coming out of solution, was forced up by rising water and allowed to escape at the top. The filtered water overflowed through a black polyvinyl chloride pipe, 1½-inch inside diameter, into an acrylic plastic storage tank. The water in this tank was maintained at a depth of 10 inches to provide a uniform head pressure. Both the filter and the storage tank were enclosed in black cloth to exclude light, thus inhibiting algal growth. The troughs for rearing the larvae were ½ inch wide, 1 inch deep, and 4 feet long, and each had a flat bottom and vertical sides. Ten or 11 troughs were assembled together as a unit, and two units (21 troughs in all) were supported, 2 to 3 ft below the water level of the storage tank, in a single, galvanized iron pan and serviced by a single manifold (Fig. 1). Each manifold was an acrylic plastic tube, 1 inch inside diameter, with a row of 1/16-inch holes each fitted with a 1-inch length of plastic tube to direct the flow of water into each trough (Fig. 2). Each small tube was kept clear of the sides and bottom of the trough, otherwise larvae migrated into the manifold. Clean, small pebbles were placed along each trough at intervals of 2 to 4 inches to provide a variety of current velocities and of attachment sites for the larvae. The troughs were usually inclined at a slope of 1 inch in 36 inches. The foot of each trough was deepened into a reservoir terminating in a stainless steel screen (100 mesh per inch). This prevented the escape of larvae, except those in the first two instars.

[1]Demonstration at 8th Technical Session of Advisory Committee on Fisheries and Wildlife Research, Research Council of Ontario, Kingston, Ontario, February 1954.

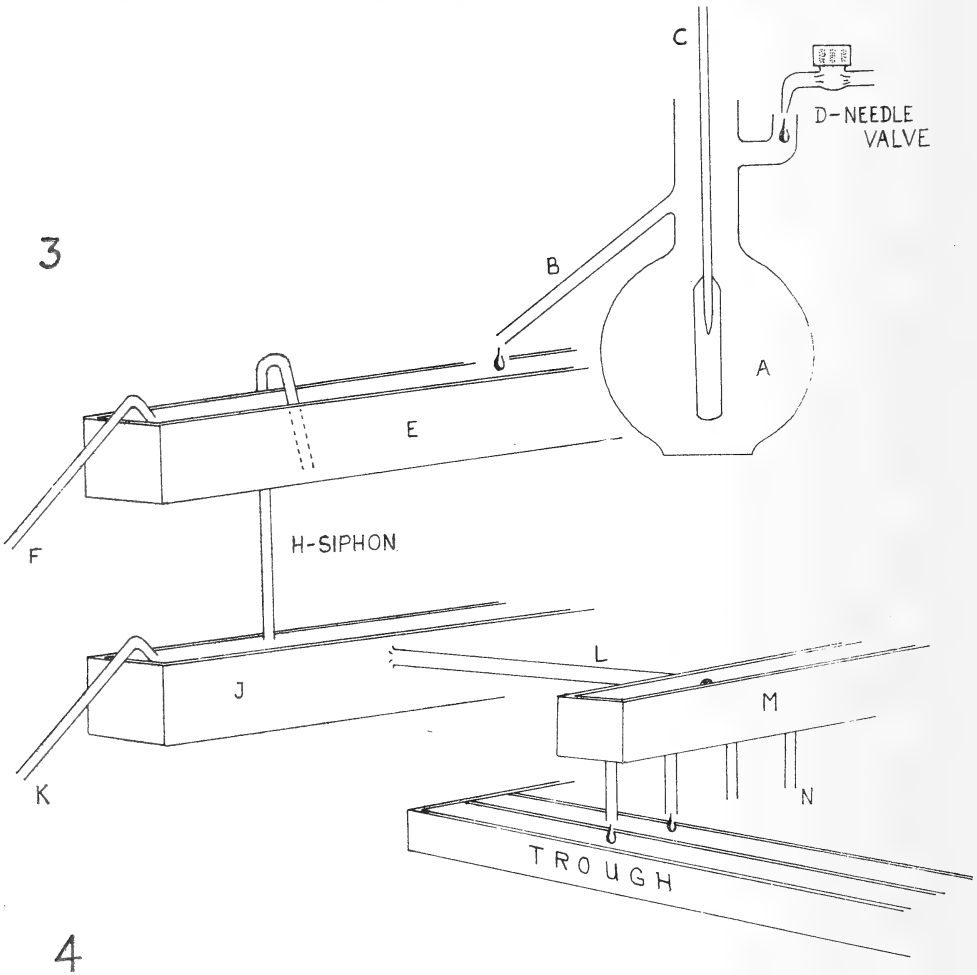
[2]Made from coke by Atlas Powder Co., Brantford, Ontario.

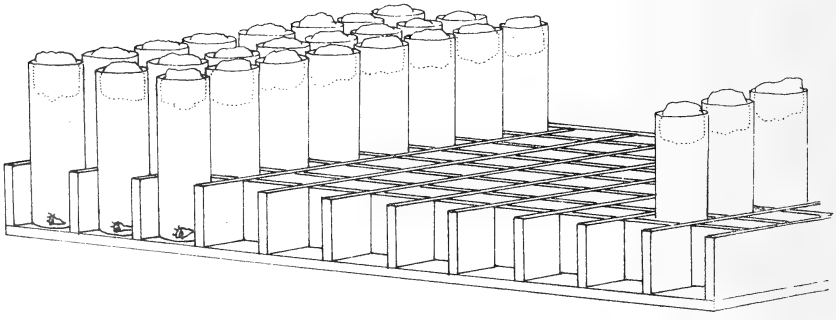
The temperature of the water varied between 60-70°F in the summer and between 40-60°F over the rest of the year.



FIGS. 1-2. Trough-rearing apparatus. 1. Diagram of complete apparatus. 2. Manifolds for releasing filtered water and yeast suspension.

The larvae were fed baker's yeast exclusively. Each day ½ lb of moist yeast cake was suspended in filtered water with an electric food blender, and then released by separate apparatus which could be regularly dismantled for cleaning





FIGS. 3-4. 3. Complete system for releasing yeast suspension. 4. Tray for rearing pupae individually.

without interrupting the water flow in the troughs. The feeding apparatus consisted of three parts: a container for the concentrated yeast suspension, a series of small tanks for dilution, and a manifold for releasing the diluted suspension at the desired rate into each trough (Fig. 3). Concentrated yeast in a glass Florence flask (A) was kept in continual suspension by an electrically driven stirring rod (C) or by a carefully regulated stream of air bubbles. Water was admitted by a valve (D) through an upper side arm into the flask, one drop per 2-10 sec, the rate depending on the number of larvae being reared. The resulting overflow from the lower side arm (B) of the flask collected in a small acrylic plastic tank (E), measuring 6 X 2 X 4 inches. The yeast suspension in container E was greatly diluted by filtered water (F); the excess overflowed into the drain. The diluted suspension was drawn from tank E by one or more siphons (H). Each siphon, controlled by a Hoffman clamp, conveyed the suspended food to another small container (J), similar to E, where it was further diluted by more filtered water from tube K. This suspension overflowed from J through a plastic tube (L), of ¼-inch inside diameter, to an acrylic plastic manifold (M), which was located above each group of troughs. Above each trough was a 1/32-inch hole in the manifold (M) and the suspension was conveyed to the trough by a short plastic tube (N) of ⅛-inch inside diameter. The rate of flow of the suspension into the stream varied directly with the level of suspension in the manifold. This level was controlled by regulating, with a Hoffman clamp, the amount of water entering through K.

The feeding apparatus described above supplied only the rack of 21 troughs. When it was necessary to install another rack, an additional siphon (H) was added to draw off more suspension from container E, and the apparatus from J to N was duplicated. It was then necessary to increase the flow of water at both D and F. When both racks were in operation the supply of baker's yeast in flask A had to be renewed twice daily.

The components of the feeding apparatus were dismantled and cleaned once a week. It was also necessary to clean the screening at the bottom of the troughs every day or two by brushing the outside surface with a test-tube brush to dislodge any detritus from the screening.

When the larvae were mature, some were removed for preservation (see below) and for fixation in Carnoy's solution for cytological study (Rothfels and Dunbar, 1953), and the remaining larvae were left to pupate.

Results and Discussion

Adults of *Simulium aureum* Fries (mainly form A (Dunbar, 1958)), were reared from over 150 batches of eggs, with 300-800 eggs in each. The yield was as high as 80% and usually at least 50-60%. *S. vittatum* and *S. verecundum* S. & J. were also frequently reared from the egg. In addition, adults of the following species have been obtained from first and second instars: *Prosimulium fuscum* S. and D., *P. gibsoni* (Tw.), *P. magnum* D. and S., *Cnephia mutata* (Mall.), *Simulium pugetense* (D. and S.), and *S. pictipes* Hagen. Preference for current velocity in nature varies considerably among these species. One *(S. pictipes)* inhabits only large waterfalls, and larvae of this species appeared unsettled in the artificial streams, many moving from place to place perhaps in search of faster water. Nevertheless, a number pupated in the stream, and produced well-formed adults.

The apparatus has been in operation continuously for over three years, using only the original carbon. By employing continuously replaced water from the city mains, the difficulties of maintaining recirculation pumps or air pumps and the hazards of electric power failure were avoided. Accumulation of contaminants such as larval excretory products, believed by Hocking and Pickering (1954) and

Wright (1957) to be the major factor in the death of their larvae, was also avoided. The small pebbles in the troughs created a variety of current velocities and micro-habitats and we believe this variety helped to reduce wandering by larvae that were small enough to escape through the screen. By changing the slope and regulating the amount of water entering, larger changes in current velocity were obtained.

Control of temperature, which varied slowly during the year from 40-70°F, was not attempted. This could probably be controlled by inserting a heater or cooler in the storage tank, thus altering the temperature before it entered the troughs. The amount of carbon that was used, as well as the size of the filter, are perhaps unnecessarily large for the amount of water required.

Induced Oviposition

Fredeen (1959b) has described methods for obtaining black-fly eggs from the stream bottom after the eggs have been laid. It is difficult, however, to find eggs of some species in the field and one must resort to obtaining them from gravid flies. In this way eggs may be obtained free from the eggs of other species or individuals, and when reared can thus provide suitable series for taxonomic and other studies.

Engorged and presumably mated females of *Simulium aureum* of both forms A and B (Dunbar, 1958) were obtained by exposing a bantam hen in the forest canopy according to the method described by Bennett (1960). The blood-fed flies were maintained in 8- to 10-inch cubic holding cages (Anderson, 1956). The floor of each cage was covered with damp paper towel and a lump of sucrose, wrapped in gauze, was suspended in the cage (Davies, 1953) or was attached to the outside of the netting. After 10 days in darkness at 55-60°F, each female was confined at room temperature, in moderate light, in a petri dish with a short length of green grass or sedge leaf floating on a drop of water. Eggs were laid on the edge of the wet part of the leaf. Flies which laid no eggs in one to two hours were returned to the holding cage; the process was repeated the following day for these flies. Over 150 flies were induced to oviposit in this way. Occasionally some eggs were laid on the damp floor of the cage.

Several females of *S. aureum* were re-fed the day following oviposition by confining the fly in a tube (screened at the distal end) over the exposed comb or wattle of a bantam chicken. The use of carbon dioxide in the form of 'dry ice' to stimulate feeding (Dalmat, 1950) was sometimes helpful. Three females of *S. aureum* entered a second cycle and laid eggs 11 to 13 days after feeding.

Egg masses of *S. verecundum* and *S. vittatum* were also obtained in this way after females had fed on man. Some females of *S. nigricoxum* St., fed on man, were induced to oviposit by holding them beneath the surface of a large drop of water, the eggs being collected on filter paper beneath. *Prosimulium ursinum* Edw., a species not requiring a blood meal, laid eggs on moist filter paper when confined in vials or petri dishes.

Breaking Diapause in the Egg

In early summer, the development of the eggs of *S. aureum* (form A) proceeded rapidly and egg masses, kept at about 60°F, were transferred to the artificial streams for larval rearing as soon as sclerotized details of the head capsule, such as the egg burster and mouth parts, had appeared. The development of eggs laid later in the season, however, was delayed by diapause, as was also the case with the eggs of all the univoltine species that were studied. To break the diapause,

late season eggs of *S. aureum* were stored at 35-40°F for at least three months and then were placed at about 60°F for development. They were transferred to the artificial streams when hatching appeared imminent.

Collecting the Immature Stages

Several authors have outlined their collecting techniques in their treatments of the simuliid fauna of a particular area (Twinn, 1936; Nicholson and Mickel, 1950; Sommerman *et al.*, 1955), while Rubtsov (1956) has reviewed the methods in use in the Soviet Union. Some additional details concerning collecting and transporting larvae and pupae are added here.

Larvae and pupae of black flies may be encountered in rivulets, streams or rivers of all sizes, from a few inches to many feet in width. Although they are usually sought in swiftly-moving water, some species of *Cnephia* and *Eusimulium* are found chiefly in water that scarcely appears to be moving, as in drainage through swampy areas. All types of removable material—grass, leaves, sticks and stones of all sizes — should be lifted from the water and examined for larvae and pupae. The larvae were transferred to the bottom half of a plastic petri dish (diameter 3½ inches), in very little water, while the pupae were placed in the top of the dish on a moistened filter paper. The two halves of the dish were carried on a small wooden board each held within a circle of nails for protection from wind. When the collection was completed the petri dish was reassembled (the pupae remained on the paper in the lid upside down, clean and separated from the larvae below). Several dishes were carried in a cylindrical container (made from a 48 oz metal can) with a 2-inch wide slit down one side, and the whole unit was kept cold (35-55°F). As soon as possible thereafter, pupae were transferred to a wet filter paper in a clean dish and returned to the cold. Larvae were preserved in ample 95% ethanol (Rubtsov, 1956), at least four volumes of fluid to one volume of larvae. In this preservative larvae swell slightly, extending the head fans and often the anal "gills". In some species, however, excessive swelling occurred, resulting in rupture and subsequent collapse, but this was minimized by first killing the larva in hot, not boiling, water (Oliver, pers. comm.). The addition of glycerine was detrimental to colour and structure of the larvae. Evaporation of the alcohol was prevented by the use of neoprene stoppers.

The successful removal of pupae from their substrate sometimes presents special difficulties and care must be taken to avoid damaging them during removal. Mortality is high among pupae that have been bruised even though they show no apparent damage.

Most species of *Prosimulium,* as well as *Cnephia dacotensis* (D. & S.) and related species, spin shapeless sac-like cocoons, usually aggregated into mat-like colonies, and some pupae are killed as the mass is scraped off the substrate. Soon afterward, however, the living individuals should be separated from one another, so as to minimize loss from fungal attack and to provide better aeration. When touched, the pupa usually moves forward in its cocoon, and the posterior tip of the cocoon can then be grasped and pulled upward (Rubtsov, 1956). This method was also used to remove isolated individuals from their substrate.

Several species of *Simulium (pictipes, articum* Mall., *corbis* Tw. and close relatives) spin a boot-shaped cocoon that is firmly attached especially at the periphery of the cocoon. Sommerman *et al.* (1955) has suggested that the portion of the substrate bearing the cocoon be detached; but when the substrate is too large, or if individual rearing is desirable, removal can be done under a dissecting microscope by cutting the edges of the cocoon free with a small scalpel or the tip of watchmaker's forceps. When sufficiently lossened, the anterior rim or the

posterior end of the cocoon may then be grasped. Members of the *Cnephia saileri* St. group (e.g., *sommermanae* St., *jeanae* DeF. & P., *villosa* DeF. & P.) spin a similar boot-shaped cocoon, but often in dense colonies on large boulders. Furthermore, the cocoon is firmly detached, not only at the sides but also on most of its undersurface, and must be more extensively loosened before being lifted off the posterior tip. The cocoon is not rigid and if not freed first it collapses easily and pinches the pupa it contains.

In several other species of *Simulium (jenningsi* Mall., *luggeri* N. & M., *fibrinflatum* Tw., *meridionale* Mall., *griseum* Coq., *bivittatum* Mall.), their slipper-shaped cocoons are attached so firmly that they must also be cut away, but the cocoons of these species are usually found on trailing vegetation and thus can be left attached to a small portion of substrate. Some types of vegetation, for example, willow leaves, decompose rapidly, and we believe that removal of the cocoon from the leaf gave better results. All the species of *Eusimulium,* and *Simulium* not mentioned above (e.g., *venustum* Say., *hunteri* Mall., *vittatum, canadense* Hearle, *piperi* D. & S., *tuberosum* Lund.) spin a slipper-shaped cocoon, usually not formly attached, which may be grasped by the anterior edge, and pulled up and forward, care being taken not to touch the head or thorax of the pupa.

Pupae are sometimes scarce, because they are buried or hidden and thus difficult to find, or because few larvae have matured. Nevrtheless viable pupae were obtained from fully mature larvae with darkened histoblasts when they were kept in shallow water in a petri dish at 40-55°F. No more than 20 larvae were put together in one dish, and the water was replaced daily. Pupae of *Twinnia biclavata* Shew., *Prosimulium onychodactylum* D. & S., two undescribed species of *Prosimulium* and one of *Cnephia* were obtained in this way. Only 3 pupae of the latter were found in nature but 41 pupae were obtained from larvae by this method and completed their development.

Rearing Pupae and Freeze-drying of Pinned Adults

Simuliid pupae can withstand exposure to air if kept moist, and adults can thus be obtained from them (Newstead *et al.,* 1907, p. 37). Twinn (1936) demonstrated the importance of individual rearing and described a method, using an individual emergence vial for each pupa, which has been used subsequently by most workers. The rearing tray described below does not differ basically from this method but was developed to simplify handling large numbers of pupae per day. This tray (Fig. 4) consisted essentially of a sheet of acrylic plastic louvre, with ½-inch square openings, laid on top of wet filter paper (4 layers of Whatman #1 chromatography) in a shallow tray. Before use, the tray was washed for a minimum of three hours in a natural stream (or in the overflow from artificial streams).

Pupae collected in the field and those removed from the pebbles and sides of artificial troughs were maintained during their early development on damp filter paper in petri dishes. When close to emergence a single pupa, cleaned of adhering detritus, was placed on the wet paper in each compartment and a 2-inch length of glass tubing (just under ½-inch outside diameter) was inverted over the pupa. This tube was stoppered at the open upper end with absorbent cotton to allow some diffusion of air and to prevent changes in pressure from drawing water up into the tube.

To achieve the proper degree of wetness, the paper was thoroughly moistened with stream water or filtered tap water, and the tray was then tilted to about 45°. Water appearing at the lower edge was removed with a syringe or absorbent paper. Most pupae were kept at 55-60°F and each day or two brought out to room temperature for an hour (pupae from water warmer than 75°F were kept at room tem-

perature). The emerged flies were then removed with an aspirator modifid so that each fly was collected directly into a small shell vial (Davies, 1952, Fig. 4, p. 294). The pupal skin was dried briefly on filter paper and also placed in the vial, which was labelled; when all the adults had been removed in this way, the tray was re-moistened (see above).

Newly emerged adults were held in the dark at 40-55°F for a day or two to permit hardening and darkening of the cuticle, before they were killed. Pinning (using shellac gel as suggested by Shewell, *in* Beirne, 1955) was done quickly, and as soon as possible thereafter the fly was placed in a deep freezer (at —10°F) for three to five weeks until frozen dried. This prevented shrinkage of the head and abdomen.

Acknowledgments

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Crystal Glass and Plastics, Ltd., Toronto provided the acrylic plastics used in constructing the apparatus, and the Ontario Department of Lands and Forests made facilities available in Algonquin Provincial Park, Ontario.

Summary

1. An apparatus is described which was used to rear black-fly larvae of several species to maturity in troughs containing a continually renewed flow of tap water, dechlorinated by a filter of activated carbon. Yeast cells were added continually to the water as food for the larvae. Their escape was prevented by fine screening at the end of each trough.

2. Wild-caught females of *S. aureum* were induced to oviposit in the laboratory. Some were refed and a few lived to lay a second batch of eggs.

3. Collecting and preserving methods are described which have been used to obtain a high yield of good specimens of many North American species for taxonomic studies.

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LIGHT-TRAP COLLECTIONS OF MOSQUITOES NEAR BELLEVILLE, ONTARIO, IN 1965

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Introduction

This work is preliminary to a study of the effect of various physical factors on the swarming behaviour of native mosquitoes with the objective of their control. We were therefore primarily interested in discovering the identities of local species and their sex ratio over the season. Some species are undoubtedly more influenced

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by light than others, nevertheless a New Jersey trap of conventional design was used for sampling because of its selectivity for small and relatively slow-flying insects. As the season was exceptional in having a dry summer with record low temperatures in June and July followed by an unusually wet fall, monthly weather conditions in southeastern Ontario are figured to allow comparison with other regions and future collections.

Methods

The trap consisted of a galvanized cylinder 25 cm in diameter topped with a 1 cm (⅜ inch) galvanized screen mesh. A small synchronous motor driving a model aircraft propeller in the cylinder was selected to give a downdraft of about 30 m/min near a clear 100W bulb suspended some 5 cm above the mesh. The trap was set in a clearing in mixed woodland close to a stream and within 100 m of three annually-recurring snowmelt pools which are typical breeding sites for the majority of mosquitoes in the district. From the beginning of May onwards the trap was emptied in the morning by replacing a one-litre polyethylene bottle screwed onto the screen funnel of the trap. Tetrachlorethane in a short length of dental cotton was the killing agent. Each catch was sexed and counted and the totals converted to logarithms using a table of Log (n + 1). Geometric mean nightly catches, used in Fig. 2, were obtained by adding these logarithms over a week and dividing the total by seven. When the total catch of males exceeded 100, a random sample of 10% was identified; when it was less, all were identified. It was not possible to identify the females in the time allotted to this project. Doubtful specimens and new records for the district were submitted to the Entomology Research Institute, Ottawa, for identification or confirmation.

Weather records were taken from the nearest reporting stations in the Canadian Weather Review (Department of Transport, Toronto) using rainfall figures from Stirling, temperatures from Trenton, and humidities from Malton.

Results

The distribution of males throughout the season is shown in Fig. 1. For the purpose of the figure, each month is divided into four periods and the occurrence of any species in such a period is indicated by a horizontal line. If more than ten of one species were caught on any night during the period, the line is thickened.

Six species of *Aedes* appeared simultaneously at the start of the season and three more about a week later. All but three of the 14 *Aedes* species encountered were being trapped by the first week of June. *Aedes intrudens* Dyar had the shortest duration of these early species and *Aedes cinereus* Meig. by far the longest. Of these, *Aedes stimulans* (Walk.) was undoubtedly the commonest and outnumbered all the others put together. A later species, *Aedes vexans* (Meig.), dominated the catches from mid-July to mid-August and was on the wing for more than three months. *Aedes triseriatus* (Say) was the last of this genus to appear.

The remaining genera are much less numerous. None was trapped before the last week of June, when *Culex restuans* Theo. was the first to appear. From September onwards *Culex territans* Walk. was the commonest species, outnumbering *restuans* by more than four to one. The genus *Culiseta* yielded 27 identifiable males, of which 20 were *C. morsitans* (Theo.). Only one male of *Mansonia perturbans* (Walk.) was taken in the survey although it was a common species in Belleville.

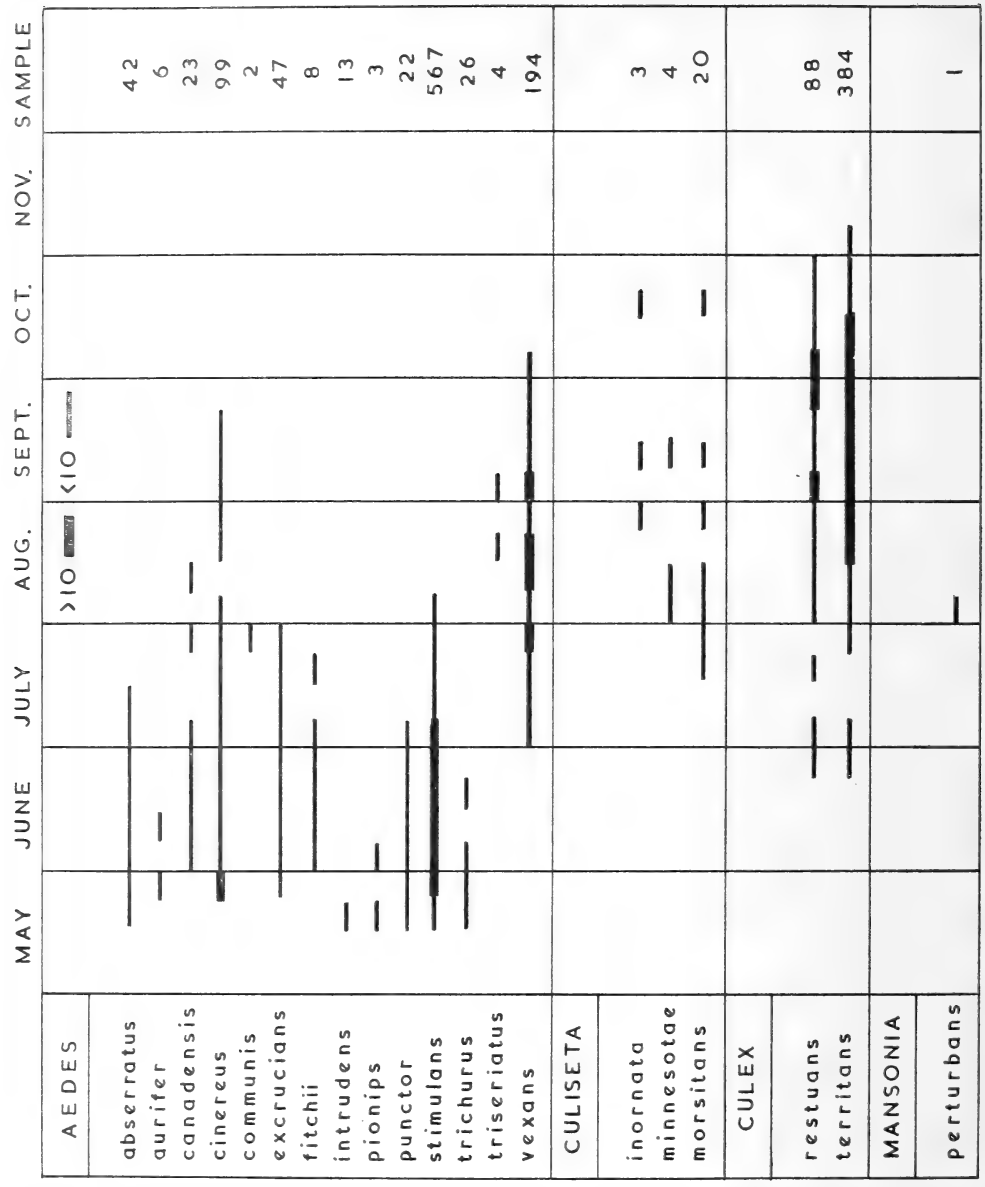

FIG. 1. Temporal distribution of male mosquitoes in 1965 as indicated by light-trap catches. Thick lines indicate that more than ten were caught on one or more nights during the period.

Local anopheline mosquitoes have been studied by Wishart and James (1946) and are not included in Fig. 1; we did, however, trap the four species that they found. *Anopheles punctipennis* (Say) was the most numerous and persistent of these, and was trapped from 6 Aug. to 1 Nov.

The figures in the "sample" column of Fig. 1 represent the numbers of male mosquitoes identified and are thus only comparable when the species are contemporaneous: those occurring in May and June are probably five to ten times more numerous than the sample indicates.

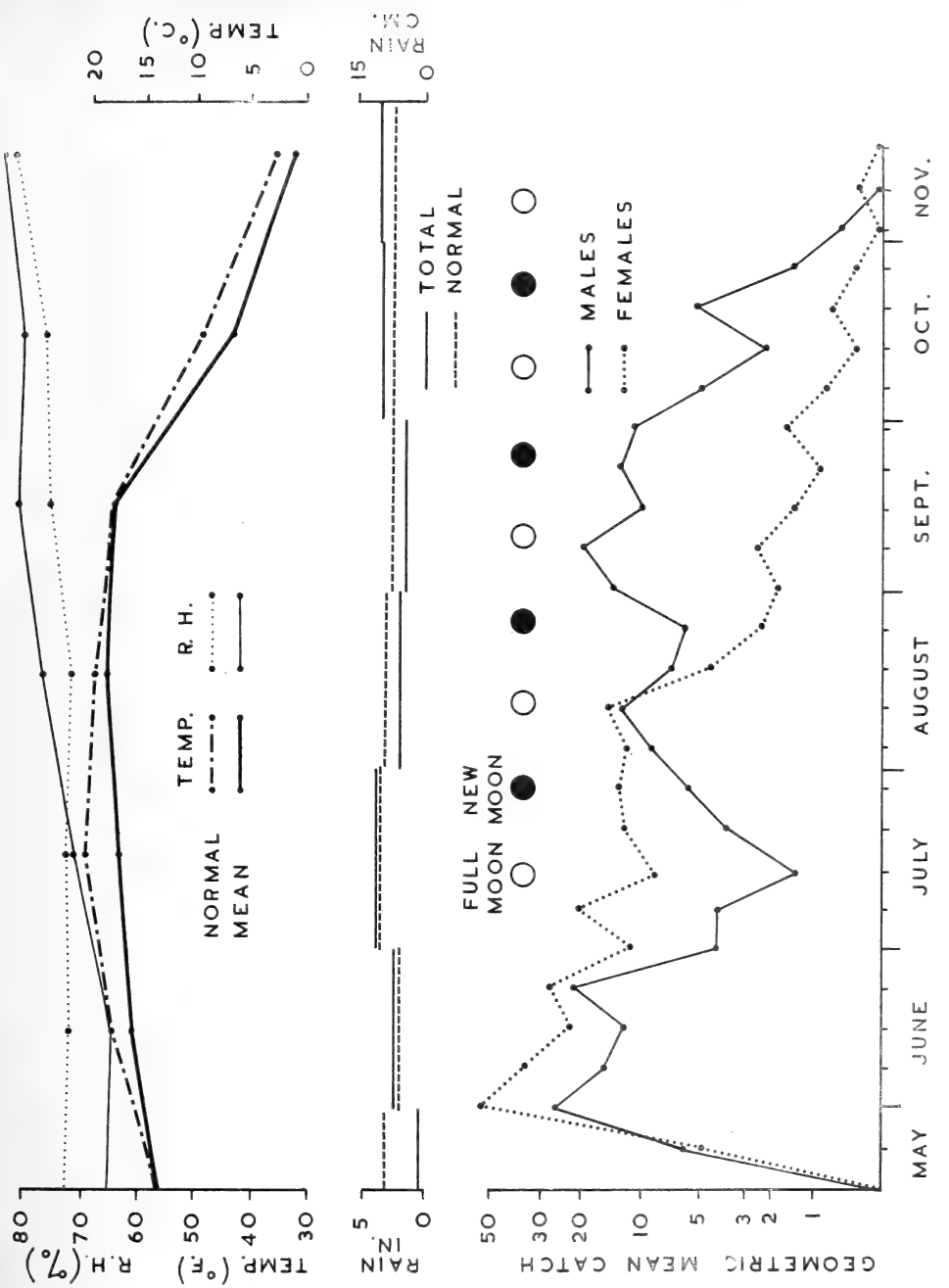

FIG. 2. Geometric mean nightly catches of all species of mosquito in 1965, plotted on a logarithmic scale. Phases of the moon, total monthly rainfall, mean temperature and humidity and deviation of the last three from normal are indicated above.

The seasonal catch of mosquitoes without regard to species is shown in Fig. 2. The largest catches were made in the second week of the season when 1061

specimens were taken. These numbers decreased gradually until the second week of July when only 60 were collected; thereafter catches remained fairly steady and did not drop below a geometric mean of ten per night until October. The sex ratio of the catches, without regard to species, shows interesting changes. On the first three nights that mosquitoes were caught, females predominated with totals of 20 to nine males. On the next seven nights, however, males predominated by about two to one but were then outnumbered by females for the next two months. The male catch reached a low between 7 and 13 July, on which two nights no males were caught. Following this the ratio of males to females began to increase until it exceeded one on 27 July. Males continued to outnumber females until the end of October. A record low temperature of —7° C (19° F) on 2 Nov. was followed by an absence of male mosquitoes, but two females of the genus *Culiseta* were collected on 7 Nov.

Discussion

Many of the species caught are new records for the immediate district but none are new to the Province. *Culiseta minnesotae* Barr has not been taken outside Ottawa but, as it was only recently described, may prove to have a wide distribution. *Aedes cinereus,* the dominant black-legged species, was described by Stewart and McWade (1961) as "not abundant anywhere" but again this may indicate merely a lack of adequate collecting over the Province. The apparent longevity of males of supposedly univoltine species is interesting. With the exception of a few, such as *Aedes intrudens* which was noted by Barr (1958) as being shortlived, most of them persisted for two or three months. This is in contrast to our casual observation in the field where we noticed, for instance, that swarms of *Aedes stimulans* did not frequent their usual sites after the end of June, although they continued to enter the trap until the first week in August. It has been claimed that some species, such as *Aedes canadensis,* breed continuously (Rudolphs, 1929), but they have been found as larvae only in natural pools, so that it has been impossible to determine exactly when the eggs were laid. *Aedes cinereus* was trapped over a much longer period than *A. canadensis* and thus may also be suspected of having more than one generation. Mail (1934) observed that *A. cinereus* larvae can hatch from pools produced by rainfall during the summer season and this is an alternative explanation. It should be noted, however, that rainfall in southern Ontario was below average in August and September of 1965.

The sex ratio of mosquitoes is normally 1:1 but it could be altered in light-trap catches by one or more of the following factors: 1) separate movements of males or females to or from the site of the trap; 2) differences in the reactions of males and females in response to light; 3) differences in the life span of males and females; 4) *changes* in reaction to light during the life span of either males or females or both.

Our results are complicated by the succession of species over the season and the role of any one species in changing the sex ratio of the total catch cannot be assessed accurately without identifying the females. Factors 1 and 2 may therefore influence the sex ratio, particularly if the behaviour of successive dominant species differs. On the whole, however, the catches of males and females show similar changes and both increase or decrease together on 20 of the 26 weeks in the year that mosuitoes were caught. Thus, although these factors may cause some change of the sex ratio they are probably not the only ones involved.

Rearing local snowmelt species from larval and pupal stages confirmed that the sex ratio was close to 1:1, and that as a rule males emerged before females.

Females of these species outlived the males in cages although they did not take blood meals. Thus, apart from the first three nights when females predominated, factor 3 can explain the ratio of the sexes trapped up to about 13 July when the ratio started to change in favour of males. Although he did not observe an initial preponderance of males in 1963, McLintock (1966) noticed that this sex was the more numerous at the end of the season in three species studied in detail at Delisle, Saskatchewan. He suggested that hibernating species find resting sites at the end of the season and that during the summer there may be heavy female mortality after oviposition. As we did not notice any overwintered females in our catches during May, it is also possible that factor 4 is involved and that responses to light change either at mating or oviposition or both.

Temperature is undoubtedly the most important single climatic factor affecting the catches of mosquitoes in a woodland environment. Even so, record low temperatures had little effect on the daily mean catch of mosquitoes in June and July. Day-to-day changes in catches can be correlated quite closely with temperature, and numbers drop off with the fall in mean temperature at the end of the season. (Fig. 2).

There is some evidence of periodicity in catches, particularly of females, during September and October, these being high during the week of the new moon and low near full moon. It has been known for some time that insects are affected in this way (Williams, 1936) but this relationship is not obvious during the peak of our season, and McLintock (1966) did not observe it. Our dominant species during September and October was *Culex territans* and it may be that this mosquito is, like *"Culex pipiens quinquefasciatus"*, affected less by artificial light during the full moon (Barr *et al.*, 1960).

No organized measures have been taken to abate the mosquitoes of this district, although in June and July they are usually troublesome enough to require the use of mosquito repellent. Local mosquitoes other than *Aedes* species bite very rarely, however, and of the *Aedes,* the most annoying species are *stimulans* from May to July and *vexans* from July to October.

Conclusions

The survey yielded a total of 5,745 mosquitoes, 2,904 of them males. These represented 20 culicine and 4 anopheline species, none of them new to the Province. The mixed woodland north of Belleville therefore provides a habitat for more than half of the Province's 40 known species in numbers adequate for future studies of their distribution and behaviour.

Summary

A New Jersey trap operating continuously from the beginning of May, 1965, onwards was used to investigate the culicine species and their temporal distribution at the field station of the Belleville Research Institute near Chatterton. Nearly 6,000 mosquitoes of 24 species were caught between 14 May and 7 Nov.

Acknowledgments

We are indebted to many of our colleagues at the Research Institute, Belleville, and to Dr. J. S. McLintock of the Research Station, Saskatoon, who have helped us with discussions. Dr. J. R. Vockeroth of the Entomology Research Institute, Ottawa, gave us valuable taxonomic advice.

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CAENORHABDITIS DOLICHURA (A. SCHNEIDER, 1866) DOUGHERTY (RHABDITIDAE, NEMATODA) IN THE HEAD GLANDS OF THE ANTS *CAMPONOTUS HERCULEANUS* (L.) AND *ACANTHOMYOPS CLAVIGER* (ROGER) IN ONTARIO

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Larvae of the nematode *Caenorhabditis dolichura* (A. Schneider, 1866) Dougherty, 1955, were found in the lobes of the post-pharyngeal glands of ants (*Camponotus herculeanus* (L.)) in the vicinity of Belleville, Ontario. Adults were found living in the nest material and could also be obtained by rearing larvae from the glands in a beef liver media (Glaser *et al.* 1942). Studies on other species of ants showed that these nematodes were also present in *Acanthomyops claviger* (Roger) but not in *Formica fusca* L. and *F. integra* Nylander. Attempts to infect colonies of *F. fusca* with *Caenorhabditis dolichura* from *Camponotus herculeanus* were unsuccessful. Infection in field-collected colonies of *C. herculeanus* and *A. claviger* was less than 25% per colony, but after two months in a formicaria in a laboratory it increased to 100%.

This association between nematodes and ants was first reported from France by Janet (1893, 1894, 1909) and de Man (1894). De Man described the nematode as *Rhabditis janeti* Lac. Duth. More recently Wahab (1962) published a comprehensive study of the nematodes associated with glands of ants in Germany and synonymized *R. janeti* with *Caenorhabditis dolichura.* This nematode was also

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placed in the genus *Pelodera* by early workers. Our search of the literature indicates that this is the first record of *C. dolichura* in North America and also the first report of its presence in the genera *Camponotus* and *Acanthomyops*.

The larvae produced by adults in the nest were observed to be the "winken" (Sachs, 1950) or waving type. They climb to the highest points of the nest material, stand on their tails, and wave the anterior end of their bodies, similar to the movement of hookworm juveniles and first-instar eucharids. They attach themselves by means of an oily secretion which covers their bodies to passing ants. Through the grooming activities of the ants, the nematodes are transferred to the buccal-cavity. Due to their size they would normally be caught in the infrabuccal pocket (Eisner and Happ, 1962), but being mobile they make their way to the openings of the post-pharyngeal glands which are located in the posterior portion of the pharynx. Should nematodes enter the oesophagus they could not be taken into the mid-gut passively and would probably be regurgitated with the crop content. Wahab (1962) suggests that infection of other ants within the colony may occur through trophallaxis.

In these studies no larval nematodes were observed to leave the ants but Wahab (1962) observed one instance which suggested that the nematode may leave by a simple migration anteriorly through the pharynx and the buccal cavity. A second method could involve entering the crop, either actively by its own movement or passively along with food ingested by the ant. From the crop they would be regurgitated and filtered from the liquid crop content by the infrabuccal pocket of the ant receiving the food. If the nematode remains passive it would then be deposited with the other foreign matter in the pellet from the infrabuccal chamber

The Belleville specimens of ants contained 3 to 25 individuals of *C. dolichura* per worker. At these levels of infection the post-pharyngeal gland is apparently not damaged. Wahab (1962) found that field-collected ants seldom contain more than 10 nematodes each per ant but was able to induce infections of over 200 juveniles per worker ant in artificial colonies. The glands with these high levels of infection had long lobes and thin walls and showed a deterioration of cell structure. No evidence of direct feeding on the gland walls was found and these changes may only have been caused by a distention of the gland wall through the heavy infection and activity by the nematodes.

The exact nature of the nematode-ant relationship is not known. The ability of the nematode to mature and reproduce in culture media and the absence of direct feeding within the gland suggests that their relationship with the ants may only be phoresis. However, as the juveniles taken from the glands of the ants also mature in water (Wahab, 1962), they may feed on the gland content, which is used as a food for ant larvae (Ayre, 1963), and could therefore be classed as parasitic.

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MELITTOBIA CHALYBII ASHMEAD (HYMENOPTERA:EULOPHIDAE) PARASITIZING *BOMBUS FERVIDUS* FABRICIUS (HYMENOPTERA:APIDAE)

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A summary of the hosts of *Melittobia chalybii* Ashm. was given by Peck (1963). These ranged from laboratory rearings from *Periplaneta americana* (L.) (Blattidae) and *Saperda candida* Fabr. (Cerambycidae) to field-collected Tenthredinidae, Vespidae, Sphecidae and Megachilidae. *Melittobia* has been recorded also from several species of the family Apidae. According to Howard (1891), Giraud included *Bombus* spp. as hosts of *Melittobia.* Plath (1922) reared a species from cocoons of *Psithyrus laboriosus* (Fabr.), a social parasite in the nest of *Bombus vagans* Sm. Frison (1926) and Plath (1934) reported *Melittobia* sp. from the nests of several species of *Bombus.* Holm (1960) was able to rear *Melittobia chalybii* on a bumble bee pupa in the laboratory. Knee and Medler (1965) found *M. chalybii* parasitizing *B. fervidus* in Wisconsin. The following note concerns the occurrence of *M. chalybii* in *B. fervidus* in Ontario.

A nest of *Bombus fervidus,* found near St. Thomas, Ontario, was moved to Guelph in early September, 1964. The bees were allowed to continue foraging until early October. The nest was then brought into the laboratory and placed in a cold room (—20°C). When the nest was examined in April, 1965, there were many unopened cocoons. These were found to contain many larvae, pupae, and adults of *M. chalybii* as well as larval or pupal remains of *B. fervidus.* Of the 325 cocoons in the nest, 170 or 52.3% were parasitized by *M. chalybii.* Cocoons with remains of host larvae contained as many as 900 parasites each, whereas those with remains of host pupae contained 300 or less. In well-formed host pupae, the parasite larvae fed on the abdominal contents through the inter-segmental membranes. Mature larvae left the host and pupated in the base of the cocoon.

The parasites were identified tentatively by comparison of the specimens with the original description (Ashmead, 1891) and also by examination of the meconium described by Flanders (1942). This identification was confirmed by C. D. F. Miller of the Insect Taxonomy Section, Canada Department of Agriculture, Ottawa. All specimens examined agreed with the type descriptions. The distinct second-form males and females, described and illustrated by Schmieder (1933) and referred to by Clausen (1940), were not seen.

Buckell (1928) and Schmieder (1933) described the behaviour of *M. chalybii* and presented illustrations of the adult forms. However, differences between the type-form of Buckell and the type-one form of Schmieder in the illustrations and in the duration of the life cycle, suggest that more than one species was involved.

In reviewing the literature on *Melittobia,* it appeared that *Sphecophaga burra* (Cresson) should not be included in the host list of *M. chalybii.* In the paper by Schmieder (1939b), quoted as the source of the record, *M. chalybii* was mentioned for the purpose of showing the similarity of its diapausing larvae to those of *S. burra.* Schmieder did not indicate that *S. burra* was a host of *M. chalybii.* The record of *M. chalybii* from the eggs of *Saperda candida* might be questioned also since the main hosts of this parasite appear to be larvae and pupae. The record is based on one specimen found in a can containing *S. candida* eggs (Hess, 1940).

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PARASITISM OF THE ORIENTAL FRUIT MOTH, *GRAPHOLITHA MOLESTA* (BUSCK) (LEPIDOPTERA : TORTRICIDAE) IN ONTARIO, 1956 - 1965[1]

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Introduction

Since the oriental fruit moth, *Grapholitha molesta* (Busck), was first discovered in Ontario in the fall of 1925, annual surveys of varying extent have been made of the degree of parasitism of the twig-infesting larvae in two- to five-year-old peach orchards. Smith (1929) and Steenburgh (1929) published the first reports on this work. Boyce and Dustan (1958) reviewed the records of parasitism from 1930 to 1955 in the Niagara Peninsula and Essex County, the two principal peach growing areas of Ontario, and listed the most important relevant papers published during the intervening years.

This paper completes the records of parasitism to the end of the 1965 season.

Methods

Boyce (1947) described the method of surveying for parasitism. Usually one man-hour was spent collecting infested twigs in each of a number of young orchards at the times when first and second generation larvae were most abundant. Since 1960 more time was spent in some orchards to obtain larger collections. In some years a few of the visited orchards were too lightly infested to yield significant collections. The infested twigs were placed on green apples in covered containers in an insectary and the subsequently emerging moths and parasites identified.

Results and Discussion

Summaries of the parasite records from 1956 to 1965 for the Niagara Peninsula and Essex County are given in Tables 1 and 2 respectively. The principal differences between the two areas are the much greater abundance of the introduced braconid parasite *Macrocentrus ancylivorus* Rohw. in the Niagara Peninsula and the greater abundance of the native ichneumonid parasite *Glypta rufiscutellaris* (Cress.) in Essex County. For the ten-year period, the average parasitism by *M. ancylivorus* of first and second generation larvae in the Niagara area was 43.2 and 64.5% respectively and in Essex County, 10.3 and 12.4%. Average second generation parasitism by *G. rufiscutellaris* was 1.4% in Niagara and 28.6% in Essex County. Probably the recent upward trend of the latter species in Essex County (Table 2) was related in part to the decrease in competition from *M. ancylivorus* which is dominant over *G. rufiscutellaris* (van Steenburgh 1935).

Of the three minor parasites listed in the tables, the ichneumonid *Temelucha minor* (Cush.) was slightly more abundant on both the first and second generations and ichneumonid *Diadegma obliteratus* (Cress.) on the first generation in the Niagara area than in Essex County. *Macrocentrus delicatus* Cress. was more abundant in Essex County, particularly on the first generation.

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TABLE I. Parasitism of twig-infesting larvae of the oriental fruit moth in the Niagara Peninsula, Ontario

Year	No. orchards	Total no. moths and parasites	Percentage parasitism by:						
			M. ancylivorus	*G. rufiscutellaris*	*D. obliteratus*	*M. delicatus*	*T. minor*	Others	Total
First Generation									
1956	33	2381	42.0		0.1		0.04		42.1
1957	32	1632	57.1			5.0	0.6	0.1	63.4
1958	30	915	39.2		2.1	0.8	2.6	0.2	44.9
1959	29	2321	42.6	0.04	0.6		0.4	0.04	43.6
1960	29	1709	34.8		0.2	0.06	0.06		35.2
1961	33	1177	69.9		0.1		0.7	0.2	70.9
1962	19	1260	16.0	1.1	0.4		0.7	0.4	18.7
1963	7	313	8.6			0.2		0.6	9.9
1964	11	825	65.9					2.4	68.3
1965	18	1923	56.2		1.8		2.4		60.4
Second Generation									
1956	30	1297	52.6	0.08		8.9		0.5	61.6
1957	28	1673	76.3	0.06		3.7	0.9	0.2	80.9
1958	28	778	73.6				0.4	0.1	14.0
1959	27	1296	71.1	0.4		0.6	0.6		72.7
1960	22	1267	55.1	0.2		2.8		0.5	58.1
1961	30	595	84.0	2.0		0.3			86.3
1962	17	1077	36.5	5.8		0.6	0.9	0.3	43.8
1963	4	441	44.9	3.6		1.1		0.6	49.6
1964	7	711	82.4	1.7				0.6	84.1
1965	13	841	68.3	0.4		0.5			69.2

As *M. ancylivorus* is dominant over *G. rufiscutellaris* in competition for hosts, the factors responsible for their relative differences in abundance in the Niagara area and Essex County probably act primarily on *M. ancylivorus*. Some differences between the two areas that may influence *M. ancylivorus* are (a) the much more widely separated peach orchards in Essex County; (b) the much greater abundance in the Niagara area of strawberry plantings which support the tortricid *Ancylis comptana fragariae* (Walsh & Riley), an alternative host of *M. ancylivorus;* and (c) weather factors, particularly those that result in relatively early hardening of peach twigs in July and thus make them unsuitable for the host larvae.

Boyce and Dustan (1958) showed that the use of DDT and parathion in peach orchards for control of the oriental fruit moth from 1949 to 1955 did not reduce the percentage parasitism by *M. ancylivorus*. The continued high rate of parasitism in the Niagara area since 1959 and 1960 when Guthion (azinphos methyl) and Sevin (carbaryl) came into extensive use in peach orchards indicates that these insecticides, as used to control the oriental fruit moth, also have not been detrimental to *M. ancylivorus*.

It is hoped that the factors influencing parasitism will be clarified by a current study of the population dynamics of the oriental fruit moth and its parasites in the Niagara area.

TABLE II. Parasitism of twig-infesting larvae of the oriental fruit moth in Essex County, Ontario

Year	No. orchards	Total no. moths and parasites	Percentage parasitism by:						
			M. ancylivorus	*G. rufiscutellaris*	*D. obliteratus*	*M. delicatus*	*T. minor*	Others	Total
First Generation									
1956	17	768	35.8			7.2	0.1	0.1	43.3
1957	7	151	20.5			7.3			27.8
1958	15	370	0.8		0.5				1.3
1959	17	820	2.1			3.0			5.1
1960	18	598	4.6			0.2			4.8
1961	17	881	21.9			0.3			22.3
1962	18	918	13.5	0.1	0.1	3.8			17.7
1963	5	175	4.0			4.6			8.6
1964	8	452			0.4				0.4
1965	7	354			0.4				0.4
1965	7	354				0.5			0.5
Second Generation									
1956	15	693	31.4	1.0		5.0			37.5
1957	7	280	24.3	2.9		6.1	1.4		44.1
1958	18	1215	6.0	6.8		0.1		0.2	13.1
1959	17	1138	13.0	9.6		1.5	0.1		24.2
1960	18	811	5.9	13.2		0.9			20.0
1961	21	1359	26.6	43.9		3.8	0.3	3.6	78.3
1962	19	1916	12.0	57.9		2.0		6.2	78.2
1963	5	125	2.4	20.8		0.8		1.6	25.6
1964	9	984	2.2	44.3		0.6		0.8	47.8
1965	7	513		75.4		0.2		3.1	78.1

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RELATIONSHIP BETWEEN THE SEASONAL DEVELOPMENT OF THE TARNISHED PLANT BUG, *LYGUS LINEOLARIS* (BEAUV.) (HEMIPTERA : MIRIDAE) AND ITS INJURY TO PEACH FRUIT[1]

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Severe injury to peaches resulting from an outbreak of the tarnished plant bug, *Lygus lineolaris* (Beauv.), in the Niagara Peninsula of Ontario in 1956 was shown to have been caused by adults of the first generation (Phillips 1958). Such outbreaks may cause considerable economic loss to growers, but because they occur infrequently control is difficult unless they can be predicted in time for growers to protect their crops. Lacking such prediction, growers who have suffered heavy losses tend to apply annual insecticidal sprays to control plant bugs. This is not only costly but may unnecessarily add to the accumulation of insecticides in peach orchards.

This paper reports the results of an attempt to measure the numbers and activity of the tarnished plant bug in the peach growing area of the Niagara Peninsula and to relate these to weather and plant development with a view to predicting the danger of injury to peach.

Methods

Six hay fields distributed from Vineland to Niagara-on-the-Lake and composed mainly of clover and alfalfa were swept with an insect net at intervals from the time plant growth started in the spring till after first-generation adult plant bugs had started to emerge. Each collection consisted of ten groups of ten sweeps, each group separated by at least 10 paces.

Plant bugs were collected from three peach orchards, that had a history of plant bug injury, by jarring a single limb of each of 100 trees over a cotton sheet one yard square. Collections were made twice weekly in the early morning before temperatures exceeded 60° F beginning when most of the petals had fallen and continuing till the end of June.

Two hundred peaches were collected from each of 20 peach orchards distributed throughout the area, once in early June before first-generation tarnished plant bugs had moved into peach orchards and again in July soon after the first cover spray was applied. Plant-bug injury was classified as early or late depending on whether it was judged to have been caused by overwintered or first-generation adults respectively (Phillips 1958).

Air temperatures and rainfall were recorded at the Research Station, Canada Department of Agriculture, St. Catharines.

Results

The sweeping collections showed that the tarnished plant bug was widely distributed, but its numbers varied greatly between localities. Few plant bugs were collected from fields where plant growth was poor but vigorous plant growth did

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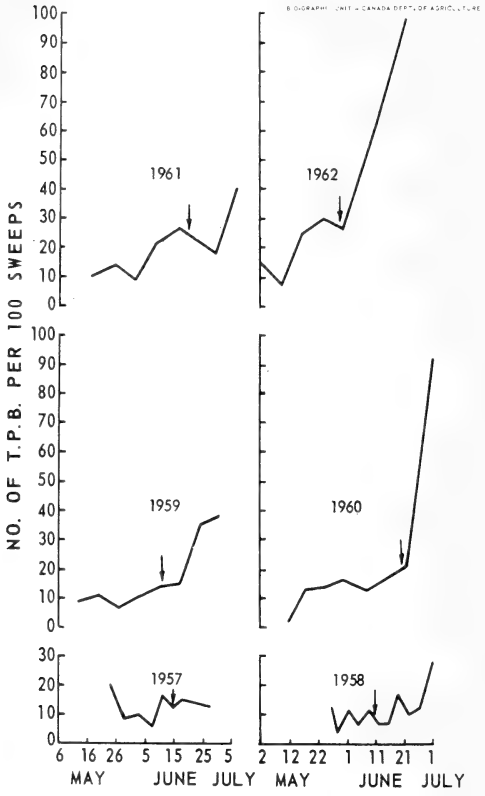
[1]Publication No. 123, Research Station, Research Branch, Canada Department of Agriculture, Vineland Station, Ontario.

[2]Deceased, November 22, 1964.

not always result in increased numbers. Cool, wet weather appeared to slow development of the nymphs and reduced the number that matured. Heavy rains were especially injurious to nymphs in the early instars removing many from the plants to which they were apparently unable to return. Harvesting the hay crop drastically reduced the number of plant bugs collected but where regrowth was rapid they soon became reestablished.



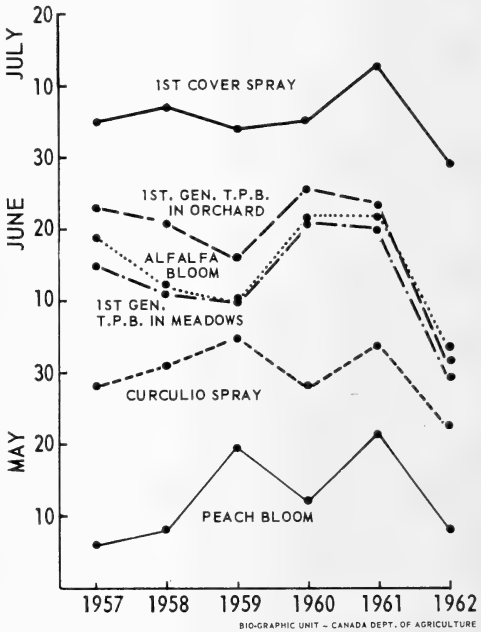


FIG. 1. Average numbers of adult tarnished plant bugs collected by 100 sweeps with an insect net in six hay fields from 1957 to 1962. Arrow indicates first appearance of first-generation adults.

FIG. 2. Development of peach, alfalfa, and tarnished plant bug in relation to average dates of first curulio spray and first cover spray from 1957 to 1962.

The average numbers of the bug collected by sweeping six hay fields for the years 1957 to 1962 are shown in Fig. 1. First-generation adults began to appear about when alfalfa was beginning to bloom (Fig. 2) and reached their maximum numbers one to two weeks later. With the appearance of first-generation adults the numbers usually rose sharply. However, when the number of plant bugs was small as in 1957 and 1958, the increase was less marked. The number of overwintered plant bugs in hay fields decreased rapidly soon after the appearance of first-generation adults.

Though the tarnished plant bug is most numerous in peach orchards just prior to bloom, their feeding at that time seldom causes important damage (Phillips

1958). An exception was the spring of 1962 when overwintered bugs were numerous enough to cause extensive injury to blossom buds not only of peach but also of pear and other fruit.

Jarring collections, begun when blossom petals were falling, indicated the relative numbers of plant bugs present in peach orchards when their feeding could be expected to cause injury to the fruit (Fig. 3). The number collected varied considerably but usually there was a marked decline after blossoms had fallen and fruit began to form. There was no apparent relationship between the number taken in the peach orchards and in the hay fields in the early part of the season. In 1958, 1960, and 1962 the orchard collections indicated that the overwintered plant bugs were numerous but this was not reflected in the hay field collections (Fig. 1). The sharp decline recorded in the peach orchards about mid-June in 1962 (Fig. 3) was the result of a special spray for plant bug that was recommended at that time.

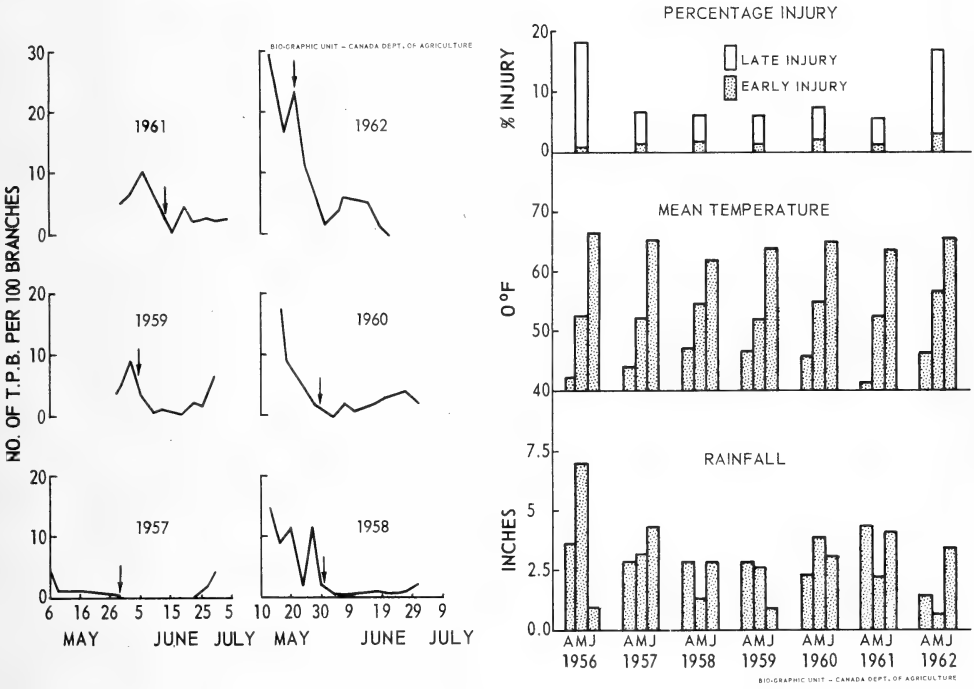


FIG. 3. Average numbers of tarnished plant bugs collected by jarring 100 branches in three peach orchards from 1957 to 1962. Arrow indicates average date of first curculio spray.

FIG. 4. Mean temperature and total rainfall for months of April, May, and June measured at St. Catharines Ontario, and average percentage injury of peach fruit by tarnished plant bug in twenty orchards from 1956 to 1962.

The application of an organo-phosphate insecticide at the shuck-split stage and again about 10 days later to control plum curculio, *Conotrachelus nenuphar* (Hbst.), usually eliminated the plant bug from peach trees. Some overwintered bugs reinfested the orchards, but significant reinfestation did not occur till first-generation adults appeared. The time and extent of this reinfestation and the interval between the emergence of first-generation adults and their appearance in

peach orchards varied considerably between years (Figs 2 and 3). In the years from 1957 to 1961 first-generation plant bugs did not reach significant numbers in the peach orchards before application of the first cover spray for oriental fruit moth, *Grapholitha molesta* (Busck.), control and this spray effectively controlled the plant bug.

Plant-bug injury of the early type varied from about 1 to 3% in the years studied (Fig. 4) and was relatively unimportant. Late injury, however, was more than 17% in 1956 and about 14% in 1962, causing rather serious losses in both years. In the intervening years it varied from 4 to 8%, and because much of the fruit recorded as injured in early June was marketable at harvest, these percentages are tolerable.

Average temperatures and rainfall for the months of April, May, and June for the years 1956 to 1962 are shown in Fig. 4. Though records for 1956 show above-normal rainfall in May nearly all of this fell before mid-month; the later half of May and all of June were relatively dry and warm. In 1962 both April and May were very dry and the drought was not relieved till mid-June after the first generation of plant bug had matured.

Discussion

Because of the great variation in local abundance of the tarnished plant bug, prediction of infestations in particular orchards is very difficult, and because the bug was abundant throughout the area in only one of the years covered by this study, conclusions are necessarily tentative. However, it was apparent that weather conditions influenced the number of first-generation nymphs that matured. In both 1956 and 1962 the period when the first generation was developing was relatively dry and warm and plant growth began early in the season. In 1957 a large initial population was drastically reduced during a period of wet, cool weather in late May and early June, and the number of first-generation nymphs that matured was small.

Though the plant bug breeds on a number of herbaceous plants the time of appearance of the first-generation adults appeared to be related to the time of alfalfa bloom, and this time varied considerably in relation to peach development and the consequent times when the trees were sprayed for plum curculio and oriental fruit moth control (Fig. 2). The interval between the last spray for plum curculio control and the first cover spray varied from year to year but was approximately one month (Fig. 2). The amount of injury to peach fruit appeared to be dependent on both the number of first-generation adults produced and the length of time before the application of the first cover spray that they moved into the orchards. In 1960, though the number of first-generation adults was large (Fig. 1), they did not begin to move into the peach orchards till about 10 days before the first cover spray. In 1962 however they began to move into the orchards 28 days before the first cover spray and in considerable numbers. All the factors affecting the timing and number of the bug that move into peach orchards were not determined. Mowing appeared to hasten movement of the bug from hay fields, but in the peach growing districts waste areas that are not cut for hay are probably more important breeding sites. Dry weather that resulted in early maturing of herbaceous plants appeared to be a more important factor.

The sweeping collections were unsatisfactory for predicting the number of plant bugs that would move into peach orchards. A relatively small number of overwintered plant bugs in hay fields in 1960 and 1962 produced a larger number of first-generation adults than did a larger initial population in 1957 (Fig. 1).

Sampling peach orchards by jarring branches appeared to be the most satisfactory method for predicting infestations. Because the important injury is caused by the plant bugs that enter the orchards after the last curculio spray, a measure of the time and extent of this movement is important. When first-generation adults mature in early June, as indicated by the blooming of alfalfa, the period over which they may move into orchards before they are controlled by the first cover spray is likely to be long. In such years jarring of peach trees would indicate if a special spray is needed to prevent injury to the fruit. If alfalfa bloom is delayed until mid-June or later the danger of plant-bug injury would be much reduced.

Barnes and Dowell (1960) suggested that control measures should be taken when an average of two or more plant bugs are taken by jarring in a five minute period. These studies indicate that considerable injury may result when only small numbers of plant bug are taken by jarring and that the length of time over which they feed in the orchard may be more important than the numbers present. Weather conditions that bring alfalfa into bloom early also favour the development of the tarnished plant bug and in such years if any bugs are jarred from peach trees when alfalfa is in bloom a special spray for their control should be applied.

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SOME RESULTS FROM ULTRA LOW-VOLUME SPRAYING IN AN ONTARIO APPLE ORCHARD[1]

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Introduction

An attempt to exploit the potential of ultra low-volume spraying in commercial orchard pest control was investigated in the summer of 1965 by the Zoology Department, University of Guelph, Guelph, Ontario. The test plot was in a three-acre commercial orchard of Northern Spy and MacIntosh trees, 28-30 years old, and located 2 miles east of Guelph on the Eramosa Road. Rose (1963) summarizes the results of European efforts up to 1960 in ultra low-volume application of

[1]Contribution No. 102, Zoology Department, University of Guelph, Guelph, Ontario.

insecticide and fungicide materials. In North America, Howitt and Pshea (1965) have investigated the ultra low-volume principle in the U.S.A. In Canada, malathion technical is the only material authorized for use in ultra low-volume applications because of toxicity and drift hazards.

Materials and Methods

Malathion technical liquid sprays were applied on 3 June and 20 July to one side of each of six Northern Spy and five MacIntosh variety, open centre pruned apple trees, in 24- by 30-foot plantings. The original intent was to try and control populations of *Aphis pomi* (De G.) the green apple aphid. It became possible with the use of beating trays and sticky boards to make detailed bionomic observations on a pest other than aphids and on two beneficial insects. Test technical material was placed in a pressurized quart jar and flowed through ¼-inch polyethylene lines under 10 lb. air pressure provided by a standard forage crop logarithmic pressure cylinder to two mini-spin[2] units mounted in the output chamber or blower of a Swanson Midget Sprayer[3]. This blower provided an air velocity of 130 mph which operated the mini-spin units at speeds of 8500 rpm. Under these operating conditions the mini-spin units break up the liquid into small uniform size droplets. The physical assembly of the mini-spin units on the sprayer is illustrated in Fig. 1. Mass median diameter of 1,000 droplets measured on glass plates coated with Dow Corning 200 Fluid 30,000 vis. silicone was 76 microns. This was smaller than droplet sizes reported by Skoog *et al.* (1965) but larger than droplets produced by Adler *et al.* (1965) in their experimental work on ultra low-volume and aerosol-type spraying. Tractor speed was 1½ mph, rate of application was 20 oz. per acre, wind on the dates of application was 2 mph from the SW on 3 June and dead calm on 20 July. Leaf residue data could not be obtained.

Sticky boards of the type described by Kaloostian and Yeomans (1944) were used to record invasion of winged aphids into sprayed and unsprayed sides of test trees. Muslin covered beating trays, 2 ft sq, were used to trap and record insect species dislodged by tapping the outer 18 inches of tree limbs.

Counts of viable aphids were made 24 hr after the technical material was applied. These counts were made by the limb tap method using beating trays and shaking the outer 18 inches of aphid infested tree branches onto the trays.

Results

Wingless green-apple aphids were eliminated from the sprayed side of the test trees by the application of malathion technical (Table I). Winged forms were not eliminated as they migrated into the sprayed side less than 24 hr after technical material was applied. This migration was evident from sticky boards hung in canopies of both the sprayed and unsprayed sides of test trees. Recolonization by aphid populations was noted within 9 days of the technical application and by the 16th day aphid populations equalled pre-spray populations.

Mortality was heavy among the larvae of the red-banded leaf roller (*Argyrotaenia velutinana* (Wlk.)). Sixty-eight (68) of 91 larvae collected on beating trays on the sprayed side were moribund or dead and similarly 32 of 86 were affected on the unsprayed side of the test trees (Table I). Larvae from check trees were vigorous and responded to probe stimulus.

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[2]Supplied by Cyanamid of Canada, Ltd., Rexdale, Ontario.

[3]Supplied by Swanson Sprayers Ltd., Winfield, British Columbia, and Clarksburg, Ontario.

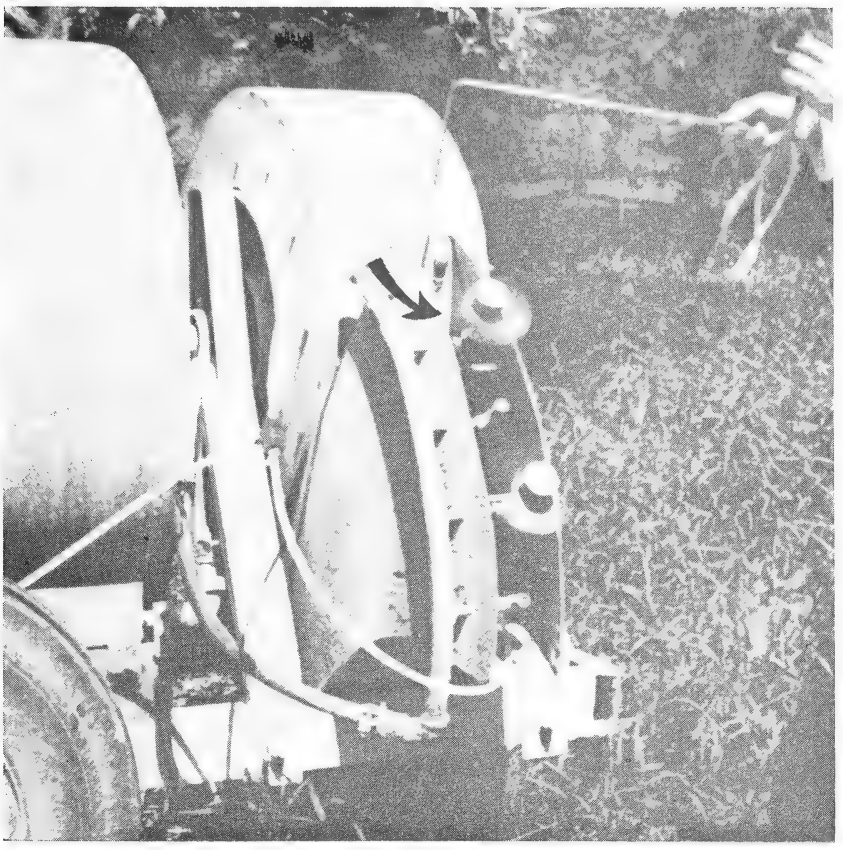

FIG. 1. Physical assembly of mini-spin units (black arrow) on a Swanson blower used for ultra low-volume spray applications in an apple orchard, Guelph, Ontario, 1965.

Beneficial lacewing larvae of *Chrysopa* sp., were eliminated on the sprayed side of test trees, reduced in numbers on the unsprayed side (11 found) and abundant on check trees where 118 were recorded from limb tapping. The number of spiders (not identified) was reduced by the technical application, as compared to populations on check trees (Table I).

Seventy-two hours after the 20 July application of technical material, 25 water sprouts were collected from the canopy interiors of the malathion plot trees, 25 from trees concentrate sprayed with Guthion WP (25%) on July 21 at a rate of 3 lb per acre in the same orchard, and 25 from check trees. Percentages of aphid kill in these plots is illustrated in Table II.

A further sampling of water sprouts on 5 August showed aphid re-colonization was occurring. Some aphids responded sluggishly to stimulus from a camels hair brush but all aphids so stimulated were capable of movement. Remaining aphids responded similarly to those in check trees.

Aphid populations in the cover crop remained viable. Visual observations showed negligible drop or drift of the applied material onto the cover crop. A comparison of terminals, leaves, and fruit from treated trees with those from check trees did not show any observable phytotoxicity such as chlorosis, necrosis, or russetting.

TABLE I. Limb-tap totals 24 hours after ultra low-volume application of Malathion technical insecticides in the Heming Orchard, Guelph, Ontario, 4 June, 1965.

Spray plot	Species Recorded				
	Live aphids *Aphis pomi*	Leaf-roller larvae *Argyrotaenia velutinana*		Live Spiders	Live lacewing larvae *Chrysopa* sp.
		Alive	Dead		
Sprayed side of test trees					
6 (winged)	91		68	70	0
0 (wingless)					
Check trees					
6 (winged)					
67 (wingless)	108		0	104	118
Unsprayed side of test trees					
12 (winged)					
18 (wingless)	86		32	109	11

TABLE II. Mortality of apple aphids, *Aphis pomi* (De G.) on water sprouts in Malathion technical sprayed plot, Guthion sprayed plot, and check plot, Heming Orchard Guelph, Ontario, 23 July, 1965

Test plot and application date	Dead	Living	Percent mortality
Malathion technical July 20	132	10	92.4
Guthion July 21	96	22	77.1
Check —	14	244	5.7

Discussion

Pest control in commercial orchards by the use of ultra low-volume spray equipment adapted to conventional spray machines is feasible in Ontario orchards for certain pests. In the matter of aphid re-colonization, this problem requires a preventive or fixed schedule spray programme in an infested orchard if the total orchard area is not subject to ultra low-volume spraying. This would reduce or eliminate the flight of winged aphids from unsprayed orchard areas, the primary factor in re-invasion and re-colonization.

The reduction of lacewing larvae early in the growing season should be avoided. Better timing of this type of ultra low-volume spray, applied either before larvae appear or after the larvae have attained the winged adult stages, should be considered. Temporary reduction of arachnids is not serious as re-establishment can be affected by cover crop populations moving back into tree canopies.

The aspect of nil run-off onto cover crops from this type of ultra low-volume spraying is of biological significance because of its minimum lethal effects on survival of beneficial arthropods.

Absence of visible phytotoxicity in test trees was noted. Reduction in terminal growth, leaf and fruit size was not observed and was similar to growth on check trees.

Summary

Green apple aphid and red-banded leaf roller larvae control achieved without phytotoxicity and with the use of light weight low cost spray apparatus, the elimination of heavy equipment needed to haul and apply large volumes of water sprays, and the lack of run-off onto cover crops, are advantages of ultra low-volume spraying with technical malathion in fruit orchards of Ontario.

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IV. RESEARCH NOTES

DISTRIBUTION OF THE ALFALFA WEEVIL, *HYPERA POSTICA* (GYLL.), IN NEW YORK

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Introduction

In New York State as elsewhere on the East Coast the alfalfa weevil, *Hypera postica* (Gyll.), is the most important pest of alfalfa. From the time of its first discovery in New York in 1955 (Neunzig *et al.* 1956), the alfalfa weevil has continued to spread slowly throughout the state, making its greatest strides since 1957 in 1964 and 1965.

Methods

Each county in New York where the weevil was not known to occur or was only known to be present in limited areas was surveyed during late May, June and late October of 1965. The selection of fields in each county was done in a more or less random manner except that fields chosen were along state or county highways and spaced at least 5 miles or more apart. Sampling was conducted with a standard 15-inch-diameter beating net with an 18-inch-long handle. Insect sweepings from each field were examined at the collection site immediately after sweeping for alfalfa weevil larvae and adults.

Results and Discussion

Alfalfa weevil collection localities for each county are illustrated in the New York State distribution map shown in Fig. 1. The acreage of alfalfa and alfalfa mixtures grown in New York, according to the 1959 Census of Agriculture (Bratton, 1962) is shown in Fig. 2. It is evident that the weevil has now moved into New York's prime alfalfa regions and is dangerously close to Ontario and Quebec Provinces of Canada. Positive finds in Niagara, Orleans, Monroe, Genesee, Erie, Lewis and Jefferson Counties were first found during the October survey. These counties were found to be free of alfalfa weevil during the previous spring and summer survey of 1965.

The alfalfa weevil is now known to be present in all counties of New York except St. Lawrence, Franklin, Clinton and Hamilton Counties. It is particularly widespread and destructive in Orange, Dutchess, Ulster, Columbia and to a lesser degree in Chenango, Broome, Tioga and Chemung Counties.

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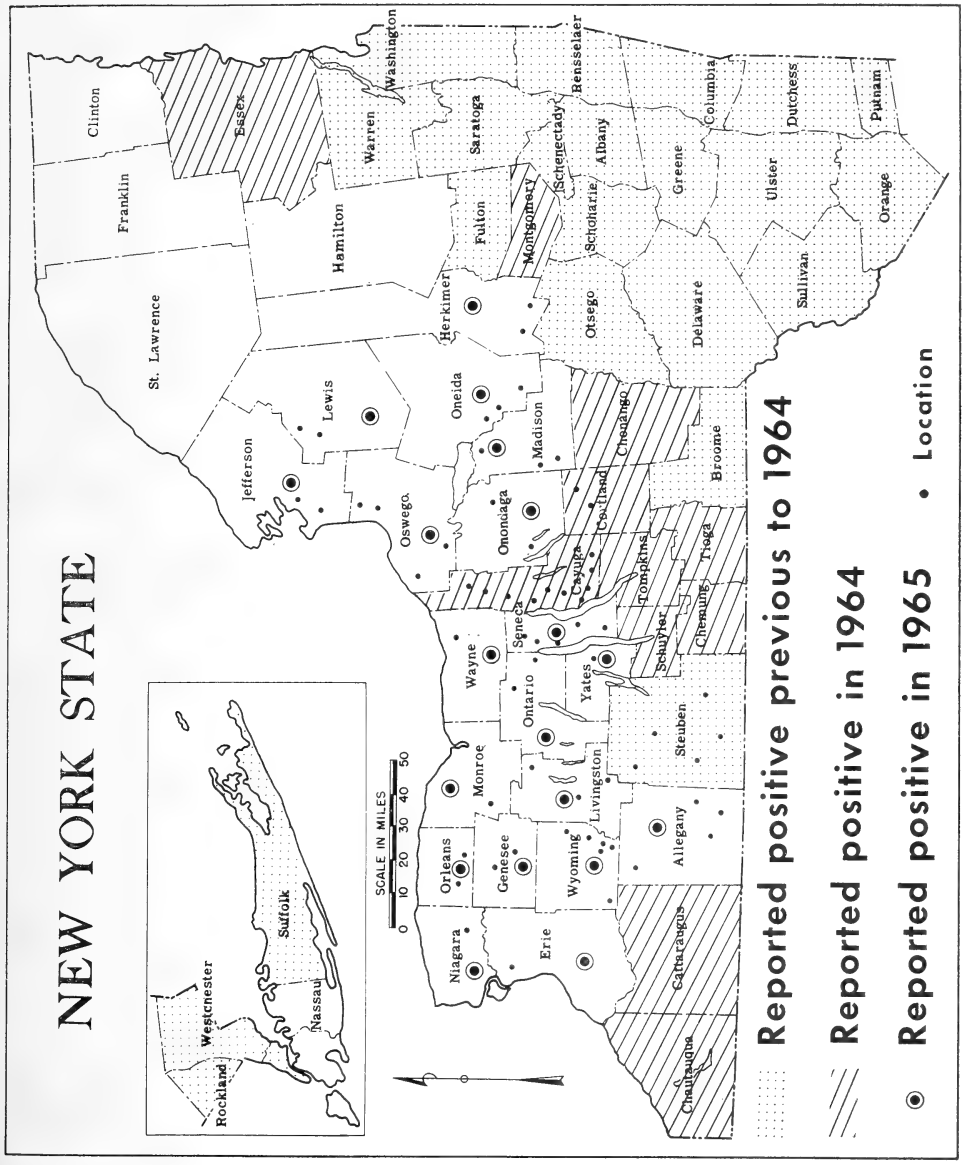

FIG. 1. Distribution of the alfalfa weevil in New York State.

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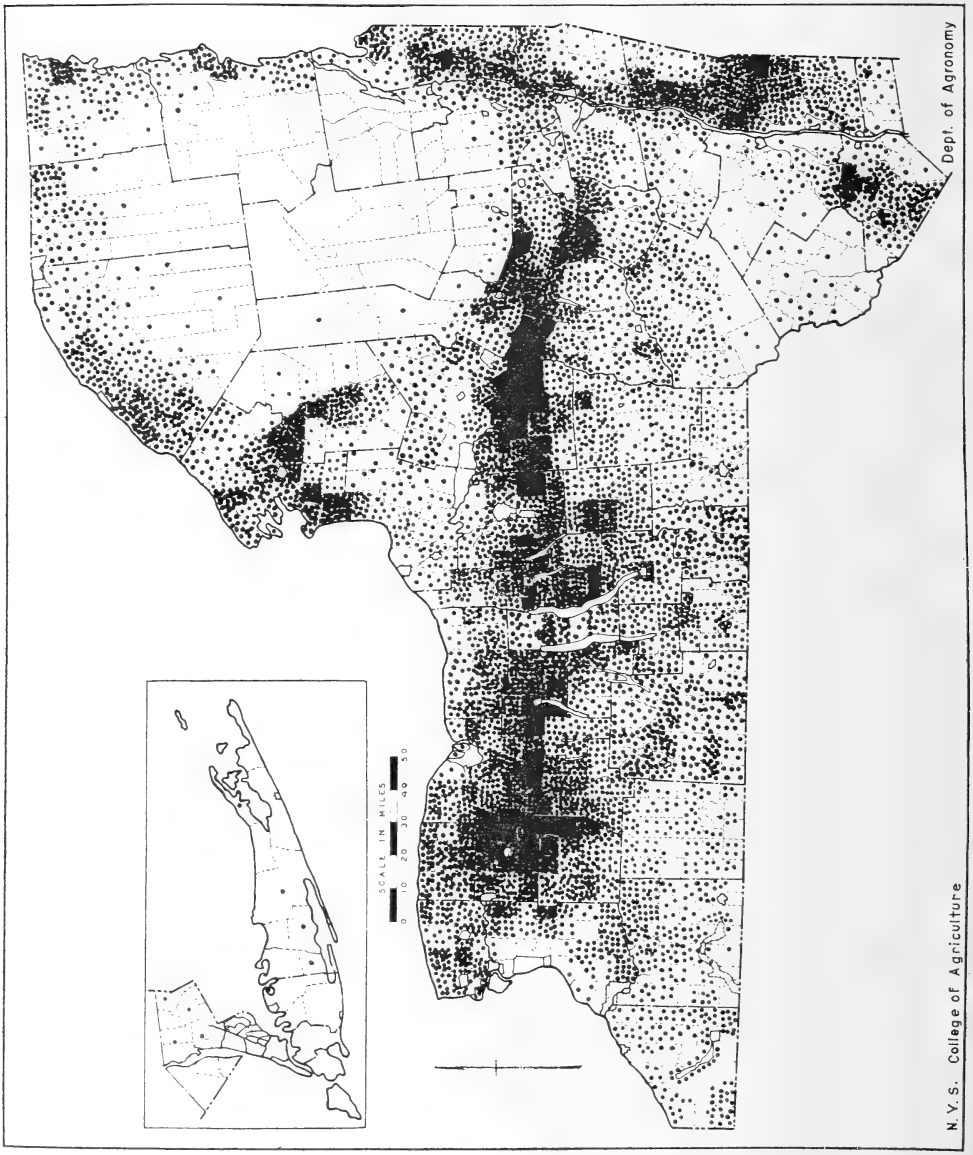

FIG. 2. Distribution of alfalfa and alfalfa mixtures grown in New York in 1959, one dot equals 100 acres.

A REPORT ON THE OCCURRENCE OF PEAR FRUIT SAWFLY *HOPLOCAMPA BREVIS* (KLUG), IN THE NIAGARA DISTRICT

C. Y. Hovey[1]
Plant Protection Division, Canada Department of Agriculture, Niagara Falls, Ontario

The pear fruit sawfly, *Hoplocampa brevis* (Klug), has been an important pest on pears in various European countries for many years according to Thomas (1936). There is evidence that it may have been present in New York State adjacent to the Niagara frontier for a few decades. Dustan (1966) reported that the insect was first found in Ontario in 1964, near Queenston. Between May 26 and June 16, 1965 officers of the Plant Protection Division, Niagara Falls, Ontario scouted for it in the area of the Niagara Peninsula shown in Fig. 1.

Scouting for the sawfly larva was conducted with no standard number of personnel but included up to six men as other work allowed; this number was broken down to a minimum of two per team. Search was purposely biased by searching roadside trees or abandoned orchards. Twenty minutes was the maximum time allowed in any location to search for damaged fruitlets with larvae present. These were identified only as sawfly species. Some larvae were preserved and eventually provided to Mr. G. G. Dustan.

Working from the Queenston area, infested pears were found quite readily to the west of the village of St. Davids and, more frequently, in the rural area (formerly Stamford Township) on the west side of the city of Niagara Falls and in Thorold Township as far as the Welland Ship Canal. Infestations were contacted less frequently to the west of the canal, and the last interception was near the west border of Clinton Township in Lincoln County. No infestation was found across the Welland River to the south of Niagara Falls; only a single contact was made south of the river on the eastern edge of the city of Welland about five miles from other known infestations. Locations of sawfly infested pears are indicated by black dots on the map (Fig. 1).

As could be expected, sawfly interceptions were most frequent on untended orchards or volunteer roadside trees, the implication being that spray programs designed for control of other pests on commercially-producing orchards have quite effectively held this insect in check. An unfavourable factor in this 1965 survey was the very light set of pear fruits in much of the areas covered. Particularly to the south of the city of Niagara Falls, where roadside trees were largely untended, fruit was almost non-existant, probably accounting for the lack of interceptions in that sector. It is quite possible that the survey west of the Welland Canal will not reflect an accurate picture of the infestation, because, by the time survey personnel were working in that area, infested fruit may have fallen from the trees. Workers in Europe have given fruit drop dates that range from 30 May in France to 10 July in Denmark.

No adult sawflies were encountered during the survey, though Dustan (1966) found a few near Queenston. Many of the adults may have died by the time scouting for the larvae started late in May.

The following brief history of the pear fruit sawfly has been summarized from Thomas (1936), and, of course, applies to the insect in Europe and England. Adults appear at about pear blossom time, late April to early May. Eggs are deposited singly beneath the epidermis of the fruitlet just below the level of the sepals, creating a noticeable blister. There seems to be no accurate record of the

[1]Plant Protection Officer

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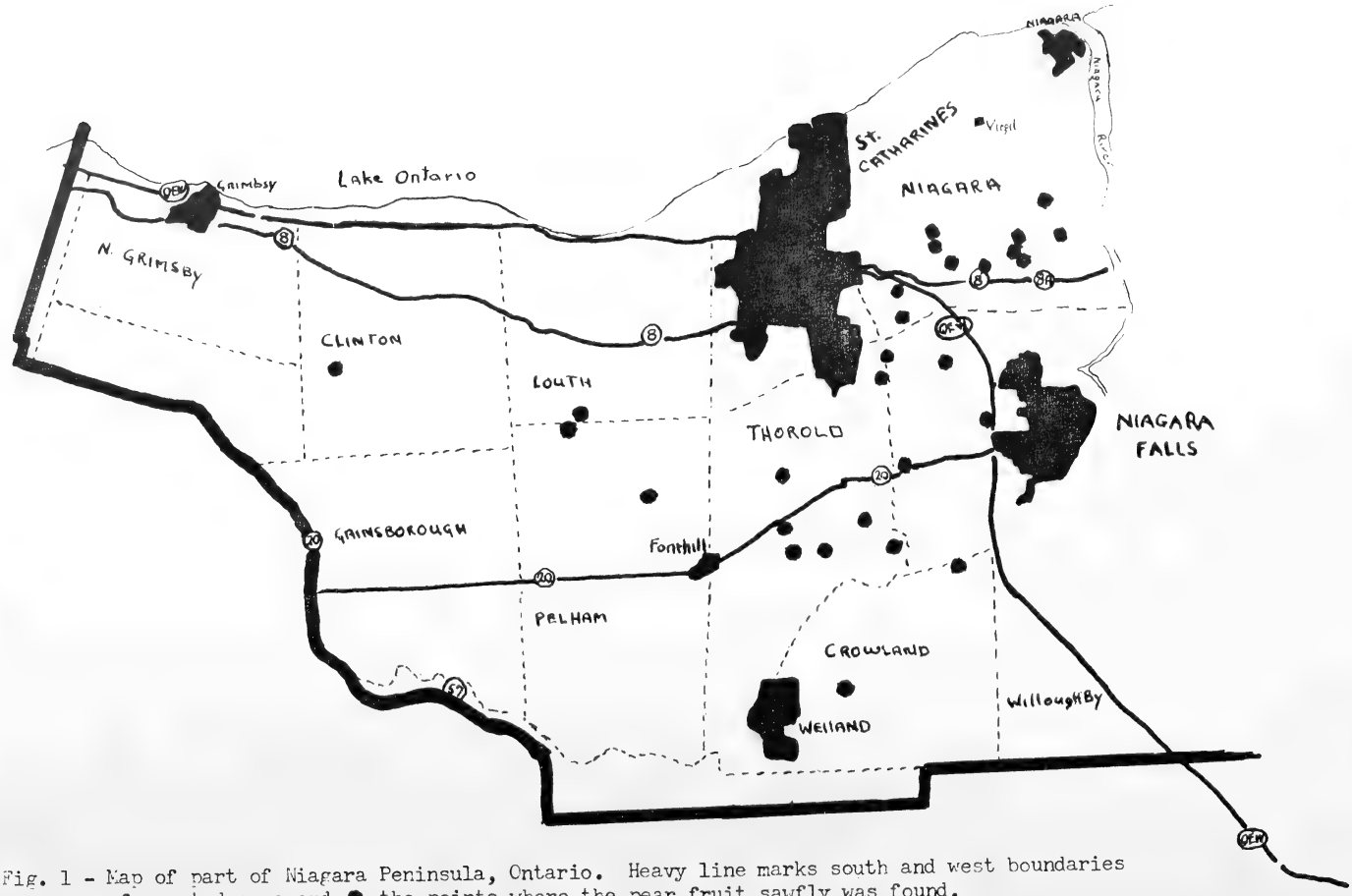

Fig. 1 - Map of part of Niagara Peninsula, Ontario. Heavy line marks south and west boundaries of scouted area and ● the points where the pear fruit sawfly was found.

hatching period, but it is believed to be in the region of 5 to 6 days. The larva appears to bore directly into the fruitlet from the blister causing a blackening in this area and a tiny hole with exuding frass. Larvae mature in five instars, drop to the ground, enter the soil, and produce a cocoon of dark brown parchment-like material; cocoons have been recovered at depths varying from 2 to 8 inches. It appears that the species over-winters as a larva, and Thomas (1936) gave no indication of the period of the pupal stage.

Acknowledgments

The writer is indebted to Mr. G. G. Dustan, Research Station, C.D.A., Vineland Station, Ontario and Mr. J. C. Paddon, Plant Protection Division, C.D.A., Niagara Falls, Ontario for their advice and assistance, and to Plant Protection Division personnel who were involved in the survey.

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(Accepted for publication: April 28, 1966)

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A MODIFICATION OF THE LEAF-DISC TECHNIQUE FOR ACARICIDE TESTS

W. H. Foott and H. R. Boyce

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The use of leaf discs for mite studies rather than entire plants has several advantages. There is an economy of space and host plants, uniformity of experimental units, and greater ease and exactness of observation. Also, as reported by Ebeling and Pence (1953) and Dittrich (1962), moribund mites may fall off a treated plant when their movements become incoordinated. They demonstrated that up to 50% of the total population on a test plant may be lost.

Three common methods of maintaining leaf discs in a healthy condition are to float the discs on water or a nutrient solution, place them on several layers of moist filter paper, or place them on a pad of moist absorbent cotton. The authors found that the absorbent cotton arrangement was the most desirable in acaricide tests as the cotton did not become desiccated as rapidly as filter paper and it was easier to remove dead forms from a stationary leaf disc than a floating one. However, one aspect of the technique which required improvement was to decrease the time required to keep the cotton moist, particularly on weekends and on other occasions when most of the laboratory personnel were absent. Included herein is a description of an automatic watering assembly which successfully eliminated the problem.

An individual watering unit consisted of an inverted 500 ml. Erlenmeyer flask, a short piece of glass tubing inserted through the rubber stopper of the flask, a piece of rubber tubing inserted over the glass tubing and a terminal length of glass which extended down to a short distance above the Petri dish (Fig. 1). Air pressure on the surface of the water in the Petri dish prevented the escape of water from the flask until a certain proportion of the water in the dish had evaporated. When the flask was not in use, or the Petri dish was removed for examination, a clamp was placed on the rubber section to prevent the flow of water. A rack was constructed which permitted the use of several dozen of these units at the same time (Fig. 2). Although the arrangement illustrated was used in a greenhouse it could also be utilized in a controlled atmosphere environment on a smaller scale.

The most suitable thickness of absorbent cotton used in the Petri dishes was approximately 3/8 inch. This permitted an adequate depth of water to saturate the cotton but prevented water from extending over the surface of the leaf. A circle of cotton 4 inches in diameter provided ample space for leaves of any host plant used in our experiments. Most acaricide tests were conducted during the winter when greenhouse temperatures commonly ranged from the high 60's to the low 80's in Fahrenheit degrees. Under these conditions one flask of water lasted from 17 to 23 days.

The flask arrangement described was used mainly in tests with the two-spotted spider mite, *Tetranychus urticae* Koch. Discs cut from leaves of Clark's bush lima bean plants generally remained healthy for three weeks. Leaves which were

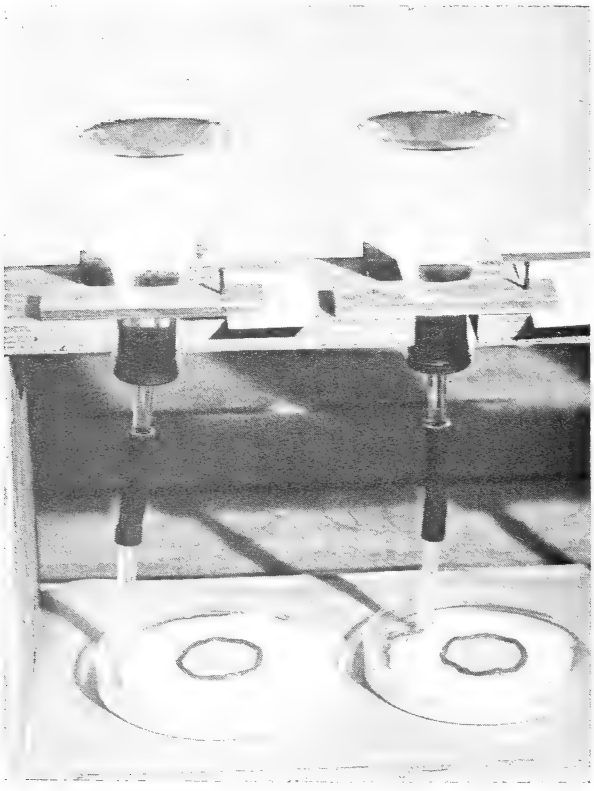

FIG. 1. Components of an automatic watering unit for maintenance of leaf discs.

FIG. 2. A rack to hold a series of automatic watering units.

thin or had abrasions could not be used as they often became water-soaked within a few days. The absorbent cotton method of maintaining leaves was unsatisfactory when tests were conducted with the European red mite, *Panonychus ulmi* (Koch) on peach leaves. Peach leaves developed a severe chlorosis within a few days and the majority of the mites either died or became trapped in the tanglefoot barrier which was placed around the edge of each leaf or leaf disc.

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(Accepted for publication: February 18, 1966)

A CONE TRAP FOR IMMATURE BLACK FLIES (DIPTERA: SIMULIIDAE)

A. F. Johnson and D. H. Pengelly
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The habit of black fly larvae and pupae of attaching to stones, sticks, vegetation, and many extraneous objects found in flowing water, makes possible the sampling of populations. For this, a form of cone trap was suggested by Phillipson (1956) and Wolfe and Peterson (1958).

The unit described here was designed to simplify the sampling procedure. This trap consisted of a galvanized, sheet-steel cone covered by a removable paper cone of the type used at soda fountains (Fig. 1). The paper cones were No. 7080, made by the Dixie Cup Co. (Canada) Ltd., Brampton, Ontario. The metal cone was attached to a short length of steel fence-post by means of a short carriage bolt, with the apex of the cone pointing upstream. Sampling was accomplished quickly by removing the paper cones, which, with attached insects, were preserved in 95% ethyl alcohol or held in petri dishes for later examination. Removal of larvae with the aid of a low power dissecting microscope permitted collection of the small, early-instar larvae.

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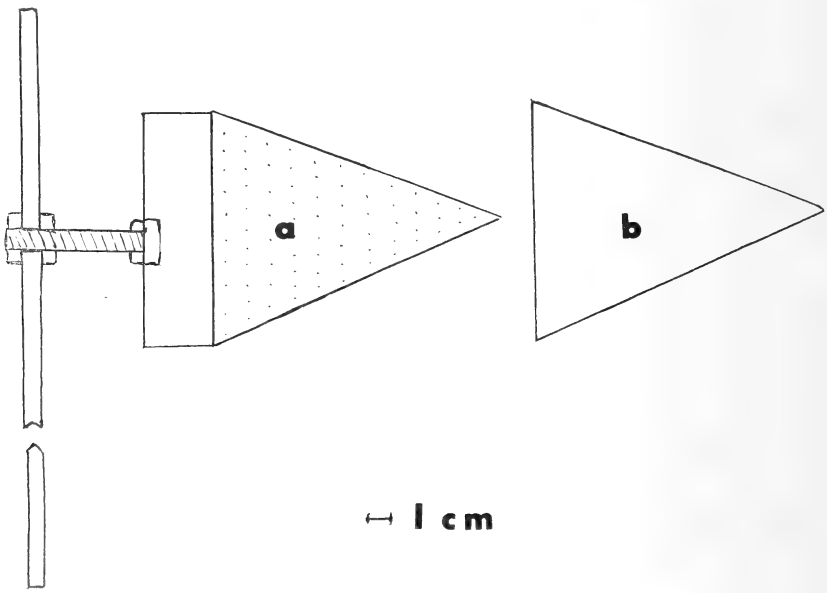

Fig. 1. Side view of black-fly larval and pupal trap with removable paper cone. a—galvanized sheet-metal support cone; b—paper cone (Dixie No. 7080).

(Accepted for publication: December 10, 1965)

V. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND SECOND ANNUAL MEETING — ENTOMOLOGICAL SOCIETY OF ONTARIO

LONDON, ONTARIO

September 8-10, 1965

The 102nd Annual Meeting of the Society was held in Middlesex College, University of Western Ontario. The opening session began at 9:30 a.m. on September 8 with the President, Dr. H. E. Welch, as chairman. Members were welcomed by Dr. R. J. Uffen, Dean, College of Science, University of Western Ontario and by Dr. E. Y. Spencer, Director, Research Institute, Canada Department of Agriculture, London. After some business announcements by the Society's President, the meeting proceeded for the next three days according to the printed program and began with Invitation Papers by Drs. W. Chefurka and J. E. Steele.

On the afternoon of September 8, Dr. W. W. Judd lead a group of entomological enthusiasts to Byron Bog, a unique environment with special plants and insects, which, it is hoped, will become a Nature Preserve. Other members and wives visited the Stratford Festival to see the play "Henry IV". On the same evening an informal business meeting was held at the Labatt's Building, at which Professor A. W. A. Brown, Head, Department of Zoology, University of Western Ontario presented an illustrated talk "Entomologists Abroad". This was concerned with the work of the World Health Organization in controlling human diseases (e.g., malaria) and their vectors, work in which Dr. Brown has played an active part. On the evening of September 9 a reception and banquet was held in Sydenham Hall, after which the President's prize was awarded, and Professor J. Havelka, Department of Psychology, University of Western Ontario stimulated the over 100 members and wives with a talk "Mind: a Problematic Evolution", which was followed by a lively discussion.

The following 30 papers were presented during the meeting (some of these appear in the preceding sections of this volume. Those marked with * were read by university students for the President's Prize (for result of the award see Appendix II).

CHEFURKA, W. (London). Evaluation of pathways of carbohydrate metabolism in insects.

STEELE, J. E. (U. Wrn. Ont.) Hormonal control of carbohydrate metabolism in insects.

BECKEL, W. E. (U. Toronto). Ultrastructure of blood cells in insects.

Three types of blood cells are commonly seen in many routine thin sections of *Rhodnius prolixus* nymphs. These types will be illustrated, accompanied by wild speculation as to their activities and functions.

HANNAY, C. L. and BOND, E. F. (London). Electron microscopy of the blackfly wing.

*TADANO, T. (U. Wrn. Ont.) Development and inheritance of insecticide resistance in *Culex fatigans* Wied.

Strains of this important mosquito vector of disease were selected in the laboratory in successive generations with certain insecticides considered by WHO for world use. Resistance to DDT was rapidly developed by strains from Rangoon (Burma) and Fresno (California). Resistance to dieldrin was rapidly developed in strains from Freetown (Sierra Leone) and Douala (Cameroun) as well as the Rangoon, but not the Fresno, strain. Resistance to the organophosphorus compounds—malathion, diazinon and fenthion — developed comapartively slowly (an approximately 5-fold increase in 10-15 generations) in the strains from Freetown, Douala and Rangoon. Resistance to the carbamate insecticide AC-5727 developed equally slowly.

The DDT-resistance proved to be due to a dominant gene linked to the marker *y* (orange-larva) on chromosome 2, at a crossover distance of 20-21 units from it. Dieldrin-resistance proved to be due to a single gene, neither dominant nor recessive, assorting independently with *y* and with *w* (white-eye) on chromosome 1. Its linkage with the marker *kps* (clubbed-palpi) on chromosome 3 is being investigated.

*Johnson, A. F. (U. Guelph). Some aspects of the ecology of *Simulium rugglesi* N. & M. (Diptera: Simuliidae).

The black fly, *Simulium rugglesi,* is relatively abundant in certain streams in Algonquin Park. The immature forms have been studied with respect to distribution within the stream, associated species of black flies in the same areas, and with their growth and development. Collections of black flies were made at intervals throughout the late fall and winter in an attempt to locate the early stages of *S. rugglessi.* Sampling was resumed after the females were known to be ovipositing. This paper reports on the progress of these studies.

*Smith, S. M. (McMaster U.). Attraction of blood-sucking flies to olfactory stimuli.

The extent to which different species of simuliids and tabanids are attracted to chemicals emitted by the avian or mammalian host, is being investigated. In this presentation emphasis will be given to the attraction to carbon dioxide.

*Jalil, M. (U. Waterloo). Chemosterilant studies on the two-spotted mite, *Tetranychus urticae* (Koch).

This paper gives a brief account of the effect of certain chemosterilants on the two-spotted mite, *Tetranychus urticae* (Koch). Observations on the sterility of this mite are presented, as a result of the treatment of various immature stages with these chemosterilants.

Atwood, C. E. (U. Toronto). Continuous laboratory rearing of some diprionid sawflies.

Sullivan, C. R. and Wallace, D. R. (Sault Ste. Marie). Interaction of temperature and photoperiod in the induction of prolonged diapause in *Neodiprion sertifer* (Geoff.).

When *Neodiprion sertifer* cocoons, arising out of rearings at 21°C and 0-, 16-, 20-, and 24-hr photoperiods, were held at 10°C, the larvae underwent a prepupal diapause of 2-3 weeks before morphogenesis, and emerged as adults 83-89 days after cocoon spinning.

Individuals from photoperiods of 4-12 hr, day-lengths normally associated with a non-diapause condition at 21°C, underwent prepupal diapause ranging from 2 weeks to 2 years, within which four distinct phases of diapause could be distinguished.

There is a loss of reproductive potential associated with extended periods of diapause.

Females undergoing normal diapause at 10°C or 21°C produce approximately 1.38 eggs/mg initial cocoon weight. Phase 2 individuals, emerging about 180 days after cocoon spinning, produce about 1.26 eggs/mg initial cocoon weight. Phase 3 individuals, emerging about 425 days after cocoon spinning, produce approximately 1.10 eggs/mg initial cocoon weight, and phase 4 individuals, emerging about 725 days after cocooning, produce about 0.92 eggs/mg initial cocoon weight.

Belton, P. and Galloway, Mary M. (Belleville). Some observations on mosquitoes of the Belleville, Ontario district.

Pengelly, D. H. (U. Guelph). Reproduction in *Laelius utilis* Ckll. (Hymenoptera: Bethylidae). *Laelius utilis* Ckll. is a parasite of immature dermestids. Data from laboratory studies have been used to construct life tables used in determining the intrinsic rate of natural increase of the wasp. This paper will report on this and related aspects of the population development.

Nickle, W. R. (Belstville, Md.) and Ayre, G. L. (Belleville). *Caenorhabditis dolichura* (A. Schneider, 1886) Dougherty, 1955 (Nematoda: Rhabditidae) in the head glands of the ants, *Camponotus herculeanus* (L.) and *Acanthomyops claviger* (Roger) in Ontario.

Smith, S. G. (Sault Ste. Marie). The Mendel Centennial.

Herne, D. H. C. (Vineland). Genetics of resistance to parathion in the Niagara strain of the two-spotted spider mite. (read by G. G. Dustan).

Grant, C. D. and Brown, A. W. A. (U. Wrn. Ont.). DDT-tolerance in the mayfly *Heptagenia hebe* in New Brunswick.

Recently mayfly populations in areas sprayed for spruce budworm control have been recovering more strongly than at first. Nymphs of *Heptagenia hebe* from the Renous River, DDT-sprayed 7 times between 1956 and 1963, showed an LC_{50} of about 2 p.p.m. DDT, as compared to 0.15 p.p.m. for nymphs from the Pollet River which had never been sprayed. Nymphs of *Stenonema* spp. from Rocky Brook, a locality sprayed 7 times with DDT, also showed an LC_{50} no less than 10 times greater than those from Pollet River.

Dixon, S. E. and Shuel, R. W. (U. Guelph). Diet and hormone balance in insects.

Hormones are generally considered central to the regulation of growth and development. Nutrition may be considered as the prime mover in establishing the hormonal milieu. Evidence from research on honeybee and cockroach is presented to support this thesis.

Harvey, G. T. (Sault Ste. Marie). Nutritional studies of eastern spruce budworms.

The eastern spruce budworm, an exclusively coniferophagous insect, readily accepts and develops on an artificial diet developed for lepidopterous larvae feeding on broad-leaved plants. Wheat embryo is the most-poorly defined component of this diet and has been found to supply essential unsaturated fatty acids and cholesterol, as well as an unidentified component present in the wheat germ residue after extraction with organic solvents. Early results indicate that both linoleic and linolenic acid may be needed for full larval and adult development. Although the diet contains ascorbic acid, it is not essential in the presence of wheat germ.

Fast, P. G. (Sault Ste. Marie). Comparative studies on lipids of some insects. (read by T. A. Angus).

Musgrave, A. J. (U. Guelph), Nigam, P. C. (Can. Dep. Forest., Ottawa), and Hauser, M. (U. Guelph). Insect microflora as an indicator of host metabolism.

Experiments were done to see if changes in insects' metabolism caused by toxicants were reflected in quantitative changes in microflora.

Bucher, G. E. and Bracken, G. K. (Belleville). Fungus disease of insect parasite adults caused by *Torula nigra* (Marpmann).

Torula nigra (Marpmann), a yeast-like fungus of the family Dematiaceae, produces lesions on the legs of adults of the insect parasitoid, *Exeristes comstockii* (Cress), in laboratory cultures. The fungus grows saprophytically on frass and litter of cages and invades the tissues of the insects at the sites of wounds caused by fighting or cleaning. A strong host reaction usually successfully localizes infections so that mortality is light.

There is no previous record of *T. nigra* being associated with insects and records of related fungi associated with or attacking insects are rare.

Leech, R. (Belleville). Studies on spiders of Hazen Camp, Ellesmere Island.

About 20,600 spiders were studied during a period of two summers and winters. Thirteen species were found. Detailed studies in courtship, mating, seasonal occurrence of adults, solar orientation, and habitat were made. Zoogeographical data indicate that northern Ellesmere Island served as a refugium during the Wisconsin glaciation and perhaps the entire Pleistocene epoch.

(Not judged a publication as the abstract and paper have been published in *Quaestiones Entomologicae 2:* 153-212).

Ayre, G. L. (Belleville). A preliminary report on two species of predacious ants introduced into pine and spruce plantations in Ontario.

Colonies of *Formica integroides* Emery and *F. obscuripes* Forel, predacious ants native to the interior valleys of British Columbia, were transferred to pine and spruce plantations at Actinolite, Ontario. The establishment and behaviour of these ants at their new location is discussed and a preliminary report on their effect on indigenous insect populations is given. (Not a publication).

Harris, P. and Peschken, D. (Belleville). Further observations on the release of *Chrysolina* spp. against St. Johns wort in British Columbia.

Releases of *Chrysolina quadrigemina* and *C. hyperici* were made against St. Johns wort in B.C. following their rapid control of the weed in California. Results in B.C. for the first 8 years were disappointing; however, after 14 years the population of both species has increased and spread, depressing the weed in most areas. It is suggested that a natural selection to local conditions must often be necessary in biological control. These control attempts should not be regarded as a failure too rapidly.

Bond, E. J. and Monro, H. A. U. (London). Investigations on the use of DDVP for the control of insect infestations in empty cargo ships.

The volatile properties, high insect toxicity and relatively low mammalian toxicity of dimethyl 2,2 dichlorovinyl phosphate give this insecticide considerable potential for use in the control of insect pests in the empty cargo holds. Field tests have shown that vapors of this material can be dispersed throughout the space of a ship's hold in quantities sufficient to kill insect species commonly found in ships. Experiments have also shown that DDVP may be effective for practical use over a wide rangs of temperatures.

Begg, J. A. (Chatham). Toxicity of various insecticides against resistant cutworms.

Hovey, C. Y. (Niagara Falls). A report on the occurrence of pear fruit sawfly (tentatively identified as) *Hoplocampa brevis* Klug, in the Niagara district.

ARTHUR, A. P. (Belleville). The present status of the introduced skipper, *Thymelicus lineola* (Ochs.) (Lepidoptera:Hesperiidae) in Canada, and possible methods of control.

Surveys in eastern Ontario showed that *T. lineola* is spreading eastward from the areas known to be infested in 1961 (Arthur, 1962)[1]. It is widely distributed in northern Ontario, and a few adults have been recorded from Quebec.

Three methods of control are under investigation. These are: cultural control, spraying with *Bacillus thuringiensis* Berliner, and parasite introduction. Tests indicate that fields cut just prior to adult emergence, will not be used for oviposition. Spraying with *B. thuringiensis* will control larval populations. The European pupal parasite, *Stenichneumon scutellator* Grav., is under investigation at Belleville prior to possible release in Canada.

[1]Proc. Entomol. Soc. Ont. (1961) 92: 190-191. 1962.

STEVENSON, A. B. (Vineland). Seasonal history of leaf-infesting grape phylloxera in the Niagara Peninsula.

MONRO, H. A. U. (London). A preliminary report on the golden nematode *Heterodera rostochiensis* Woll. on Vancouver Island.

Annual Business Meeting

The annual meeting was held in Room 105B, Middlesex College, University of Western Ontario with President H. E. Welch in the chair. Fourty-three members were present.

On a motion from T. Angus, seconded by H. R. Boyce, the minutes of the last annual meeting, (Guelph, September 2, 1964) as circulated to the membership were adopted.

President's Report

At the time of the last meeting there was the necessity of finding replacements for the Editor of the Proceedings, D. G. Peterson, and the Secretary-Treasurer, C. C. Steward. These positions were filled by D. M. Davies and D. H. Pengelly respectfully. President Welch outlined the year's activities. Letters were sent to the various research and teaching institutions in Ontario to bring to their attention the Proceedings as a means of publishing data.

The President's report was accepted on a motion by A. J. Musgrave, seconded by D. M. Davies. Carried.

Secretary-Treasurer's Report

The audited financial statement for 1964 and the interim financial statement to August 31, 1965 were presented.

The successful candidates elected to the Board of Directors were C. E. Atwood, P. Belton, G. W. Green, Anne Hudson, H. A. U. Monro, W. Y. Watson and W. H. A. Wilde.

The 1965 membership as of August 31 was 235 as compared to 238 of 1964. The reduction was the result of excluding 4 student members of the Canadian Society who did not affiliate with the Ontario society but were listed.

Moved by Anne Hudson, seconded by G. W. Green that the Secretary-Treasurer's report be adopted. Carried.

Library Committee Report

During the past year the Library has continued to operate for the benefit of all members.

The facilities have been used extensively by many graduate students in the Department of Zoology, and also by staff members. Library Loan Services across the country have used our journals and publications to quite a large extent and we have loaned journals to a wide range of workers in Entomology and other fields.

The Library handles approximately 75 exchanges at the present time and these have been catalogued and indexed so that they are immediatly available to all members.

Considerable discussion followed the reading of this report. However, in the absence of W. C. Allan little information was available. The main point in question concerned the notification of members as to what publications were available to the members and that perhaps a listing of the holdings could be placed in the Proceedings. Suggestions were made that duplicates of the more valuable holdings could be made if requested on interlibrary loan. On a motion by W. E. Heming, seconded by G. G. Dustan, the Library Report was accepted.

Editor's Report

Twenty-six papers had been received for the forthcoming Proceedings. An appeal was made for review articles on insects of economic importance.

In reply to a question by A. Wilkes it was reported that the circulation of the Proceedings was about 1600, being the same as that of the Canadian Entomologist plus about 120 on the Librarian's mailing list. The Proceedings reaches over 40 countries.

Moved by A. Wilkes that the Editor's Report be accepted. Seconded by W. F. Baldwin. Carried.

Grant to Zoological Society of London

In response to a plea for help from this Society, the publishers of the Zoological Record, our Society has made an annual grant of $100.00. Moved by E. J. Bond, seconded by W. W. Judd that this be continued for 1965. Carried.

Auditors

On a motion by H. R. Boyce, seconded by T. Angus, Payton and Saunders were reappointed auditors.

Resolutions

The following Resolutions were presented by W. F. Baldwin and A. J. Musgrave:

1. WHEREAS the University of Western Ontario, by making available its excellent accommodations and facilities has greatly contributed to the success of the 102nd Annual meeting,

BE IT RESOLVED that our Society through the Secretary extend to the President of the University, Dr. Hall, our sincere thanks for the meeting and housing facilities placed at our disposal.

2. WHEREAS the Program and Social Committees under Dr. H. A. U. Monro and Dr. W. W. Judd have done an outstanding job in preparing for our Annual meeting,

BE IT RESOLVED that our Society, through the Secretary, express our appreciation for their fine efforts.

3. WHEREAS the annual competition for the Pesident's Prize has become an integral and important part of our meeting, and since the judges have such a great responsibility in deciding the winner of the competition,

BE IT RESOLVED that the Society extend our appreciation to Miss Hudson, Dean Beckel and Mr. Fletcher, the chairman.

4. WHEREAS several amateur entomologists attended our meeting, our Society extends to them a sincere welcome and our best wishes for their entomological endeavours.

5. WHEREAS the informal business meeting on Wednesday was made possible by the hospitality of The Labbatt Company,

BE IT RESOLVED that our Secretary express our sincere appreciation to this organization.

T. Angus moved that these be amended to extend to the retiring executive the appreciation of the Society for their efforts during the year.

W. F. Baldwin moved that this report be accepted as amended. Seconded by J. Begg. Carried.

New Business

Mr. F. Fletcher asked the Society to consider the drafting of a guide to be used by judges in grading the student papers in the President's Prize competition. The representatives of the universities were sympathetic with Mr. Fletcher but in the discussions that followed it was very evident that they did not want the judging criteria to be made known to students nor to the professors involved. From the discussions it was clear that there was agreement on several points.

1. Judges are selected for their abilities to choose the best of the student papers submitted.

2. There has been no dissatisfaction on the part of universities on the decisions made.

3. The society has full confidence in judges and appreciates greatly the seriousness of their efforts.

Place for the 1966 Meetings

C. E. Atwood extended an invitation from the University of Toronto subject to final approval as it was expected that university residences would be available — if possible, the time and date not to conflict with the Canadian Society meetings. The invitation was accepted — unanimously.

The date of the Annual Meeting was discussed and it was agreed that serious consideration be given to the conflicting schedules of the Regional and National Societies. Also it was agreed that the problem be left with the executive who were now aware of the strong feelings of members concerning communication with the National Society and the need for a policy concerning date selection.

The meeting adjourned on a motion by G. Dustan, seconded by W. E. Heming.

D. H. Pengelly,
Secretary-Treasurer.

APPENDIX I

ANNUAL FINANCIAL STATEMENT FOR 1965

RECEIPTS

Membership dues	$ 2,147.93
Exchange	37.29
Sales of Reprints	538.00
Sales of "Proceedings"	20.00
Grant from Minister of Agriculture	300.00
Receipts from Annual Meeting	324.06
Cash returned after Annual Meeting	300.00
Bank Interest	47.48
Bond Interest	18.00
Government Bonds	400.00
Bank Balance January 1, 1965	1,013.86
	$ 5,147.02

Signed:

C. J. Payton
B. E. Saunders
Auditors

DISBURSEMENTS

Dues to Ottawa	$ 1,654.00
Exchange on cheques	23.05
Library Maintenance	200.00
Postage	90.75
Express	8.99
Printing, Stationery	79.44
Honorarium to Secretary (2 year term 1964-5)	100.00
Zoological Society, London	100.00
Annual Meeting:	
Cash for Annual Meeting	300.00
President's Prize	50.00
Guest Speaker	50.00
Accommodation and Banquet	486.88
Government Bonds	400.00
Bank Balance January 1, 1966	1,603.91
	$ 5,147.02

February 4, 1966

APPENDIX II

PRESIDENT'S PRIZE

Four papers were presented by university students at the 102nd annual meeting in the fifth annual competition for the President's Prize (see list of titles and abstracts above).

The judges, Anne Hudson, W. E. Beckel and P. W. Fletcher, awarded the fifty-dollar prize and Certificate of Merit to Mr. A. F. Johnson, the presentation being made at the banquet by Dr. H. E. Welch.

Mr. Allan F. Johnson was born in Toronto and enrolled at the University of Guelph in 1958. He was granted his B.S.A. degree in 1964 and began immediately to work towards his Masters degree under Dr. D. H. Pengelly. His thesis was on the ecology of the immature stages of the black fly, *Simulium rugglesi* N. & M.

IN MEMORIAM

JOHN ARTHUR BEGG, 1916-1965

Although not altogether unexpected, the death of John Begg on December 19, 1965, nevertheless was a shock, especially to those of us who knew him in his prime. Jack first came to the Chatham Entomology Laboratory in 1948 as a summer assistant. Then he was a towering giant, of seemingly limitless strength. He belonged to that generation of veteran servicemen who, having been through grim experiences while still young, regarded life as a song. It was sad to see this buoyancy slip away during his long illness.

Jack Begg was born in Chatham, Ontario, on June 6, 1916. His early boyhood was spent near Storrs, Connecticut, where his father was on the staff of the Connecticut State Agricultural College. In 1928 the family returned to the old homestead near Tiverton, Ontario. Here Jack attended High School and, later, worked the family farm until August, 1941, when he enlisted in the R.C.A.F. He spent nearly three years in Britain, mainly as a navigator in Bomber Command, and was demobilized in 1945, with the rank of Flying Officer.

After demobilization Jack attended the Ontario Agricultural College, being a member of the famous class of '49, which was mainly composed of ex-servicemen. This class carved a niche for itself in the history of the O.A.C., not all of which was academic. Jack specialized in entomology, and proved to be a fine student despite a proclivity for high jinks. This love of practical jokes was inherent in Jack. I recall being with him when he re-visited his boyhood home at Storrs in 1962. One of the people he insisted on seeing was his old Sunday School teacher, a very old, active, little lady, with shrewd, bright eyes. Yes, she remembered Johnnie Begg, the cleverest boy she ever taught, and, with a twinkle, one of the naughtiest.

Jack received his B.S.A. degree in 1949. Later, in 1956, he obtained his M.Sc. from the University of Western Ontario. This was gained at great personal sacrifice, and resulted in a severe bout with pneumonia from which he never completely recoverd. After graduation from O.A.C., Jack joined the staff of the Chatham Entomology Laboratory, where he remained for the next sixteen years.

Jack Begg was pre-eminently a field entomologist whose chief desire was to help the farming community. He first became widely known for his control studies on wireworms and, later, for field studies of cutworms and root maggots attacking tobacco. Jack, in fact, became the recognized Canadian authority on tobacco insects to which subject he devoted many years of research. He published quite a number of both scientific and popular papers, many of which appeared in the Proceedings of the Entomological Society of Ontario. His ability as a researcher was recognized in 1964 when co-workers of the United States elected him chairman of the entomology section of the Tobacco Workers' Conference. Jack was outstanding in extension entomology, and was greatly admired and respected by extension workers and tobacco growers, who turned to him instinctively when problems arose. Indeed, many a perverse grower had reason to be thankful for Jack's great patience—a quality that was often overlooked.

Jack was a member of the Entomological Society of Ontario (Director in 1958-1959), the Entomological Society of Canada, and the Entomological Society of America. He was also a member of the Professional Institute of the Public Service of Canada.

In 1943 Jack married the former Vera Foster of Selby, Yorkshire, England. He was the father of four sons of whom he was justly proud. Three of the boys were university scholarship winners, two being valedictorians of their High School graduating classes. Ian is

a student at the University of Western Ontario; Robin and Richard are students at the University of Toronto, and Geoffrey is a High School student. Jack was a director of the Chatham Boy Scout camp, and an elder in Park Street United Church, where he taught Sunday School for many years.

On a Sunday evening, as he sat quietly with all his family around him, Jack suffered his last and fatal heart attack. Death was almost instantaneous. We shall remember him, as we knew him, a kindly, good-humoured soul who, in his own way, made his contribution to his community and to his profession.

Harry B. Wressell

GEORGE ALLAN MOORE, 1878-1966

Canada has lost one of the last of the old-time naturalists and amateur systematists in Entomology with the passing of George A. Moore at his home in Outremont, Montreal, on March 18, 1966.

Mr. Moore was born in Toronto, October 3, 1878, but moved to Montreal at the age of one year. He was on the staff of the Bell Telephone Company of Canada for 47 years, from 1898 to 1947.

He served as secretary of the Lyman Entomological Committee of McGill University from the time this committee was formed in 1914 until 1961, and continued as a member of the committee until the time of his death. He was curator of the Lyman Entomological Collection and Library for 30 years, retiring only in 1961 at the age of 83.

George Moore was a member of many scientific societies. He had been a member of the Montreal Branch of the Entomological Society of Ontario (now a branch of the Quebec Society) since 1896, and had served the Branch as Secretary-Treasurer for 12 years, Vice-president for two years and as President for 26 years. He was President of the Entomological Society of Ontario during 1944-45 and was made an Honorary Life Member in 1945. In 1951 he was made Honourary Life Member of the Entomological Society of Canada and also of the Entomological Society of Quebec. Among other honours conferred upon him were: a citation for contributions to Entomology in Canada, during the Centennial of Entomology in Canada in 1963; Fellow of the Royal Entomological Society of London, 1937; Fellow of the Entomological Society of America, 1951; Life Member of the Canadian Society of Zoologists, 1965; Honourary degree of Master of Science, McGill University, 1955. He was a member of the American Association for the Advancement of Science; McGill University Chapter, Sigma XI; the Quebec Society for the Protection of Plants; and the Province of Quebec Society for the Protection of Birds.

Mr. Moore is survived by his wife, one son and one daughter. He will be missed not only by his family and friends, but also by all those interested in Entomology in Canada.

V. R. Vickery

JOHN HENDRIKUS DE RONDE, 1919-1964

With the sudden death of J. H. de Ronde on November 22, 1964 the agricultural community lost a dedicated worker. Born in Heerde, Netherlands and completing his early education at Zandvoort, he graduated with a diploma in floriculture after three years at the State horticultural school in Aalsmere. After serving in the army, John spent the difficult years of the German occupation of the Netherlands avoiding the compulsory labour draft. At the war's end he opened a retail flower business, but in 1953 he emigrated to Canada with his wife (née Alice Vissar, three young boys and little else.

He joined the Entomological Laboratory, Vineland Station in 1958 as an assistant technician. His quickness to learn, his knowledge of horticultural practices, his willingness to work and his cheerfulness soon showed that the laboratory had an invaluable addition to the staff. In 1961 John became one of the original members of the spray team that field tested pesticides used in fruit production. A year later he took over the testing of fungicides at the St. Catharines branch of the newly formed Research Station and was responsible for recommendations for spray calendar revision. His ability and versatility were illustrated when, soon thereafter, he also became involved in the investigation of dead arm disease of grapes and made a valuable contribution in the short period remaining to him. Lacking the formal academic training, considered necessary for a research career in this country, John's ability and hard work won the respect of his associates. His cheerful good humour also earned him a great many friends, both in the pesticide industry and among his associates.

John was an expert flower arranger and this ability was utilized by many of his friends and colleagues for weddings and other special occasions, and his well trained baritone voice was a welcome addition to church and community choirs. He is survived by his widow and three sons.

J. H. H. Phillips

LEONARD ROY FINLAYSON, 1903-1965

Roy Finlayson belonged to the first generation of Belleville scientists. Born and educated in Montreal, he joined the Belleville staff in 1930, shortly after graduation from Macdonald College. A serious heart condition caused his premature retirement at age 56, and his death on October 26, 1965, at age 62.

His work at Belleville was in two main phases. In 1933 to 1942 he was responsible for the work with imported parasites of the sawflies, especially the spruce sawfly. This was by far the largest biological control project handled at Belleville. In some years more than 70 assistants worked at rearing and propagating the parasites, of which nearly 800 million were produced and liberated.

A heart attack in 1947 terminated Finlayson's Ph.D. studies. From then until his retirement he engaged in experimental laboratory studies on the food and nutrition of adult parasites, in collaboration with his wife, the former Thelma Green, who is now a Research Scientist on the Belleville staff.

An unassertive, philosophical, likeable, and justice, Finlayson had in his quiet way a humorous man with a strong sense of fairness lasting influence on the Belleville programme. He had more ideas than many of his colleagues, and he initiated various lines or research that were original bases of research projects of associates. He tried to be a perfectionist in everything he did, and this retarded his rate of publishing. Neverthless he was author or co-author of some 15 research papers, mostly in the Canadian Entomologist.

Bryan P. Beirne

ROCHESTER WEBB SMITH, 1901-1966

Chester Smith was also of the first generation of Belleville scientists. He worked in biological control for more than 40 years, from his graduation from Ontario Agricultural College in 1924 until his death on Febraury 6, 1966, a week before he was due to retire.

His work was essentially in two phases. The first, mainly during the 1930's, was attempts at the biological control of various pest species: the wheatstem sawfly, European earwig, Oriental fruit moth, European corn borer, greenhouse whitefly, lecanium scale, and Comstock's mealybug. It had varying degrees of success. The most successful was the permanent control by imported parasites of the wheatstem sawfly in Ontario.

Unsuccessful attempts to control grasshoppers with parasites imported from Argentina led Smith into his major work: an intensive and extensive study that continued for over 20 years on the role of parasites in regulating grasshopper populations, both in the Belleville district and in about 100 localities in the Prairie Provinces. This was probably the most detailed study of its kind that has been made. It involved, for example, careful individual dissection of a total of over 250,000 specimens of grasshoppers of a total of 25 species. Smith published several important papers on the subject, notably in the Canadian Journal of Zoology in 1950 (with Thelma Green, who became Mrs. Roy Finlayson), 1958, and 1965. Much of his data remains to be analysed, but there are plans at Belleville to analyse it.

Smith was a careful and meticulous worker who would not publish until he was satisfied that he had completed a thorough and comprehensive study in which every detail was accurate. Though this retarded his rate of publication he nevertheless published about 22 research papers. In his last ten years his rate of work was retarded progressively by a serious heart condition.

A good and kindly man, always willing to assist others, Smith was unassuming and had a diffidence that increased as his health deteriorated. His work was his main interest. He was much liked and much respected. His contributions to Canadian agriculture were significant and lasting.

He is survived by his wife, the former Grace Holland (a sister-in-law of Dr. Tom Burnett, of the Belleville Institute), and by a son, Peter, an accountant in Toronto.
(He was a Director of the Entomological Society of Ontario in 1943-44 and 1955-56—Editor).

Bryan P. Beirne

LIST OF MEMBERS

(as of December 31, 1965)

Members are requested to check their addresses on this list and to report any errors or omissions to the Secretary-Treasurer.

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PROCEEDINGS

of the

ENTOMOLOGICAL SOCIETY OF ONTARIO

Volume Ninety-Seven

1966

Published September, 1967
by authority of
THE HONOURABLE WILLIAM A. STEWART
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ENTOMOLOGICAL SOCIETY OF ONTARIO

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1965 - 1966

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D. H. Pengelly, Dept. of Zoology, University of Guelph

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I REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

ECONOMICALLY IMPORTANT NEMATODES IN ONTARIO — 1966

J. L. TOWNSHEND[1]

The number of soil samples processed by the Ontario Nematode Diagnostic and Advisory Service increased again in 1966. Most of these were from tobacco fields; others originated from cereal, fruit, ornamental and vegetable crops.

The oat cyst nematode, *Heterodera avenae* Filipjev, caused severe damage in some oat fields. In one field the crop was a total loss. The root-lesion nematode, *Pratylenchus* sp., also occurs in oat roots and appears to be compounding the problem. Corn has been used for the control of the oat cyst nematode because it cannot complete its life cycle in corn roots. However, corn is damaged by the oat cyst larvae; also the root-lesion nematode can multiply readily in corn. Generally rotations using cereals are not practical because barley and wheat are hosts of the oat cyst nematode as well. Thus farmers are advised to use legume crops in their rotations.

The northern root-knot nematode, *Meloidogyne hapla* Chitwood, occurred in soils in which cereal crops were growing but it was found that susceptible vegetable crops had been grown in the preceding years. To date, root-knot nematodes have not been found on cereals and grasses in Ontario, though they are now known to occur on these crops elsewhere.

In peach and cherry orchards, the root-lesion nematode,*Pratylenchus penetrans* Filipjev and Stekhoven, continues to be responsible for replant failures and decline. In prospective strawberry plantings, more fumigation was done this fall for the control of *P. penetrans* than ever before.

In greenhouse rose production, the dagger nematode, *Xiphinema diversicaudatum* Thorne, is no longer a serious problem because of the widespread use of Nemagon. However, the root-lesion nematode, *P. penetrans,* has now become a problem on roses particularly in ground beds with sandy soil. Though root-lesion nematodes are not as effectively controlled as dagger nematodes by Nemagon, this compound will increase rose production when used against both nematodes.

In the production of greenhouse azaleas, two potentially serious nematode problems were detected when large numbers of the stunt nematode, *Tylenchorhynchus claytoni* Steiner, and the stubby-root nematode, *Trichodorus christiei* Allen, were found about the roots of a number of plants. The stunt nematode occurs in Canadian soils but the stubby-root nematode occurs rarely, if at all, and likely came in with imported azalea stock. Growth of affected plants was arrested and the foliage somewhat paler than normal. Nemagon was recommended for the control of both nematodes.

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[1]Research Station, Canada Department of Agriculture, Vineland Station, Ontario.

The root-lesion, root-knot, and cyst nematodes were all found on vegetable crops. Table beet when planted on former rhubarb land was severely damaged by the sugar beet cyst nematode, *Heterodera schachtii* Schmidt. The northern root-knot nematode, *Meloidogyne hapla,* was much more serious this year than in 1965, especially on carrots on muck soils at Thedford and Bradford. The root-lesion nematode, *P. penetrans,* was found in all vegetable soils.

Almost all samples of tobacco soil contained *P. penetrans.* About 10,000 acres were fumigated in 1966 — about 10 per cent of all tobacco land in the province. The acreage treated has increased steadily in the past eight years — 20 acres were treated in 1958. Fumigation, this year, has saved more than a million dollars worth of tobacco.

In summary, almost every crop was attacked by root-lesion nematode which indicates its wide distribution in Ontario. Cherry, oats, peach, rose, strawberry, and tobacco suffered the most damage. The cyst and root-knot nematodes have a more limited distribution; the latter nematode was more destructive this year than last, particularly to carrots on muck soils.

(Accepted for publication: January 17, 1967)

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INSECTS OF THE SEASON 1966 RELATED TO FRUIT, VEGETABLES AND ORNAMENTALS

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Fruit

The crop loss from insect injury on fruit was again small in the 1966 season. The extremely high temperatures during early summer did, however, result in some high populations. The European red mite, *Panomychus ulmi* (Koch), was the most troublesome on tree fruits. Even with increased miticide sprays, populations were very high and persisted in late summer and into September. Infestations of the apple maggot, *Rhagoletis pomonella* (Walsh), were not as severe as in 1965, probably caused by a lower adult fly population in August. The apple seed chalcid, *Torymus varians* (Walker), a minor insect in commercial apple production, was plentiful on wild apples, ornamental crab apples and the fruit of other *Malus* where the apples were small. It was also found in some commercial orchards in southwestern Ontario in the seeds of large fruit, the eggs apparently having been laid in early June. Dimpling of the apples near the calyx end was evident during pre-harvest apple maggot inspection. The cherry fruit flies, *Rhagoletis cingulata* (Loew) and *R. fausta* (O.S.) were not a problem where an efficient spray program was carried out.

Lepidoptera such as the Oriental fruit moth, *Grapholitha molesta* (Busch), codling moth, *Carpocapsa pomonella* (L.) and red-banded leaf roller, *Argyrotaenia velutinana* (Wlkr.) were present in small numbers. An exception was a

very heavy loss in a few orchards in the Georgian Bay area where a second brood of codling moth developed. Pear psylla, *Psylla pyricola* Forester, was at a low level. The sap bettle, *Glischrochilus quadrisignatus* Say, continued to increase in numbers on raspberries.

Vegetables

There were some insect problems on vegetables. Probably the most important was the sap beetle, *Glischrochilus quadrisignatus* Say, on tomatoes and corn. This beetle, that has been very important as a contaminant of raspberries for a number of years, was in outbreak form in southwestern Ontario. They worked their way into cracks and injuries on the fruit of tomatoes and into the tips of the cobs of corn. The beetles were removed as contaminants in corn being processed; but some infested table sweet corn for the fresh market did not find a market. Root maggots, *Hylemya* spp. were present in large numbers in May and June but crop losses were greatly reduced compared to 1965 because growers applied organo-phosphorus insecticides from the start. Populations of these insects were small during the hot, dry weather in late June, July and August. No infestation of peppers by the pepper maggot, *Zonosemata electra* (Say), was found or reported by growers but large numbers were found in the fruits of horse nettle, a wild host. The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), was very abundant in Essex County. The second brood of the European corn borer, *Ostrinia nubilalis* (Hubner), was very plentiful on corn and peppers.

Field Crops

The armyworm, *Pseudaletia unipuncta* Haworth, was reported from only one field in Ontario in 1966. The garden slug continued to be a problem in home gardens during wet weather. They also damaged some commercial plantings of field and processing corn in June before the plants were well established. The red-headed flea beetle, *Systena frontalis* Fabr., was present in destructive numbers in 57 acres of white beans in N. Simcoe county and also in a home garden area in Waterloo County. These intense, yet localized, infestations are interesting.

Ornamental Plants

Cottony maple scale, *Pulvinaria innumerabilis* Rathvon, was in outbreak form on soft maples in ornamental plantings in many areas. The attack was so severe that some soft maples have many dead branches. Smaller numbers occurred on some other trees. The last major attack was in 1959. The honey locust pod gall, *Dasyneura gleditschiae* O.S. continued to be abundant on Moraine locust and its ornamental varieties. The bronze birch borer, *Agrilus anxius* Gory, was serious on ornamental birch, especially the cut-leaf weeping birch.

(Accepted for publication: February 10, 1967)

IMPORTANT FOREST INSECTS OF ONTARIO IN 1966

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This report is intended to provide entomologists with a concise review of forest insect conditions in 1966 as determined by the Forest Insect and Disease Survey of Ontario. Throughout most of the Province, reports of new damage caused little concern, as many of our serious native pests occurred in relatively low numbers or were less destructive than in 1965, and few of the introduced pests which are spreading across Ontario made more than a minor change in their advancing front. A few forest insects not commonly collected, were very abundant in various localities, and entomologists should be aware of changes in the distribution and abundance of these insects.

Indigenous Insects

On Coniferous Trees

Small, but increased numbers of the spruce budworm, *Choristoneura fumiferana* Clemens, were contained in samples from white spruce study areas distributed (two per forest district) throughout Ontario. Numbers of the closely related jack pine budworm, *Choristoneura pinus* Freeman, increased sharply and caused severe defoliation of hill-top jack pine in a 6,500 square-mile area near Lake of the Woods. The severe infestations which occurred in stands of jack pine east and west of the City of Sault Ste. Marie, and on ornamental pines in the City were attributed directly to the influx of egg-laden moths observed during the week of July 18, 1965. The larch sawfly, *Pristiphora erichsonii* (Hartig), is increasing in numbers throughout northwestern Ontario to levels similar to those of the 1940's. Severe defoliation of tamarack occurred west of the Lakehead, especially between Kenora and Fort Frances. Infestations of the red-headed pine sawfly, *Neodiprion lecontei* Fitch, were prevalent throughout central and southern Ontario and only the timely and wide-spread use of chemical and biological sprays prevented serious damage to red-pine plantations. Persistently heavy infestations were responsible for some red and Scots pine tree mortality around Parry Sound. Another pine sawfly, *Neodiprion pratti paradoxicus* Ross, caused severe defoliation of jack pine in southeastern Ontario. Other native sawflies occurred on conifers in low or reduced numbers. These included *Neodiprion swainei* Middleton, *Neodiprion abietis* complex, *Neodiprion nanulus nanulus* Schedl, *Neodiprion virginianus* complex, *Pikonema alaskensis* Rohwer, and *Pleroneura borealis* Felt.

On Broad-leaved Trees

The widespread defoliation of poplar stands by the forest tent caterpillar, *Malacosoma disstria* Hubner, which has occurred annually in northwestern Ontario since 1961, failed to develop in 1966. Although the extent of defoliation was expected to decline, the reduction from 34,800 square miles in 1965 to 4,400 square miles in 1966 could not be foreseen. The decline in northern areas was due to failure of the eggs to hatch, and in other areas to the low survival of larvae due to a late spring. It was only along the Ontario-Minnesota border that appreciable

numbers of young caterpillars became established on the foliage. It is postulated that many fully formed larvae, after becoming active in the spring, gradually used up much of their food reserve and died before sufficient warm weather occurred to effect eclosion and that those which hatched were unable to become established on the foliage. A further decline in infestations is forecast for northwestern Ontario in 1967. Elsewhere in Ontario, forest tent caterpillar infestations along the North Channel, near Sudbury, around Lake Nipissing, and particularly near Ottawa enlarged and intensified. The outlook for 1967 based on light trap records and egg band counts is for a decline in the extent and intensity of infestations in areas affected longest, near Sudbury, Muskoka, and Pembroke, and a further increase in infestations east of Sault Ste. Marie, south of Lake Nipissing, and near Ottawa. It is obvious that the current outbreak is failing to attain the magnitude of the outbreak which occurred between 1948 and 1956. Populations of the closely-related tent caterpillar, *Malacosoma americanum* Fabricius, were particularly abundant in southeastern Ontario this year. Infestations of the Bruce spanworm, *Operophtera bruceata* (Hulst), a rather uncommon pest of hard maple in Ontario, declined in intensity at each of three widely-separated localities, namely on Great Duck Island in Lake Huron, in Algonquin Park and north of Sault Ste. Marie, yet caused considerable damage to foliage. These infestations are expected to collapse in 1967. Populations of common geometers including the cankerworms, *Paleacrita vernata* (Peck) and *Alsophila pometaria* Harris, and the basswood looper, *Erannis tiliaria* Harris, were at their lowest levels in years. *Dimorphopteryx pinguis* (Norton), a little known sawfly, caused complete defoliation of mature yellow birch trees in numerous stands, 40 to 140 miles north of Sault Ste. Marie. This outbreak was much more extensive and severe than two previous minor outbreaks recorded in 1958 and 1961. Two other sawflies, the amber-marked birch leaf miner, *Profenusa thomsoni* Konow, in northern Ontario, and the elm leaf miner, *Fenusa ulmi* Sunderwall, in southern Ontario, caused appreciable browning of foliage during the summer.

Introduced Insects

On Coniferous Trees

Following the discovery of the European pine sawfly, *Neodiprion sertifer* Geoffroy, in two plantations on Manitoulin Island in 1965, the following steps were taken. An intensive survey was made of all Scots pine plantations to determine where on the Island the sawfly occurred. In cooperation with the Insect Pathology Research Institute, Sault Ste. Marie, virus sprays were applied as operational trials to control the two infestations discovered in 1965 and the four additional ones found in 1966. The results were excellent in five plantations but were unsatisfactory in the sixth as the infestation was discovered too late for effective control. In southern Ontario, the known range of the sawfly was advanced about ten miles to the north of the 1965 limit in Simcoe County and the same distance to the east in Durham County. Virus and chemical sprays were used widely to control infestations which were much higher in intensity than in 1965. The European spruce sawfly, *Diprion hercyniae* (Hartig), has been one of the most commonly collected insects on white spruce for a number of years, but severe damage has never been reported in Ontario. Sampling over the entire Province continues to show narrow fluctuations in numbers. Much the same situation has prevailed in recent years with the larch casebearer, *Coleophora laricella* Hubner and its distribution bears a strong resemblance to that of the European spruce sawfly. Throughout most of its range, the introduced parasites,

Agathis pumila Ratzeburg and *Epilampsis laricinellae* Ratzeburg are known to be destroying a large proportion of the casebearers annually. Few sizeable infestations of the European pine shoot moth, *Rhyacionia buoliana* Schiffermuller, were found. In plantations on Manitoulin and Cockburn islands damage declined from heavy in 1965 to light in 1966, probably as a result of high overwintering mortality of larvae.

On Broad-leaved Trees

The widespread browning of birch foliage throughout the present range of the birch leaf miner, *Fenusa pusilla* Lepeletier, and the spread of this pest near Chapleau, and from a pocket around Port Arthur, into natural forested areas attests to the ability of this pest to cope with the northern Ontario climate. The same applies to the mountain ash sawfly, *Pristiphora geniculata* (Hartig), which was collected this year in considerable numbers on mountain ash trees at Quebec Harbour on Michipicoten Island. Exceedingly high numbers of elm bark beetles were again present throughout the southernmost parts of Ontario owing to the prevalence of Dutch elm disease and the abundance of brood material. The northward spread of the smaller European elm bark beetle, *Scolytus multistriatus* Marsham, appears to have slowed up or stopped. In the northern counties this beetle is failing to replace the native elm bark beetle, *Hylurgopinus rufipes* Eichhoff, as it did along the north shore of Lake Erie.

For further information on these and other forest insects, your attention is drawn to the Annual Report of the Forest Insect and Disease Survey (Sippell *et al., in press.)*

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II. SUBMITTED PAPERS

ENTOMOLOGY AND ENTOMOLOGISTS

Presidential Address

H. A. U. Monro

"How do you think the vote is like to go to-morrow? — I said.

—It isn't to-morrow, – he said, — it's next month.

—Next month! — said I. — Why what election do you mean?

—I mean the election to the Presidency of the Entomological Society, sir, — he creaked with an air of surprise, as if nobody could by any possibility have been thinking of any other. Great competition, sir, between the dipterists and the lepidopterists as to which shall get in their candidate. Several close ballotings already; adjourned for a fortnight. Poor concerns, both of 'em. Wait till our turn comes.

—I suppose you are an entomologist? — I said with a note of interrogation.

—Not quite so ambitious as that, sir. I should like to put my eyes on the individual entitled to that name. A society may call itself an Entomological Society, but the man who arrogates such a broad title as that to himself, in the present state of science, is a pretender, sir, a dilettante, an impostor! No man can be truly called an entomologist, sir; the subject is too vast for any single human intelligence to grasp.

—May I venture to ask, — I said, a little awed by his statement and manner, — what is your special province of study?

I am often spoken of as a Coleopterist, — he said, — but I have no right to so comprehensive a name. The genus *Scarabaeus* is what I have chiefly confined myself to, and ought to have studied exclusively. The beetles proper are quite enough for the labor of one man's life. Call me a Scarabeeist if you will; if I can prove myself worthy of that name, my highest ambition will be more than satisfied."

This extract is from the "Poet at the Breakfast-Table", by Oliver Wendell Holmes, first published in 1872[1]. As a text for a Presidential Address to our society today these observations appear to be highly relevant. We have an idea of what is meant by an "entomological society" but what is an "entomologist"?

Those of my generation will recall that many of us started our professional careers in the, then, Dominion Department of Agriculture with the rather bizarre title of "Insect Pest Investigator". The Entomological Branch was one of the principal agencies of this Department and was headed by an official called the Dominion Entomologist. The significance of injurious insects as threats to the economy was reflected in the names of the Divisions of this Branch:— Field Crops, Fruit Insects, Forest Insects and, optimistically, Foreign Pests Suppression. The appropriate leaders were appointed to supervise the field entomologists dealing

[1]I am indebted to Mr. John L. Rogerson, amateur entomologist, of London, Ontario for bringing this passage to my attention.

with the problems under these headings. A small number of agricultural colleges had full Departments of Entomology which turned out a few trained entomologists to fill the demands for federal and provincial positions. The training was fairly well standardized, with a strong emphasis on economic entomology, insect taxonomy and morphology.

Today much, if not all, of this has changed. The once clear identity of a federal agency for entomology has been submerged in a general research organization for agriculture or forestry. At lower levels of organization in the federal service there may be institutes or laboratories specifically named for entomological research, but in many cases those investigating insect problems may work in teams with exponents of other disciplines such as chemistry or biochemistry. There is no one senior official in the federal government who can be said to represent the science of entomology as a whole. Such an individual would have to be chosen from among several Research Coordinators or the heads of certain Institutes. However, in Ontario there is still an official position of Provincial Entomologist and, I understand, most Provinces maintain the title. At the universities the tendency is to absorb entomological teaching into departments of biology or zoology. In the undergraduate curriculum the emphasis on the specialised subjects of insect morphology and taxonomy has been considerably lightened or removed. Today it is possible for a trained biologist working entirely with insects to have obtained the highest academic qualifications without specific training in these two subjects.

There are today many scientists working in some aspect of entomology who are unable to identify at sight the more common insects. I say this without disparagement in order to emphasize the fact that it is quite usual nowadays for a scientist to work closely with insects without himself being or becoming an entomologist. A curious statement by Nobel Laureate George Beadle and his co-author wife even suggests that there might be some loss of status in such a concentration of interest in the insect itself. In their recent book "The Language of Life" they say: (p. 101) "The average layman tends to equate research *on* fruit flies with a burning interest *in* fruit flies, an interest that is pretty low on his list of what a red-blooded American man ought to spend his time thinking about".

Insects are readily available and certain common species may be reared quickly in large numbers. For this and other reasons insects are ideal material for many biological studies. Thus they are being studied and worked upon today by geneticists, biochemists, physiologists, neuro- and electro-physiologists, ecologists, behaviourists, insect pathologists, biometricians, to name a few disciplines, all in addition to the work of "ordinary" entomologists ranging from economic control to pure taxonomy. Such change is all for the good and ensures that our knowledge of insects is advancing on a very wide front. I must point out that, in recounting these developments, I am not being nostalgic or reactionary. I am reviewing the change in the organization of entomological research and education as it may affect the status and objectives of our Society.

This brings us to the two closely related problems of communication and representation. In his address last year, my worthy predecessor in this office dealt with the subject of communication and talked about the role of comparatively small societies in the dissemination of new knowledge between workers in different fields of entomology. I do not need to enlarge on his thesis except to relate it to the present argument. An entomological society such as ours can, in its meetings allow for the presentation of papers from a wide range of disciplines, such as those listed above, and thus give each member of the audience an opportunity to look beyond the confines of his own specialty. In this way our Society may be justly called entomological, even if some participants are not strictly entomologists themselves.

We now come to the second problem I mentioned, that of representation. The tendency for the disappearance of entomology as a distinct subject in universities and as an organizational entity in some governmental agencies leaves the entomological societies as the only coherent bodies throughout Canada today which may stand for the science of entomology as a whole. When vital problems arise affecting the overall contribution of our science to the conservation of our natural resources, to the wealth of our country and to the welfare of our people it may be necessary for the national and provincial societies, in their respective spheres, to speak for entomology as a whole.

(Accepted for publication: January 13, 1967)

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RECORDS OF THE ORTHOPTEROID INSECTS IN ONTARIO

V. R. Vickery[1] and D. K. McE. Kevan[2]

Introduction

Numerous papers have been written on the orthopteroid insects of Ontario, and many others of a more general nature refer to these insects, but no single publication has yet included all the species known from the Province. The earliest contribution of consequence was that of Caulfield (1888), but we are principally indebted to Dr. Edmund M. Walker, whose early work, 1898 to 1920, was mainly on orthopteroids, for our present knowledge of the Ontario species. Wherever the name Walker appears in this paper without initials, the reference is to a publication of E. M. Walker; initials are used to distinguish the works of Francis Walker and Thomas J. Walker. The other principal contributor to our knowledge of Ontario orthopteroids was Dr. F. A. Urquhart, who published on the group from 1937 to 1954, and who may be said to have continued where Walker left off.

The present paper lists all of the species known to occur in Ontario, together with others which are merely casual adventives reported from the Province. Previous literature references and synonymy are given for each of the species, together with alphabetical lists of localities in which the species have been found. These references are reasonably complete, although records given in Canadian Insect Pest Review are not listed. The localities cited are those recorded in previous literature, to which have been added many more that have not hitherto been published. The latter are nearly all for specimens which have been examined by the senior author in the Canadian National Collection, Ottawa, the Royal Ontario Museum, Toronto, or the Academy of Natural Sciences of Philadelphia. Undoubtedly there is material from additional localities in other institutions, particularly the Museum of Zoology, University of Michigan, Ann Arbor, and in the United States National Museum, Washington, D.C., which has not been seen. The Lyman Entomological Museum also has very many specimens from Ontario, the majority of which, however, were collected by the senior author only during 1966, and which are not included as they could not be processed in time for inclusion in this review.

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It is, perhaps, regrettable, that no keys for separation of species, no descriptions and no illustrations are included herein, but it is hoped that entomologists will find this preliminary work useful.[3]

The "References" section of this paper includes only those papers actually cited. Synonymic and locality references are adequately listed under the species concerned. Each of these synonymic and locality references, other than those to original descriptions of species, is to the species as it occurs in Ontario; complete synonymy is not given.

The systematic arrangement within the principal groups is based on the most modern accepted usage: Isoptera, after Snyder (1949); Blattodea, after McKittrick (1964); Dermaptera, after Popham (1965); Acridoidea, after Uvarov (1966); Ensifera, generally after Chopard (1949). The Grylloidea here follow the Gryllacridoidea, and are placed ahead of the Tettigonioidea, since this relationship is more logical according to Randell (1964), who compared the genitalia of the various groups.

ORDER DERMAPTERA
SUPERFAMILY LABIOIDEA

Family Carcinophoridae
Subfamily Carcinophorinae

Euborellia Burr

1910. *Euborellia* Burr, Proc. U.S. nat. Mus. *38*:448.

EUBORELLIA ANNULIPES (Lucas)

1847. *Forficesila annulipes* Lucas, Ann. Soc. ent. France, Sér. 2, *5*:84.

Anisolabis annulipes; Urquhart, 1942, Can. Field-Nat. *56*:3.

Adventive only.

The "Ring-legged" earwig has been transported by commerce to most parts of the world and has often become established, particularly in maritime situations, and also under certain artificial conditions. It does not appear to have become established anywhere in Ontario. It is recorded from Toronto and Niagara Falls.

Family Labiidae
Subfamily Labiinae

Labia Leach

1815. *Labia* Leach, Edinb. Encycl. *9*:118.

LABIA MINOR (Linnaeus)

1758. *Forficula minor* Linnaeus, Syst. Nat., Ed. 10, *1*:423.

Labia minor; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:72; *Blatchley,* 1920, Orth. N.E. Amer.: 52; *Criddle,* 1925, Rept. ent. Soc. Ont. *55*:106; *Urquhart,* 1942, Can. Field-Nat. *56*:3.

Labia [*minor*]*; Harrington,* 1896, Rept. ent. Soc. Ont. *26*:92.

Localities:

Arnprior; Guelph; Lincoln County; Ottawa; Port Hope; Toronto.

This species apparently reached North America from Europe in the very early days of settlement. It was known to be well established and widespread nearly a hundred years ago. Despite this, it is an uncommon species, only single captures being reported from Ontario. *L. minor* lives under natural conditions and gives the impression that it is a native insect. It is not of economic importance. It is probably reimported from time to time by ship.

[3]The authors are engaged in preparing comprehensive works on Canadian orthopteroids, which will include keys and illustrations, and will welcome receiving specimens and records from any part of the country.

SUPERFAMILY FORFICULOIDEA

Family Forficulidae
Subfamily Forficulinae

Doru Burr

1907. *Doru* Burr, Trans. ent. Soc. Lond. *1907*:123.

DORU ACULEATUM ACULEATUM (Scudder)

1876. *Forficula aculeata* Scudder, Proc. Bost. Soc. nat. Hist. *18*:262.

Doru aculeatum; Spencer, 1926, Can. Ent. *58*:184.

Doru aculeatum aculeatum; Urquhart, 1941, Contrib. R. Ont. Mus. Zool. *20*:9; 1942, Can. Field-Nat. *56*:3.

Localities:

Arner; Essex County; Point Pelee; Toronto.

Spencer (1926) first reported this species for Ontario from Toronto. It was subsequently recorded from the other localities by Urquhart (1941, 1942a) where it is apparently well established. This is the only native Canadian earwig, if indeed it is native.

DORU LINEARE (Eschscholtz)

1822. *Forficula lineare* Eschscholtz, Entomographien : 81.

Doru lineare; Urquhart, 1942, Can. Field-Nat. *56*:3.

Adventive only.

This widespread New World species was intercepted in a shipment from Texas. It has never become established in Canada.

Forficula Linnaeus

1758. *Forficula* Linnaeus, Syst. Nat. Ed. 10, *1*:423.

FORFICULA AURICULARIA Linnaeus

1758. *Forficula auricularia* Linnaeus, Syst. Nat. Ed. 10, *1*:423.

Forficula auricularia; Twinn, 1938, Rept. ent. Soc. Ont. *69:* 125; *McNally,* 1939, *Ibid. 70*:30; *Baird,* 1939, *Ibid. 70*:54; *Twinn,* 1939, *Ibid. 70*:119; *McNally,* 1939, Can. Ent. *71*:116; *Smith,* 1941, Rept. ent. Soc. Ont. *71*:29-32; *Twinn,* 1941, *Ibid. 71*:57; *Copeland,* 1942, *Ibid. 72*:27-28; *McNally,* 1942, *Ibid. 72*:29; *Urquhart,* 1942, Can. Field-Nat. *56*:3; *McNally,* 1944, Rept. ent. Soc. Ont. *74*:41-42; *Anon.* [staff, Ent. Res. Lab., Belleville], 1958, *Ibid. 88*:50; *Kevan,* 1963, Can. Ins. Pest Rev. *41*:92; *McNay,* 1965, Proc. ent. Soc. Ont. *96*:14.

'European earwig'; *MacNay,* 1947, Rept. ent. Soc. Ont. *77*:47; 1948, *Ibid. 78*:72; 1949, *Ibid. 79*:67; 1953, *Ibid. 83*:71; 1954, *84*:123.

Localities:

Ayton, Grey County; Durham; Galt; Hanover; Neustadt; Niagara Falls; Toronto; near Wiarton.

Forficula auricularia was accidentally introduced into Ontario at Ayton, Grey County, at some time shortly prior to 1937. When discovered, the infestation was well established. Attempts at control did not prevent its spread to other areas, and the species certainly occurs in more localities than those listed above. It is not now confined to the vicinity of human habitation, but it is only in such areas that it can be regarded as a nuisance, either in houses or as a minor horticultural pest. As the species is largely carnivorous, its actual status as a pest is somewhat dubious.

ORDER ISOPTERA[4]

SUPERFAMILY TERMITOIDEA

Family Rhinotermitidae
Subfamily Heterotermitinae

Reticulitermes Holmgren

1913. *Reticulitermes* Holmgren, K. Svensk. Vetensk. Akad. Handl. *50*:60-61.

RETICULITERMES FLAVIPES (Kollar)

1837. *Termes flavipes* Kollar, Verhandl. Landw. Ges. Wien *5*:411.

Reticulitermes flavipes; Twinn, 1945, Rept. ent. Soc. Ont. *75*:49; *MacNay,* 1947, *Ibid. 77*:62; 1948, *Ibid. 78*:89; 1949, *Ibid. 79*:86; 1950, *Ibid. 80*:68; 1951, *Ibid. 81*:124; *Urquhart,* 1953, Can. Ent. *85*:292-293; 1954, *Ibid. 86*:576; *Snyder,* 1954, Nat. Pest Cont. Assoc.:16; *MacNay,* 1956, Rept. ent. Soc. Ont. *86*:124; *Anon.* [staff, Ent. Res. Lab., Belleville], 1958, *Ibid. 88*:50; *MacNay,* 1958, *Ibid. 88*:78; 1960, Proc. ent. Soc. Ont. *90*:73.

Localities:

Kincardine; Ottawa; Oxley; Point Pelee; Toronto; Windsor.

This destructive cosmopolitan species was first reported in Canada from Toronto by Twinn (1945), and since that time it has gradually extended its range despite concerted efforts to contain it. It is largely confined to heated buildings where it may cause considerable damage to structural timbers, etc., but it also appears to have managed to establish itself outdoors, beneath rubbish near the railway station at Kincardine (Urquhart, 1954).

RETICULITERMES VIRGINICUS (Banks)

1907. *Termes virginicus* Banks, Ent. News *18*:392.

Reticulitermes virginicus; Kirby, 1965, Can. Ent. *97*:311.

Adventive only.

This species was intercepted at Ottawa in cypress slabs supporting *Philodendron* plants from Florida. It was exterminated.

ORDER DICTYOPTERA

SUBORDER BLATTODEA
SUPERFAMILY BLATTOIDEA

Family Blattidae
Subfamily Blattinae

Blatta Linnaeus

1758. *Blatta* Linnaeus, Syst. Nat. Ed. 10, *1*:424.

BLATTA ORIENTALIS Linnaeus

1758. *Blatta* Linnaeus, Syst. Nat. Ed. 10, *1*:424.

Stylophyga [*sic, Stylopyga*] *orientalis; Caulfield,* 1888, Rept. ent. Soc. Ont. *18*:71. *Blatta orientalis; Walker,* 1912, Can. Ent. *44*:172; *Walker in* Faull (ed.), Nat. Hist. Toronto Reg.:299; *Hebard,* 1917, Mem. Amer. ent. Soc. *2*:176; *MacNay,* 1956, Rept. ent. Soc. Ont. *86*:123.

'Oriental Cockroach'; *MacNay,* 1949, Rept. ent. Soc. Ont. *79*:85; 1950, *Ibid. 80*:75; 1951, *Ibid. 81*:123; 1952, *Ibid, 82*:112; 1954, *Ibid. 84*:147.

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[4]McKittrick (1965) suggests once again that Isoptera should be regarded as a suborder of Dictyoptera. There are good grounds for this argument but for the present we retain the traditional arrangement.

Localities:

Brockville; Leamington; Ottawa; Sarnia; Seaforth; Toronto; Windsor.

This cosmopolitan pest, the so-called 'Oriental' cockroach, was introduced into North America long ago, presumably from western Europe, where it is also an established alien. It has been reported from the above Ontario localities but it undoubtedly occurs in many others. Its dirty habits and objectionable odour are too familiar to warrant further comment. The species is found in buildings almost all over the world. In Canada, as in many other temperate countries, it is rarely found outdoors and is able to maintain itself throughout the year only in heated premises. With the increased use of household insecticides, it is not so common now as in previous years.

Periplaneta Burmeister

1838. *Periplaneta* Burmeister, Handb. Ent. *2*:502.

PERIPLANETA AMERICANA (Linnaeus)

1758. *Blatta americana* Linnaeus, Syst. Nat. Ed. 10, *1*:424.

Periplaneta americana; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Bethune,* 1898, *Ibid. 28*:52; *Walker,* 1912, Can. Ent. *44*:172; *MacNay,* 1949, Can. Dept. Agr. Proc. Publ. *109*:2; 1953, *Ibid. 109*(rev.):3.

'American cockroach'; *MacNay,* 1953, Rept. ent. Soc. Ont. *83*:52.

Localities:

Essex County; Ottawa.

These seem to be the only localities reported for Ontario, but the so-called 'American' or 'Ship' cockroach is almost certainly present in buildings in some of the industrial cities of southern Ontario. It does not establish itself as readily as the last species and all Canadian records do not necessarily refer to established colonies. It is probably even more cosmopolitan than the Oriental cockroach and is frequently found outdoors in warm countries but only in heated premises in Canada. It may occur in deeper mines. It is commonly reintroduced in seaports. Its economic importance is too well known to warrant further comment.

PERIPLANETA AUSTRALASIAE (Fabricius)

1775. *Blatta australasiae* Fabricius, Syst. ent.:271.

Periplaneta australasiae; Gibson, 1911, Rept. ent. Soc. Ont. *41*:119; *Walker,* 1912, Can. Ent. *44*:172; *Walker in* Faull (ed.), Nat. Hist. Toronto Reg.:299; *Blatchley,* 1920, Orth. N.E. Amer.:102.

'Australian cockroach'; *MacNay,* 1948, Rept. ent. Soc. Ont. *78*:89; 1950, *Ibid. 80*:75.

Localities:

Hamilton; Toronto.

Although recorded from only two cities, the so-called 'Australian' cockroach may well be much more widespread. The general remarks under *P. americana* are more or less applicable to this species also. Heated greenhouses often harbour this species in some other countries.

SUPERFAMILY BLABEROIDEA

Family Blattellidae

Subfamily Blattellinae

Blattella Caudell

1903. *Blattela* Caudell, Proc. ent. Soc. Wash. *5*:234.

BLATTELLA GERMANICA (Linnaeus)

1767. *Blatta germanica* Linnaeus, Syst. Nat., Ed. 12, *2*:688.

Ectobia germanica; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Blattella germanica; Walker, 1912, Can. Ent. *44*:172; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299; *Hebard,* 1917, Mem. Amer. ent. Soc. *2*:59; *Gibson,* 1917, Rept. ent. Soc. Ont. *47*:17; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:9; *MacNay,* 1956, Rept. ent. Soc. Ont. *86*:123.

Blatella [*sic, Blattella*] *germanica; Twinn,* 1936, Rept. ent. Soc. Ont. *66*:128.

'German cockroach'; *MacNay,* 1947, Rept. ent. Soc. Ont. *77*:61; 1951, *Ibid. 81*: 123; 1953, *Ibid. 83*:71.

Localities:

DeGrassi Point, Lake Simcoe; Goderich; Hamilton; Kitchener; Ottawa; Toronto.

The statement by Urquhart (1941), that this introduced species, the so-called 'German cockroach', occurs "throughout southern Ontario", indicates that it is presumably more widespread than has actually been reported. *B. germanica,* as a result of commerce, is of world-wide distribution and among pest cockroaches, ranks high among those which have caused the general public to consider all cockroaches with disgust. In Canada it is seldom found outdoors and cannot maintain itself except in heated premises. It is normally the most difficult of all cockroach species to eradicate. Its only virtue, from an anthropocentric point of view, is that its presence usually assures the absence of other cockroach species.

Parcoblatta Hebard

1917. *Parcoblatta* Hebard, Mem. Amer. ent. Soc. *2*:70.

PARCOBLATTA PENNSYLVANICA (DeGeer)

1773. *Blatta pensylvanica* [*sic*] DeGeer, Mém. Hist. Ins. Orth. *3*:537 [emend. Saussure, 1864, Mém. Hist. nat. Mex.:84]

Ischnoptera pensylvanica [*sic*]*; Walker,* 1912, Can. Ent. *44*:171; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Parcoblatta pennsylvanica; Hebard, 1917, Mem. Amer. ent. Soc. *2*:143-146; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:9; *MacNay,* 1949, Can. Dept. Agr. Sci. Serv. Ent. Proc. Publ. *109*:3; 1952, Rept. ent. Soc. Ont. *82*:112; 1953, *Ibid. 83*:91, 1953, Can. Dept. Agr. Sci. Serv. Ent. Proc. Publ. *109*(rev.): 3; 1954, Rept. ent. Soc. Ont. *84*:147; *Judd,* 1955, Can. Ent. *87*:98-99; *MacNay,* 1957, Rept. ent.. Soc. Ont. *87*:100; 1962, Can. Dept. Agr. Ent. Proc. Publ. *924*(rev.):4.

Parcoblatta pennsylvanicus [*sic*]*; Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*: 40-41; *MacNay,* 1955, Rept. ent. Soc. Ont. *85*:88; 1956, *Ibid. 86*:123.

Localities:

Cedar Point; Gull Lake; Hastings County; Ottawa; Point Pelee; Rondeau Park; Sudbury; Thessalon; Toronto.

P. pennsylvanica is the only species of cockroach certainly native to Ontario. The Lyman Entomological Museum has a living culture which is derived from specimens collected at Thessalon, a locality not recorded in the literature. The first two localities cited have also been hitherto unrecorded; specimens are in the collection of the Academy of Natural Sciences of Philadelphia. This species, sometimes called the 'woods cockroach', is frequently considered to be a nuisance as it often invades summer cottages, seldom, however, in sufficient numbers to be regarded as a pest.

PARCOBLATTA FULVESCENS (Saussure and Zehntner)

1893. *Ischnoptera fulvescens* Saussure and Zehntner, Biol. cent. Amer. *1*:36.

Parcoblatta fulvescens; Urquhart, 1941, Contrib. R. Ont. Mus. Zool. *20*:7.

Localities:

Go Home Bay; Point Pelee; Toronto?; Welland.

Urquhart's (1941) record extended the known range of the species farther north than it had previously been known. The late Morgan Hebard, who identified the specimens, considered them to be adventives from the southern United States, but Urquhart thought it more likely that the species was native to southern Ontario in "certain suitable localities".

It is quite likely that the species reported by Caulfield (1888) and by Walker (1912) as *Ischnoptera uhleriana* (Saussure), from Welland and Toronto respectively, should be referred to *P. fulvescens* (possibly adventives). The specimens recorded by Walker (1912:171 and 1913:299) from Toronto as *Ischnoptera borealis* Rehn [= *Parcoblatta virginica* (Brunner von Wattenwyl)] may have been misidentified and should perhaps also be referred to *P. fulvescens*. If the determination of this last is valid, *P. virginica* should be regarded as only a casual adventive. We have, so far, not been able to examine any of these specimens.

Subfamily Plecopterinae

Supella Shelford

1911. *Supella* Shelford, Ent. Mon. Mag. *47*:155.

SUPELLA LONGIPALPA (Fabricius)

1798. *Blatta longipalpa* Fabricius, Supp. ent. Syst.:185.

Supella supellectilium; MacNay, 1956, Rept. ent. Soc. Ont. *86*:123; 1957, *Ibid.* *87*:100; 1962, Can. Dept. Agr. Sci. Serv. Ent. Publ. *924*(rev.):3; 1965, Proc. ent. Soc. Ont. *96*:14.

Supella supellestilium [*sic*]*; MacNay,* 1958, Rept. ent. Soc. Ont. *88*:77.

'Brown-banded Roach'; *MacNay,* 1959, Rept. ent. Soc. Ont. *89*:86; 1960, Proc. ent. Soc. Ont. *90*:72.

Localities:

Carleton Place; Ottawa.

Although *S. longipalpa* became established in Canada only quite recently and has been reported in Ontario for only ten years and in but two localities, its potential for increase and dispersal is great enough that it could spread throughout southern Ontario within the next decade or two. In some regions of the world it ranks with *Blattella germanica* or even replaces it as a household pest. It has consistently been recorded as the synonym *S. supellectilium* Audinet-Serville, 1838.

Subfamily Nyctiborinae

Nyctibora Burmeister

1838. *Nyctibora* Burmeister, Handb. Ent. *2*:501.

NYCTIBORA NOCTIVAGA Rehn

1902. *Nyctibora noctivaga* Rehn, Trans. Amer. ent. Soc. *29*:3.

Nyctibora holosericea [*nec* Burmeister, 1838]; *Walker,* 1912, Can. Ent. *44*:172; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Nyctibora noctivaga; Hebard, 1917, Mem. Amer. ent. Soc. *2*:263-264.

Nyctobora [*sic, Nyctibora*] *noctivaga; Blatchley,* 1920, Orth. N.E. Amer.:91-92.

Adventive only.

N. noctivaga, the 'Great brown roach', is from the West Indies and Central America, but, as only a juvenile male was found (in bananas in Toronto) by Walker (1912), identification is not certain.

NYCTIBORA LAEVIGATA (Palisot de Beauvois)

1805. *Blatta laevigata* Palisot de Beauvois, Ins. Afr. Amer. St. Dom. U.S. 1786-1797:228.

Nyctobora [*sic, Nyctibora*] *sericea; Gibson,* 1911, Rept. ent. Soc. Ont. *41*:119.

Nyctibora sericea; Walker, 1912, Can. Ent. *44*:172; *Walker in* Faull (ed.), 1913, Nat Hist. Toronto Reg.:299.

Nyctibora laevigata; Hebard, 1917, Mem. Amer. ent. Soc. *2*:264-265.

Nyctobora [*sic. Nyctibora*] *laevigata; Blatchley,* 1920, Orth. N.E. Amer.:92.

Adventive only.

N. laevigata is smaller than *N. noctivaga,* ovate, and brilliantly coloured. It is native to Jamaica and Haiti, and is occasionally found in shipments of bananas as in the case of the single record from Toronto (Walker, 1912).

Family Blaberidae

Subfamily Pycnoscelinae

Pycnoscelus Scudder

1862. *Pycnoscelus* Scudder, J. Bost. Soc. nat. Hist. *7*:421.

PYCNOSCELUS SURINAMENSIS (Linnaeus)

1767. [*Blatta*] *surinamensis* Linnaeus, Syst. Nat. Ed. 12, *2*:687.

Pycnoscelus surinamensis; Gibson, 1911, Rept. ent. Soc. Ont. *41*:119; *Hebard,* 1917, Mem. Amer. ent. Soc. *2*:269(Footnote).

Leucophoea surinamensis; Walker, 1912, Can. Ent. *44*:172; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Adventive only (so far as is known).

Recorded only once, from Toronto, a single specimen found in bananas (Walker, 1912). This species, the so-called 'Surinam cockroach', is cosmopolitan in distribution; in temperate countries it sometimes becomes established in large greenhouses; its habits are subterranean and it could be overlooked in such situations in Ontario. *P. surinamensis* is parthogenetic.

Subfamily Panchlorinae

Panchlora Burmeister

1838. *Panchlora* Burmeister, Handb. ent. *2*:506.

PANCHLORA CUBENSIS Saussure?

1862. *Panchlora cubensis* Saussure, Rev. Mag. Zool. (2) *14*:230.

Panchlora virescens; Gibson, 1911, Rept. ent. Soc. Ont. *41*:119; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Pancheora [*sic, Panchlora*] *virescens; Walker,* 1912, Can. Ent. *44*:172.

Adventive only.

This insect was found in banana shipments from tropical America. The taxonomy of this genus is not well understood and the actual identity of the many adventive specimens known from eastern Canada is doubtful. In Ontario, it has been reported from Toronto.

Walker (1912) also reported *Panchlora* (as *Pancheora* [*sic*]) *acolhua* Saussure & Zehntner, so determined by Caudell, from Toronto. The specimen has since been destroyed. About all that can be said is that it was an adventive introduction of a second species of *Panchlora.*

SUBORDER MANTODEA

SUPERFAMILY MANTOIDEA

Family Mantidae

Subfamily Mantinae

Mantis Linnaeus

1758. *Mantis* Linnaeus, Syst. Nat., Ed. 10, *1*:425.

MANTIS RELIGIOSA RELIGIOSA Linnaeus

1758. *Mantis religiosa* Linnaeus, Syst. Nat., Ed. 10, *1*:426.

Mantis religiosa; Walker, 1915, Can. Ent. *47*:135; *Gibson,* 1915, Rept. ent. Soc. Ont. *45*:15; 1915,*Ibid. 45*:147; 1916, *Ibid. 46*:225; *Caesar and Ross,* 1931, *Ibid. 61*:10; *Ross and Caesar,* 1932, *Ibid. 62*:11; *Corfe,* 1938, Can. Ent. *70*:21; *Urquhart and Corfe,* 1940, Can. Field-Nat. *54*:130-132; *James,* 1942, Rept. ent. Soc. Ont. *72*:45-46; 1945, *Ibid. 75*:35-37; *Judd,* 1947, Can. Field-Nat. *61*:197; *Salt,* 1947, Can. Ent. *79*:33-36; *James* ,1949, Rept. ent. Soc. Ont. *79*: 41-43; *MacNay,* 1950, *Ibid. 80*:60; *Sheppard,* 1956, *Ibid. 86*:50; *Rivard,* 1965, Phytoprotection *46*:142; *Mook and Davies,* 1966, Can. Ent. *98*:913.

'European Mantis'; *MacNay,* 1949, Rept. ent. Soc. Ont. *79*:67; 1953, *Ibid. 83*:71.

Localities:

Actin; Actinovale; Aldershot; Alliston; Almonte; Ameliasburg; Ancaster; Ashton; August Twp.; Baldwin; Bathurst Twp.; Beamsville; Belleville; Bethany; Blockwater; Bowmanville; Brampton; Brechin; Brighton Twp.; Brockville; Burlington; Camp Borden; Campden; Carleton Place; Carp; Carrying Place; Charleston Lake; Chatterton; Clinton; Codrington; Colborn; Coldwater; Colebrook; Collingwood; Consecon; Cooksville; Dempsey; Deseronto; Downsview; Drummond Twp.; Dunnville; Elmsvale; Erin; Exeter; Finch; Fort Erie; Fruitland; Galt; Goderich; Green Point; Grimsby; Guelph; Halton County; Hamilton; Harold; Highland Creek; Kempville; Kincardine; Kingston; Lafontaine; Lake Opincon; Lanark Twp.; Lin; Lindsay; Lucknow; Markham; Meaford; Midland; Mimosa; Miner's Bay; Nelson Twp.; New Lowell; Niagara Falls; Niagara-on-the Lake; N. Burgess Twp.; N. Emsley Twp.; Newmarket; Oakville; Orono; Orton; Oshawa; Ottawa; Owen Sound; Oxford Twp.; Palgrave; Penetanguishene; Peterborough; Picton; Plantagenet; Port Dover; Port Perry; Pt. Traverse; Prince Edward County; Puslinch; Richmond Hill; Rosemount; Rouge River; Russell Twp.; Sandford; Scarboro; Scarborough Bluffs; Simcoe; Solina; Southampton; Spencerville; Stouffville; St. Catharines; Thornton; Toronto; Vineland; West Hill; Wiarton; Williamsburg Twp.; Willowdale; Wingham; Woodstock.

The list of Ontario localities from which *M. r. religiosa* has been reported exceeds that for any other orthopteroid insect, mute evidence of the wide interest in the establishment and dispersal of this assumedly beneficial predator. Walker (1915) first recorded the species from Ontario in a collection made by Bethune "some years" prior to 1915, at Simcoe. At the same time, Walker recorded it from Picton, Green Point and Carrying Place, all in Prince Edward County. *M. r. religiosa* is now found throughout eastern Ontario and western Quebec and probably will continue to spread to the survival limits for the species. Other subspecies occur widely throughout much of the world: *M. r. inornata* Werner, Iran to India; *M. r. polonica* Bazyluk, Poland; *M. r. eichleri* Bazyluk, N. Rhodesia; *M. r. siedleckii* Bazyluk, Celebes; *M. r. sinica* Bazyluk, China; and *M. r. beybienkoi* Bazyluk, U.S.S.R. (Bazyluk, 1960). The typical subspecies is native to southern Europe and part of Africa.

Tenodera Burmeister

1838. *Tenodera* Burmeister, Handb. Ent. *2*:534.

TENODERA ARIDIFOLIA SINESIS Saussure

1898. *Tenodera sinensis* Saussure, Ent. News *9*:144.

Tenodera aridifolia sinensis; MacNay, 1957, Rept. ent. Soc. Ont. *87*:88.

This species was reported by MacNay (1957) to be present at Harrow in 1955 and 1956. There has been no further report. *T. a. sinensis* could persist in extreme southern Ontario, but it is doubtful that it will become established in other parts of the Province.

ORDER PHASMATODEA

Family Phasmatidae

Subfamily Heteronemiinae

Diapheromera Gray

1835. *Diapheromera* Gray, Synops. Ins. Phasmidae:18.

DIAPHEROMERA FEMORATA (Say)

1824. *Spectrum femoratum* Say, West. quart. Rep.:297.

Diapheromera femorata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Williams,* 1905, *Ibid. 35*:6; *Gibson,* 1905, *Ibid. 35*:78; *Williams,* 1906, *Ibid. 36*:10; 1907, Can. Ent. *39*:261-263; 1909, Rept. ent. Soc. Ont. *39*:11; *Morris,* 1911, *Ibid. 41*:45-46; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299; *Blatchley,* 1920, Orth. N.E. Amer.: 134; *Hutchings* 1925, Rept. ent. Soc. Ont. *55*:8; *Brown,* 1939, *Ibid. 70*:112; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:9; *Hebard,* 1943. Trans. Amer. ent. Soc. *68*:305.

'Stick Insect'; *Williams,* 1907, Rept. ent. Soc. Ont. *37*:17; *Grant,* 1908; *Ibid.* 38: 24; *Williams,* 1908, *Ibid. 38*:24.

Localities:

Kingston; Niagara Glen; Orillia; Ottawa; Point Pelee; Pontypool; Port Hope; Toronto.

The 'walking stick' was first recorded by Caulfield (1888) and at times reported as very numerous and causing defoliation of trees at Niagara Glen (Williams, 1905). *D. femorata* in Ontario has now become more of a curiosity which is reported infrequently. It is still, however, a potential defoliator of shade trees, here, as well as in other areas of its distribution.

ORDER ORTHOPTERA

SUBORDER ENSIFERA

SUPERFAMILY GRYLLACRIDOIDEA

Family Rhaphidophoridae

Subfamily Rhaphidophorinae

Tachycines Adelung

1902. *Tachycines* Adelung, Ann. Mus. zool. Acad. Imp. St. Petersburg 7:56.

TACHYCINES ASYNAMORUS Adelung

1902. *Tachycines asynamorus* Adelung, Ann. Mus. zool. Acad. Imp. St. Petersburg 7:59.

Tachycines asynamorus; Walker and Urquhart, 1940, Can. Ent. *72*:16; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; *Rehn,* 1944, Ent. News *55*:36.

Localities:

Guelph, Scarboro, Toronto.

T. asynamorus is a more or less cosmopolitan species, well established in greenhouses in Quebec and Ontario. It undoubtedly occurs in several localities in addition to those listed above. It does not occur outdoors in temperate latitudes.

Subfamily Ceuthophilinae

Ceuthophilus Scudder

1862. *Ceuthophilus* Scudder, Bost. J. nat. Hist. *7*:433.

CEUTHOPHILUS BREVIPES Scudder

1862. *Ceuthophilus brevipes* Scudder, Bost. J. nat. Hist. *7*:434.

Ceuthophilus terrestris; Walker, 1905, Can. Ent. *37*:117; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301; *Blatchley,* 1920, Orth. N.E. Amer.:636.

Ceuthophilus brevipes; Hubbell, 1936, Univ. Fla. biol. Ser. Publ. *2*:114, 126; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:302.

Localities:

Algonquin Park; DeGrassi Point, Lake Simcoe; Goderich; Guelph; Gull Lake; Morris Island; Nipigon; Orillia; Ottawa; Point au Baril; Spencerville; Thunder Beach; Toronto.

This species is common in eastern Canada and boubtless occurs throughout Ontario. It is often found in basements and about houses where it may be a harmless nuisance.

CEUTHOPHILUS MERIDIONALIS Scudder

1894. *Ceuthophilus meridionalis* Scudder, Proc. Amer. Acad. Arts & Sci. *30*:66.

Ceuthophilus meridionalis; Hebard, 1934, Ill. nat. Hist. Surv. Bull. *20*:229; *Hubbell,* 1936, Univ. Fla. biol. Sci. Publ. *2*:116, 174; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:15; 1941, Univ. Toronto Stud. biol. Ser. *50*:30.

Localities:

Norfolk County; Pelee Island; Simcoe; Strathroy.

The distribution of this species is generally southern, and it penetrates into Canada only in the southern part of Ontario.

CEUTHOPHILUS PALLIDIPES E. M. Walker

1905. *Ceuthophilus pallidipes* E. M. Walker, Can. Ent. *37*:114.

Ceuthophilus pallidipes; Walker, 1905, Can. Ent. *37*:114; 1906, Rept. ent. Soc. Ont. *36*:67; 1909, Can. Ent. *41*:210; *Blatchley,* 1920, Orth. N. E. Amer.: 632-633; *Hubbell,* 1936, Univ. Fla. biol. Sci. Publ. *2*:175, 184.

Ceuthophilus pallipedes [*sic*]*; Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301.

Localities:

Arran Lake; DeGrassi Point, Lake Simcoe; Go Home Bay; Lake Muskoka; Niagara Glen; Ragged Lake, Algonquin Park; Thunder Bay; Thunder Beach; Timagami Falls; Toronto [Type locality].

E. M. Walker (1905) described this species from Toronto. The known distribution is mid-continental. It extends westwards into Manitoba, but apparently is not found in eastern Ontario and Quebec.

CEUTHOPHILUS LATENS Scudder

1862. *Ceuthophilus latens* Scudder, Bost. J. nat. Hist. *7*:437.

Ceuthophilus latens; Walker in Gibson, 1910, Rept. ent. Soc. Ont. *40*:126; *Hubbell,* 1936, Univ. Fla. biol. Sci. Publ. *2*:460, 464; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:228.

Locality:

London.

Walker *in* Gibson (1910) reported *C. latens* from London. Subsequent mention by Hubbell and Froeschner repeated Walker's record. There is apparently no other record of this species in Ontario (or in Canada) but the record must stand, since the general distribution of the species indicates that it could, and probably should, occur in southern Ontario; Hubbell (1936) did not dispute the record.

CEUTHOPHILUS MACULATUS (Harris)

1841. *Rhaphidophora maculata* Harris, Rept. Ins. Mass. inj. Veg.,:126.

Ceuthophilus maculosus [*sic*]*; Caulfield,* 1886, Can. Ent. *18*:212.

Centophilus [*sic, Ceuthophilus*] *maculosus* [*sic*]*; Caulfield,* 1887, Can. Rec. Sci. *2*:17.

Ceuthophilus maculatus; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:69; *Fyles,* 1902, *Ibid. 32*:93-99; *Walker,* 1905, Can. Ent. *37*:114; *Blatchley,* 1920, Orth. N.E. Amer.:623; Hebard, 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:49; 1934, Ill. nat. Hist. Surv. Bull. *20*:226-227; *Hubbell,* 1936, Univ. Fla. biol. Ser. Publ. *2*:197, 209; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:15; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Ceuthophilus terrestris [*nec* Scudder, 1894]; *Walker,* 1909, Can. Ent. *41*:210; 1910, *Ibid. 42*:354.

Localities:

Portage, Kabinakagami River; Kirkwood Twp.; Mer Bleue; Niagara Glen; Nipigon; North Shore of Lake Superior; Ottawa; Point Pelee; Strathroy; Sugar Island; Vineland.

This species and *C. brevipes* are the most common species of the genus in eastern Canada. It is frequently found in basements of houses, where, like *C. brevipes,* it may be a harmless nuisance.

CEUTHOPHILUS GUTTULOSUS GUTTULOSUS F. Walker

1869. *Ceuthophilus guttulosus* F. Walker, Cat. Derm. Salt. Brit. Mus. *1*:203.

Ceuthophilus neglectus; Walker, 1905, Can. Ent. *37*:117 [*partim*]; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.: 301.

Ceuthophilus nigricans; Blatchley, 1920, Orth. N.E. Amer.:662; Hubbell, 1936, Univ. Fla. biol. Sci. Publ. *2*:407, 419.

Ceuthophilus guttulosus; Eades, 1962, Ent. News *73*:147.

Localities:

Black Rapids, near Ottawa; Niagara Glen; Ottawa; Toronto.

The synonomy of this species was established by Eades(1962), following examination of F. Walker's type of *guttulosus* by Hubbell, a course that Hubbell (1936) had intimated might follow.

CEUTHOPHILUS GUTTULOSUS THOMASI Hubbell

1936. *Ceuthophilus thomasi* Hubbell, Univ. Fla. biol. Ser. *2*:419.

Ceuthophilus neglectus; Walker, 1905, Can. Ent. *37*:117 [*partim*]; *Hubbell,* 1936, Univ. Fla. biol. Sci. Publ. *2*:419.

Localities:

Niagara Glen; Thunder Beach.

Hubbell (1936) lists only one Canadian locality, Niagara Glen. A specimen in the Royal Ontario Museum, Toronto, from Thunder Beach is labelled *C. thomasi* (determiner not stated), but it has not been critically re-examined.

C. thomasi Hubbell was reduced to a subspecies of *guttulosus* Walker by Eades (1962).

SUPERFAMILY GRYLLOIDEA

Family Gryllidae

Subfamily Gryllinae

Acheta Fabricius

1775. *Acheta* Fabricius. Syst. Ent. ed. 10, *1*:279.

ACHETA DOMESTICUS Linnaeus

1758. *Gryllus (Acheta) domesticus* Linnaeus, Syst. Nat., Ed. 10, *1*:428.

Gryllus domesticus; Fyles, 1902, Rept. ent. Soc. Ont. *32*:93; *Walker,* 1904, Can. Ent. *36*:252; *Blatchley,* 1920, Orth. N.E. Amer.:709; *Caesar,* 1926, Rept. ent. Soc. Ont.. *56*:17; *Ross and Caesar,* 1929, *Ibid. 59*:22; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:14.

Acheta domestica [*sic*]*; MacNay*, 1956, Rept. ent. Soc. Ont. *86*:123; 1957, *Ibid. 87*:100.

'House Cricket'; *MacNay,* 1952. Rept. ent. Soc. Ont. *82*:112; 1954, *Ibid. 84*:147; *84*:147; 1955, *Ibid. 85*:88; 1960, *Ibid. 90*:72.

Localities:

Kitchener; Ottawa; Toronto.

Introduced from western Europe, where it is also an alien, in the early days of settlement, the 'House cricket' has been reported as a household and bakery pest from three Ontario cities. It undoubtedly occurs in others. It is seldom found, and cannot maintain itself, outdoors in Canada, although it may sometimes occur in rubbish heaps in other temperate countries.

Gryllus Linnaeus

1758. *Gryllus* Linnaeus, Syst. Nat. Ed. 10, *1*:425.

Only two species of this genus occur in Ontario, but the literature reports in all but a few cases are insufficiently detailed to make it possible to determine which species is referred to: the 'Fall field cricket', *Gryllus pennsylvanicus* Burmeister, or the 'Spring field cricket', *Gryllus veletis* (Alexander and Bigelow). If the date of capture is known, which, very often it is not, there is seldom any difficulty. Adults and larger nymphs occuring in the latter part of the summer and in the fall belong to the first species; those occuring in spring and early summer to the latter; the reverse is more or less true for smaller nymphs. The two species were separated only quite recently by Alexander and Bigelow (1960) on other than morphological grounds and upon them the authors based a theory of "allochronic speciation". Unfortunately for this theory, although the species are almost indistinguishable in their external morphology, their phallic structures differ quite significantly, indicating that they are not so closely related as was supposed. Randell (personal communication) places them in different species groups.

GRYLLUS PENNSYLVANICUS Burmeister

1838. *Acheta pennsylvanica* Burmeister, Handb. Ent. *2*:734.

Gryllus neglectus; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:69; *Brodie,* 1891, Can. Ent. *23*:137-138.

Gryllus pennsylvanicus; Walker, 1904, Can. Ent. *36*:249; 1906, Rept. ent. Soc. Ont. *36*:67; 1909, Can. Ent. *41*:210; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Gryllus abbreviatus; Walker, 1904, Can. Ent. *36*:249; 1906, Rept. ent. Soc. Ont. *36*:67; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302.

Gryllus assimilis pennsylvanicus; Blatchley, 1920, Orth. N.E. Amer.:701 [*partim*].

Gryllus assimilis luctuosus; Blatchley, 1920, Orth. N.E. Amer.:701.

Gryllus assimilis; Walker and Urquhart, 1940, Can. Ent. *72*:17; *James,* 1942, Rept. ent. Soc. Ont. *72*:46; 1945, *Ibid. 75*:36.

Gryllulus assimilis luctuosus; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *48*: 116; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:14-15.

Acheta assimilis; Fox, 1953, Rept. ent. Soc. Ont. *83*:53; *James,* 1959, *Ibid. 89*:53; *Goble,* 1965, Proc. ent. Soc. Ont. *96*:6.

'Field cricket'; *MacNay,* 1949, Rept. ent. Soc. Ont. *79*:66; 1955, *Ibid. 85*:66, 88.

Localities:

Algonquin Park; Arner; Batchawana; Bear Island; Belleville; Bell's Corners; Bruce Peninsula; Chatterton; Cottam; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Goderich; Leamington; Marmora; Niagara Glen; North Bay; Owen Sound; Palmer Rapids; Picton; Point Pelee; Port Dover; Rondeau; Rostrevor; Sarnia; Southampton; South Woodslee; Timagami; Toronto; Trenton; Wellington; Wheatley; Windfall.

Most of the above literature records probably refer to *G. pennsylvanicus,* as the 'Fall field cricket' is always more numerous and more noticeable than the spring-occurring species, *G. veletis.* It is doubtful if any of the records refer only to the latter, but some may refer to both species.

GRYLLUS VELETIS (Alexander & Bigelow)

1960. *Acheta veletis* Alexander & Bigelow, Evolution *15*:335.

Gryllus pennsylvanicus; Walker, 1904, Can. Ent. *36*:251.

Gryllus assimilis pennsylvanicus; Blatchley, 1920, Orth. N.E. Amer.:703 [*partim*].

Gryllulus assimilus pennsylvanicus; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *48*:116-117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:14.

Gryllus veletis; Martin, 1965, Proc. ent. Soc. Ont. *95*:100.

Localities:

DeGrassie Point, Lake Simcoe; Hamilton; Kirkwood Twp.; Marmora; Niagara Glen; Normandale; Ottawa; Point Pelee; Toronto.

Although records of the 'Spring field cricket', *G. veletis,* are fewer than for *G. pennsylvanicus,* the distribution of the two species in Ontario is probably quite similar, with *pennsylvanicus* almost certainly ranging farther north and occurring more abundantly than *veletis.*

Subfamily Nemobiinae

Nemobius Audinet-Serville

1838. *Nemobius* Audinet-Serville, Hist. nat. Ins. Orth.:345.

NEMOBIUS FASCIATUS (DeGeer)

1773. *Gryllus fasciatus* DeGeer, Mém. Hist. Ins. *3*:522.

Nemobius vittaut; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:69; *Fyles,* 1902, *Ibid. 32*:92.

Nemobius fasciatus; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:69; *Walker,* 1904, Can. Ent. *36*:183; 1906, Rept. ent. Soc. Ont. *36*:67; *Walker in* Faull (ed.),

1913, Nat. Hist. Toronto Reg.:302; *Hebard,* 1913, Proc. Acad. nat. Sci. Philad. *65*:410-415; Blatchley, 1920, Orth. N.E. Amer.:675; *Judd,* 1959, Can. Ent. *91*:179-180.

Nemobius maculatus [*nec* Blatchley, 1900]; *Walker,* 1902, Rept. ent. Soc. Ont. *32*:109; 1904, Can. Ent. *36*:185.

Nemobius fasciatus fasciatus; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:148; 1928, *Ibid. 80*:303; *James,* 1942, Rept. ent. Soc. Ont. *72*:46; 1945, *Ibid. 75*:36; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:177; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Nemobius fasciatus socius; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *48*:116; 1941, Contrib. R. Ont. Mus. Zool. *20*:14.

Localities:

Algonquin Park; Arner; Belleville; Bell's Corners; Bracebridge; Bruce Peninsula; Byron Bog; Chatham; Chatterton; Constance Bay; DeGrassi Point, Lake Simcoe; Goderich; Hamilton; Hawthorn; Kirkwood Twp.; Lake Muskoka; Malden Centre; Mer Bleue; Niagara Falls; North Bay; Ottawa; Owen Sound; Palmer Rapids; Picton; Point Pelee; Sarnia; Severn River; Southampton; Stony Lake; Summerstown; Tobermory; Toronto; Trenton; Ventner; Vineland; Wheatley.

The Kirkwood Township record of *N. fasciatus fasciatus* given by Martin (1965) was based on material determined by Vickery as *N. fasciatus;* no subspecific name was applied!

Alexander and Thomas (1959) separated the two species which were formerly included under *fasciatus* and described one of these as *N. allardi* (see below). That two distinct entities were involved was recognized by several previous authors. They were correctly separated by Urquhart (1941), but were listed by him as *N. fasciatus socius,* referring to *N. fasciatus,* and as *N. fasciatus fasciatus* referring to *N. allardi.* Most of the other records of *"fasciatus"* given above could apply to true *N. fasciatus,* to *N. allardi,* or to both.

The two species can be distinguished in the field by the stridulation of the males (Alexander and Thomas, 1959) but separation of dried specimens on the basis of external morphology is difficult.

NEMOBIUS ALLARDI Alexander and Thomas

1959. *Nemobius allardi* Alexander and Thomas, Ann. ent. Soc. Amer. *52*:592.

Nemobius canus; Walker, 1904, Can. Ent. *36*:184.

Nemobius fasciatus fasciatus [*nec* DeGeer]; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:116; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:14.

Nemobius allardi; Martin, 1965, Proc. ent. Soc. Ont. *95*:100.

Localities:

Arner; Belle River; Essex; Harrow; Kirkwood Twp.; Leamington; Maidstone; Picton; Point Pelee; South Woodslee; Wellington; Wheatley; Windfall; Windsor.

See remarks under *N. fasciatus.*

NEMOBIUS GRISEUS GRISEUS E. M. Walker

1904. *Nemobius griseus* E. M. Walker, Can. Ent. *36*:182.

Nemobius griseus; Walker, 1904, Can. Ent. *36*:182; *Fletcher,* 1906, Rept. ent. Soc. Ont. *36*:103; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302; *Hebard,* 1913, Proc. Acad. nat. Sci. Philad. *65*:434; *Blatchley,* 1920, Orth. N.E. Amer.:677-678.

Nemobius fasciatus abortivus; Walker, 1911, Can. Ent. *43*:304; *Gibson,* 1911, Rept. ent. Soc. Ont. *41*:119; *Hebard,* 1913, Proc. Acad. nat. Sci. Philad. *65*:434; *Blatchley,* 1920, Orth. N.E. Amer.:677-678; *Hebard,* 1936, N. Dak. agr. exp. Sta. tech. Bull. *284*:56 [synonymized with *N. griseus griseus*].

Nemobius griseus griseus; Hebard, 1932, Univ. Minn. agr. Sta. tech. Bull. *85*:52; 1936, N. Dak. agr. exp. Sta. tech. Bull. *284*:56; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:116; 1941, Contrib. R. Ont. Mus. Zool. *20*:13; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:317.

Localities:

DeGrassi Point, Lake Simcoe; Fort William; Mactier; Sarnia; Toronto [Type locality]; Thunder Bay.

The holotype is in the Royal Ontario Museum.

The western segment of the population was long known as *Nemobius fasciatus abortivus* Caudell, 1907. Hebard (1936) established the synonymy under *N. griseus griseus* Walker. The other subspecies, *N. griseus funeralis* Hart, 1906, does not occur in Canada.

NEMOBIUS PALUSTRIS Blatchley

1900. *Nemobius palustris* Blatchley, Psyche *9*:53.

Nemobius palustris; Walker, 1902, Rept. ent. Soc. Ont. *32*:109; 1904, Can. Ent. *36*:185; *Fletcher,* 1904, Rep. ent. Soc. Ont. *34*:97; *Walker,* 1906. *Ibid. 36*:65, 67; *Hebard,* 1913, Proc. Acad. nat. Sci. Philad. *65*:471; *Blatchley,* 1920, Orth. N.E. Amer.:685.

Localities:

Algonquin Park (Ragged Lake); DeGrassi Point, Lake Simcoe; Mer Bleue; Owen Sound; Sarnia; Southampton.

This unobtrusive little cricket is not often collected. Distribution is disjunct as the species is found only in sphagnum bogs.

NEMOBIUS CAROLINUS Scudder

1877. *Nemobius carolinus* Scudder, Proc. Bost. Soc. nat. Hist. *19*:36.

Nemobius angusticollis Walker, 1904, Can. Ent. *36*:186; 1906, Rept. ent. Soc. Ont. *36*:67.

Nemobius carolinus; Walker in Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302; *Hebard,* 1913, Proc. Acad. nat. Sci. Philad. *65*:473; *Blatchley,* 1920, Orth. N.E. Amer.:686; *Walker and Urquhart,* 1940, Can. Ent. *72*:15; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Nemobius carolinus carolinus; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:149; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:116; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:13; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:318.

Nemobius macdunnoughi Urquhart, 1938, Can. Ent. *70*:101. — NEW SYNONYMY

Localities:

Algonquin Park [Type locality of *N. angusticollis* Walker]; Brockville; Bolton; Constance Bay; DeGrassi Point, Lake Simcoe; Essex County; Hawthorn [Type locality of *N. macdunnoughi* Urquhart]; Kirkwood Twp.; Mer Bleue; Niagara Glen; Owen Sound; Picton; Point Pelee; Port Rowan; Sarnia; Severn River; Southampton; Timagami District; Toronto; Trenton; Turkey Point; Williamsford.

The reason that this species has twice been described from Ontario as new presumably lies in its variability. Genitalic studies by Hebard (unpublished)[5] established the synonymy of *N. macdunnoughi* with *N. carolinus*.

NEMOBIUS MACULATUS Blatchley

1900. *Nemobius maculatus* Blatchley, Psyche *9*:52.

[*non*] *Nemobius maculatus;* Walker, 1902, Rept. ent. Soc. Ont. *32*:109; 1904, Can. Ent. *36*:185 [= *N. fasciatus*].

Nemobius maculatus; Walker and Urquhart, 1940, Can. Ent. *72*:15; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30, 35; 1941, Contrib. R. Ont. Mus. Zool. *20*:13.

Locality:

Point Pelee.

The Canadian distribution of this species appears to be confined to Point Pelee. Earlier reports, Walker (1902a, 1904), of this species from Tobermory and Malden Centre were in error and, according to Walker and Urquhart (1940), actually referred to *N. fasciatus*.

Subfamily Trigonidiinae

Anaxipha Saussure

1874. *Anaxipha* Saussure, Miss. Sci. Mex. Amer. cent. *6*:370.

ANAXIPHA EXIGUA (Say)

1825. *Acheta exigua* Say, J. Acad. nat. Sci. Philad. *4*:309.

Anaxipha exigua; Walker and Urquhart, 1940, Can. Ent. *72*:15; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:13; 1941, Univ. Toronto Stud. biol. Ser. *50*:30.

Locality:

Point Pelee.

This species has been found in Canada only at the locality cited.

Family Oecanthidae
Subfamily Oecanthinae

Oecanthus Audinet-Serville

1831. *Oecanthus* Audinet-Serville, Ann. Sci. nat. *22*:134.

OECANTHUS NIGRICORNIS F. Walker

1869. *Oecanthus nigricornis* F. Walker, Cat. Derm. Salt. Brit. Mus. *1*:93.

Oecanthus nigricornis; Lochhead, 1898, Rept. ent. Soc. Ont. *28*:42; *Caesar,* 1912, *Ibid. 42*:31; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302; *Blatchley,* 1920, Orth. N.E. Amer.:721; *Caesar and Ross,* 1921, Rept. ent. Soc. Ont. *51*:39; *Ross and Caesar,* 1924, *Ibid. 54*:61; 1929, *Ibid. 59*:20, *Caesar,* 1929, *Ibid. 60*: 19; 1931, *Ibid. 61*:8; *Ross and Caesar,* 1932, *Ibid. 62*:9; *Caesar and Ross,* 1933, *Ibid. 63*:15; *Ross and Putman,* 1934, *Ibid. 64*:37; *Twinn,* 1934, *Ibid. 64*:73; 1937, *Ibid. 67*:81; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:116; 1941, *Ibid. 50*:30; *T. Walker,* 1963, Ann. ent. Soc. Amer. *56*:766.

Oecanthus angustipennis [*nec* Fitch, 1865]; *Lochhead,* 1898, Rept. ent. Soc. Ont. *28*:42.

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[5]A handwritten note by T. H. Hubbell, based upon a letter from Morgan Hebard in 1941, appears on page 160 of a typescript entitled "A Synonymic Checklist of the Grylloblattoidea, Dermaptera and Orthoptera of the United States and Canada", begun by Hebard, 1937, and continued by Hubbell to 1954. Paratypes have also been checked by Vickery, who concurs with this synonomy.

Oecanthus fasciatus [*nec* Fitch, 1856, *nec* DeGeer, 1773]; *Walker,* 1904, Can. Ent. *36*:254; 1906, Rept. ent. Soc. Ont. *36*:67.

Oecanthus nigricornis nigricornis; Urquhart, 1941, Contrib. R. Ont. Mus. Zool. *20*:10; *Fox,* 1953, Rept. ent. Soc. Ont. *83*:53; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:321-322.

Localities:

Algonquin Park; Bruce Peninsula; Chatham; Essex County; Go Home Bay; Grimsby; Niagara-on-the-Lake; North Bay; Ottawa; Picton; Point Pelee; Port Dalhousie; Sarnia; Toronto; Walpole Island, St. Clair River.

This common so-called 'tree-cricket' has frequently been reported as causing economic injury to raspberry canes in southern Ontario.

OECANTHUS QUADRIPUNCTATUS Beutenmuller

1894. *Oecanthus quadripunctatus* Beutenmuller, Bull. Amer. Mus. nat. Hist. *6*:250.

Oecanthus quadripunctatus; Walker, 1904, Can. Ent. *36*:255; *T. Walker,* 1963, Ann. ent. Soc. Amer. *58*:774.

Oecanthus nigricornis quadripunctatus; Walker in Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302, *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:10; *Fox,* 1953, Rept. ent. Soc. Ont. *83*:53.

Localities:

Chatham; Essex County; Toronto; Walpole Island, St. Clair River.

The taxonomic status of this and other 'difficult' species of the genus *Oecanthus* was elucidated by T. Walker (1963), who applied modern principles of taxonomy (i.e., the use of behaviour and other non-morphological characters as taxonomic tools).

O*ECANTHUS PINI* Beutenmuller

1894. *Oecanthus pini* Beutenmuller, J. N.Y. ent. Soc. *2*:56.

Oecanthus pini; Urquhart, 1942, Can. Ent. *74*:97.

Locality:

Turkey Point.

This species has been reported only once from Canada.

OECANTHUS FULTONI T. J. Walker

1962. *Oecanthus fultoni* T. J. Walker, Ann. ent. Soc. Amer. *55*:309.

Oecanthus niveus [Harris 1841, *et auctt.* — *nec* DeGeer, 1773]; *Saunders,* 1871, Rept. ent. Soc. Ont. *1*:50-51; 1874, *Ibid. 4*:10; *Harrington,* 1884, *Ibid. 14*:36; *Caulfield,* 1888, *Ibid. 18*:69; 1891, *Ibid. 21*:75; *Fletcher,* 1896, *Ibid. 26*:36; *Lochhead,* 1898, *Ibid. 28*:42; 1902, *Ibid. 32*:48; 1904, *Ibid. 34*:74, 77; *Walker,* 1904, Can. Ent. *36*:253; *Treherne,* 1911, Rept. ent. Soc. Ont. *41*:20; 1912, *Ibid. 42*:24; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302; *Blatchley,* 1920, Orth. N.E. Amer.:715; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:151; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:116; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:12; *Fox,* 1953, Rept. ent. Soc. Ont. *83*:53; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:320.

Oecanthus fultoni T. J. Walker, 1962, Ann. ent. Soc. Amer. *55*:309.

Localities:

Arner; Chatham; DeGrassi Point, Lake Simcoe; Goderich; Hamilton; Leamington; London; Niagara; Ottawa; Point Pelee; Sarnia; Toronto; Wellington; Windsor; Woodburn.

The 'Snowy tree cricket' has for many years been known in southern Ontario and other parts of North America by the name *Oecanthus niveus*. T. J. Walker (1962), upon checking the holotype of *O. niveus* (DeGeer, 1773), discovered that this name should be applied to the 'Narrow-winged tree cricket', a species which has not been reported in Canada. Since this left the present species without an available name, Walker described it as *O. fultoni,* in honour of the late Dr. B. B. Fulton, who had carried out much basic research on this group.

O. fultoni has been recorded many times as causing economic damage to plants in Ontario.

SUPERFAMILY GRYLLOTALPOIDEA

Family Gryllotalpidae

Gryllotalpa Latreille

1802. *Gryllotalpa* Latreille, Hist. nat. Crust. Ins. *3*:275.

The following species may be assigned to *Neocurtilla* Kirby, 1906 (=*Curtilla* Saussure, 1874, *nec* Oken, 1815), but the validity of this genus is still uncertain.

GRYLLOTALPA HEXADACTYLA Perty

1832. *Gryllotalpa hexadactyla* Perty, Delect. Anim. Arct. Brasil :119.

Gryllotalpa borealis; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:69; *Fletcher,* 1892, *Ibid. 22*:9; 1892, *Ibid. 22*:87; *Fyles,* 1902, *Ibid. 32*:91; *Walker,* 1904, Can. Ent. *36*:143; 1913, Rept. ent. Soc. Ont. *43*:32.

Gryllotalpa hexadactyla; Blatchley, 1920, Orth. N.E. Amer.:646; *Hebard,* 1931, Proc. Acad. nat. Sci. Philad. *83*:218; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:10; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:327; *Judd,* 1956, Rept. ent. Soc. Ont. *86*:27.

Localities:

Essex County; Leamington; Point Pelee.

The name of this species is in doubt, and will remain so until a comprehensive generic revision is made. The type locality is in Brazil (!); that of *G. borealis* Burmeister, 1838, is 'North America'. The 'American mole cricket' has been found only in two localities in Essex County, Ontario.

SUPERFAMILY TETTIGONIOIDEA

Family Tettigoniidae

Subfamily Decticinae

Atlanticus Scudder

1894. *Atlanticus* Scudder, Proc. Amer. Acad. Arts. Sci. *30*:179.

ATLANTICUS TESTACEUS (Scudder)

1900. *Engoniaspis testacea* Scudder, Proc. Davenport Acad. Sci. *8*:96.

Atlanticus pachymerus [*nec* Burmeister]; *Walker,* 1902, Rept. ent. Soc. Ont. *32*:86; 1902, *Ibid. 32*:109; 1905, Can. Ent. *37*:113.

Atlanticus testaceus; Blatchley, 1920, Orth. N.E. Amer.:592; *Hebard,* 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:46; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:15; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:296.

Localities:

Arner; Turkey Point.

Literature records indicate only one locality in Canada (Arner) for this species, but the Royal Ontario Museum, Toronto, has, as well as specimens from Arner, 3 ♂♂ and 1 ♀, from Turkey Point, 3-IX-1941, collected by F. A. Urquhart.

Metrioptera Wesmael

1838. *Metrioptera* Wesmael, Bull. Acad. Sci. Bruxelles *5*:592.

METRIOPTERA SPHAGNORUM (F. Walker)

1869. *Decticus sphagnorum* F. Walker, Cat. Derm. Salt. Brit. Mus. *2*:258.

Decticus sphagnorum; F. Walker, 1872, Can. Ent. *4*:30.

Idionotus brevipes; Caudell, 1907, Proc. U.S. nat. Mus. *32*:397; *Walker,* 1909, Can. Ent. *41*:209; 1911, Can. Ent. *43*:303; 1920, Can. Arct. Exped. Ins. Orth. App. *JJ*:4J.

Platycleis fletcheri; Caudell, 1907, Proc. U.S. nat. Mus. *32*:404; *Fletcher,* 1908, Rept. ent. Soc. Ont. *38*:131; *Caudell,* 1908, Can. Ent. *40*:332 [synonym of *I. brevipes* Caudell]; 1912, Proc. Acad. nat. Sci. Philad. *64*:167 [Type locality].

Idionotus sphagnorum; Blatchley, 1920, Orth. N.E. Amer.:600.

Metrioptera sphagnorum; Hebard, 1936, N. Dak. agr. exp. Sta. tech. Bull. *284*:7; 1939, Trans. Amer. ent. Soc. *65*:177; *Kevan et al,* 1963, Ann. ent. Soc. Quebec *7*:71.

Localities:

Favourable Lake, 53°N.; Fort William; St. Martin's River [Type locality].

This species is one of the very few orthopterans known only from Canada. It was described almost a hundred years ago from St. Martin's River, Hudson's Bay. Much later Walker collected it near Fort William. The Royal Ontario Museum has 2 ♂♂ taken at Favourable Lake, a locality included in the account of the known distribution of the species given by Kevan *et al.* (1963).

METRIOPTERA ROESELI (Hagenbach)

1822. *Locusta roeselii* Hagenbach, Symb. faun. Ins. Helv.:39, fig. 24.

Metrioptera roeseli was introduced from Europe into North America, near Montreal, about 15 years ago. It has not yet been recorded in the literature from Ontario, but it must now occur in the eastern part of the Province. Specimens were taken at Choisy, Quebec, no more than ten miles from the Ontario border, in 1962, and other specimens were captured in 1965 at Rivière Beaudette, Quebec, less than a mile from Ontario (specimens in the Lyman Entomological Museum). Considering its rapid southerly spread (Vickery, 1965), *M. roeseli* may well occupy all of south-eastern, central, and southern Ontario within the next ten years. At present, there is no reason to believe that it will be of serious economic importance.

Family Conocephalidae

Subfamily Copiphorinae

Neoconocephalus Karny

1907. *Neoconocephalus* Karny, Abh. zool. bot. Ges. Wien *4*(3):22.

NEOCONOCEPHALUS ENSIGER (Harris)

1841. *Conocephalus ensiger* Harris, Rept. Ins. Mass. inj. Veg.:131.

Conocephalus ensiger; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1904, Can. Ent. *36*:337; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301.

Neoconocephalus ensiger; Blatchley, 1920, Orth. N.E. Amer.:522; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:129; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:21; *Fox,* 1953, Rept. ent. Soc. Ont. *83*:53; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:284; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:9.

Localities:

Arner; Bell's Corners; Bowmanville; Bracebridge; Brockville; Bruce Peninsula; Burke's Island, Lake Huron; Constance Bay; DeGrassi Point, Lake Simcoe; Goderich; Lake Muskoka; Leamington; Marmora; Niagara River; Ottawa; Peterborough; Picton; Point Pelee; Rondeau; Sarnia; Summerstown; Toronto; Trenton; Turkey Point; Vineland; Warner; Wellington; York Mills.

N. ensiger, the most widely distributed species of the genus, is common throughout southern Ontario. Walker (1904) states that "it frequents fields, vacant lots and roadsides, which resound at night with the incessant monotonous song."

NEOCONOCEPHALUS LYRISTES (Rehn and Hebard)

1905. *Conocephalus lyristes* Rehn and Hebard, Proc. Acad. nat. Sci. Philad. *57*:45.

Conocephalus nebrascensis [*nec* Bruner] *Walker,* 1902, Rept. ent. Soc. Ont. *32*: 85-87; 1902, *Ibid. 32*:109; 1904, Can. Ent. *36*:337; *Fletcher,* 1906, Rept. ent. Soc. Ont. *36*:103.

Neoconocephalus nebrascensis [*nec* Bruner]; *Blatchley,* 1920, Orth. N.E. Amer.: 518; *Hebard,* 1931, Proc. Acad. nat. Sci. Philad. *83*:197; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:285.

Neoconocephalus lyristes; Thomas, 1933, Ann. ent. Soc. Amer. *26*:304; *Walker and Urquhart,* 1940, Can. Ent. *72*:16; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:21.

Localities:

Grimsby; Sarnia; St. Clair River.

This species is so far known in Canada only from these three localities in southern Ontario.

Subfamily Conocephalinae

Orchelimum Audinet-Serville

1838. *Orchelimum* Audinet-Serville, Hist. nat. Ins. Orth.:522.

ORCHELIMUM VULGARE Harris

1841. *Orchelimum vulgare* Harris, Rept. Ins. Mass. inj. Veg.:130.

Orchelimum agile [*nec* DeGeer, 1773]; *Caulfield,* 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1902, *Ibid. 32*:86.

Orchelimum vulgare; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1905, Can. Ent. *37*:35; 1906, Rept. ent. Soc. Ont. *36*:65, 67; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301; *Blatchley,* 1920, Orth. N.E. Amer.:543; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:130; 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:43; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:16, *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:287; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:5.

Orchelimum glaberrimum [*nec* Burmeister, 1838]; *Walker,* 1905, Can. Ent. *37*:35.

Localities:

Amherstburg; Angus; Arner; Bruce Peninsula; Burke's Island, Lake Huron; Chatham; Cottam; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Essex; Giant's Tomb Islands; Goderich; Go Home Bay; Johnston Harbour, Lake Huron; Lake Muskoka; Lake Superior; Leamington; Maidstone; Marmora; Oxley; Point Pelee; Port Rowan; Rondeau; Sarnia; South Woodslee; Staples; Tecumseh; Toronto; Turkey Point; Vineland; Walpole Island, St. Clair River; Wheatley.

This species is much more common in Ontario than in Quebec, where *O. gladiator* is the main representative of the genus.

ORCHELIMUM GLADIATOR Bruner

1891. *Orchelimum gladiator* Bruner. Can. Ent. *23*:71.

Orchelimum gladiator; Walker, 1905, Can. Ent. *37*:38; *Blatchley,* 1920, Orth. N.E. Amer.:546; *Hebard,* 1936, N. Dak. agr. Coll. exp. Sta. tech. Bull. *284*:64; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:16; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:287.

Orchelimum manitobense; Gibson, 1915, Rept. ent. Soc. Ont. *45*:148.

Localities:

Arden; Arner; Blackburn; Brockville; Go Home Bay; Hawthorn; Jarvis Lake; Jordan; Kahshe Lake; Lancaster; Marmora; Mindemoya, Manitoulin Island; MacGregor; Mer Bleue; Picton; Point Pelee; Smoke Lake, Algonquin Park; Summerstown; Turkey Point; Waubaushene.

O. gladiator has a somewhat more northerly distribution than other species of the genus, and is found over much of Ontario. It is the most common species of *Orchelimum* in Quebec.

ORCHELIMUM NIGRIPES Scudder

1875. *Orchelimum nigripes* Scudder, Proc. Bost. Soc. nat. Hist. *17*:459.

Orchelimum nigripes; Walker, 1902, Rept. ent. Soc. Ont. *32*:109; 1905, Can. Ent. *37*:36; *Blatchley,* 1920, Orth. N.E. Amer.:550; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:131; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:16; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:288.

Localities:

Arner; Colchester; Essex; Leamington; Malden Centre; Oxley; Point Pelee.

O. nigripes is a handsome species which, in Canada, is confined to extreme southern Ontario.

ORCHELIMUM CONCINNUM Scudder

1862. *Orchelimum concinnum* Scudder, Bost. J. nat. Hist. *7*:452.

Orchelimum indianense; Walker, 1902, Rept. ent. Soc. Ont. *32*:85-86; 1902, *Ibid. 32*:109; 1905, Can. Ent. *37*:37.

Orchelimum longipenne; Walker, 1902, Rept. ent. Soc. Ont. *32*:85-86; 1902, *Ibid. 32*:109.

Orchelimum concinnum; Blatchley, 1920, Orth. N.E. Amer.:556; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:289.

Orchelimum concinnum concinnum; Hebard, 1931, Proc. Acad. nat. Sci. Philad. *83*:199; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:17-19; *Thomas and Alexander,* 1962, Occ. Pap. Mus. Zool. Univ. Mich. *626*:9.

Localities:

Amherstburg; Arner; Kingsville; Malden Centre; Point Pelee; Sarnia; Stony Point.

The definition of this species, and of *O. campestre* and *O. delicatum,* which have sometimes been considered to be subspecies of it, is rather fluid, so that no clear statement regarding previous records and localities can be made. The references and localities given for these three species may represent any or all of them. Urquhart (1941) considered that only *O. concinnum concinnum* occurs

in Ontario, although previous authors (see above) had reported all three. However, Thomas and Alexander (1962) making reference to Urquhart's figures, stated that all three "subspecies" were represented by him under the name *concinnum*. However, if the accepted definition of a subspecies is applied, the three entities occurring together cannot be regarded as such and they are listed in this paper as species. It is likely that all are members of a species complex, but further comprehensive work is necessary to demonstrate the true relationships of each to the other.

ORCHELIMUM DELICATUM Bruner

1892. *Orchelimum delicatum* Bruner, Ent. News *3*:264.

Orchelimum delicatum; Walker, 1905, Can. Ent. *37*:37.

Orchelimum concinnum concinnum; Urquhart, 1941 [*partim*], Contrib. R. Ont. Mus. Zool. *20*:17-19 [according to Thomas and Alexander, 1962].

Orchelimum concinnum delicatum; Thomas and Alexander, 1962, Occ. Pap. Mus. Zool. Univ. Mich. *626*:9.

Localities:

Amherstburg [Royal Ontario Museum, det. E. S. Thomas, 1948]; Arner; Point Pelee; Rondeau; Sarnia.

See remarks on this species under *O. concinnum.*

ORCHELIMUM CAMPESTRE Blatchley

1893. *Orchelimum campestre* Blatchley, Can. Ent. *25*:91.

Orchelimum campestre; Walker, 1905, Can. Ent. *37*:36; *Blatchley,* 1920, Orth. N.E. Amer.:556.

Orchelimum concinnum concinnum; Urquhart, 1941 [*partim*], Contrib. R. Ont. Mus. Zool. *20*:17-19 [according to Thomas and Alexander, 1962].

Orchelimum concinnum campestre; Thomas and Alexander, 1962, Occ. Pap. Mus. Zool. Univ. Mich. *626*:9.

Localities:

Amherstburg; Arner; Point Pelee; Tecumseh [Royal Ontario Museum, det. E. S. Thomas, 1948].

See remarks on this species under *O. concinnum.*

ORCHELIMUM VOLANTUM McNeill

1891. *Orchelimum volantum* McNeill, Psyche *6*:26.

Orchelimum bruneri; Walker, 1902, Rept. ent. Soc. Ont. *32*:86.

Orchelimum volantum; Walker, 1905, Can. Ent. *37*:38; *Blatchley,* 1920, Orth. N.E. Amer.:560; *Hebard,* 1934, Ill. nat. Hist. surv. Bull. *20*:215; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:16; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:290.

Localities:

Belle River; Malden Centre; Niagara River; Point Pelee; Port Rowan; Queenston; Rondeau; marsh between Rondeau and Morpeth; Sarnia; Tecumseh; Walpole Island, St. Clair River.

Walker (1905) reported *O. volantum* from southern Ontario where it was abundant in rushes and *Sagittaria* in open marshes bordering streams.

Conocephalus Thunberg

1815. *Conocephalus* Thunberg, Mem. Acad. Imp. Soc. St. Petersburg *5*:271.

CONOCEPHALUS FASCIATUS FASCIATUS (DeGeer)

1773. *Locusta fasciata* DeGeer, Mém. Hist. Ins. *3*:458.

Xiphidium fasciatum; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1904, Can. Ent. *36*:338; 1906, Rept. ent. Soc. Ont. *36*:67.

Xiphidion fasciatum; Walker, 1909, Can. Ent. *41*:209; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:307.

Conocephalus fasciatus; Blatchley, 1920, Orth. N.E. Amer.:568; *Walker and Urquhart,* 1940, Can. Ent. *72*:16.

Conocephalus fasciatus fasciatus; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:134; 1928, *Ibid. 80*:295; 1936, N. Dak. agr. Coll. exp. Sta. tech. Bull. *284*:53; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:65; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:20; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:291.

Localities:

Algonquin Park; Arner; Belle River; Bradford; Bruce Peninsula; Chatham; Constance Bay; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Fort William; Frankford; Goderich; Gravenhurst; Hastings County; Jordan; Leamington; Marmora; Malden Centre; Mer Bleue; Nipigon; North Bay; Northumberland County; Norway Bay; Osgoode; Ottawa; Palmer Rapids; Picton; Point Pelee; Ragged Rapids, Severn River; Renfrew County; Rondeau; Rostrevor; Sarnia; Sesekinika; Southampton; Stony Point; Timagami; Toronto; Walpole Island, St. Clair River; Wheatley; Whitemouth; Windsor.

C. f. fasciatus is the most abundant and widespread species of the genus in eastern Canada, extending eastward to all of the Atlantic provinces. In Ontario, its distribution and numbers are much the same as for *C. brevipennis.*

CONOCEPHALUS BREVIPENNIS (Scudder)

1862. *Xiphidium brevipenne* Scudder, Can. nat. and geol. *7*:285.

Xiphidium fasciatum brevipenne; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70.

Xiphidium brevipenne; Walker, 1904, Can. Ent. *36*:339; 1906, Rept. ent. Soc. Ont. *36*:67.

Xiphidion brevipenne; Walker in Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301.

Conocephalus brevipennis; Blatchley, 1920, Orth. N.E. Amer.:571; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:134; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:20; *Judd,* 1953, Rept. ent. Soc. Ont. *83*:38; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:291; *Judd,* 1960, Can. Ent. *92*:242.

Localities:

Algonquin Park; Amherstburg; Arner; Belle River; Black Lake; Bradford; Burke's Island, Lake Huron; Byron Bog; Constance Bay; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Essex; Goderich; Gravenhurst; Guelph; Jarvis Lake; Jordan; Kingsville; London; Malden Centre; Marmora; Mer Bleue; Norway Bay; Ottawa; Owen Sound; Point Pelee; Prince Edward County; Ragged Rapids, Severn River; Rondeau; Sarnia; Six-mile Lake; Southampton; Staples; Stony Point; Tecumseh; Tobermory; Toronto; Walpole Island, St. Clair River; Windfall; Windsor; Wheatley; York Mills.

C. brevipennis does not occur in the Atlantic provinces but is relatively common in Ontario and western Quebec.

CONOCEPHALUS STRICTUS (Scudder)

1875. *Xiphidium strictum* Scudder, Proc. Bost. Soc. nat. Hist. *17*:460.

Conocephalus strictus; Walker and Urquhart, 1940. Can. Ent. *72*:16; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:16.

Localities:

Amherstburg; Arner; Belle River; Essex; Kingsville; LaSalle; Leamington; Point Pelee; Staples; Tecumseh; Turkey Point; Wheatley; Windfall; Windsor.

C. strictus is found in Canada only in extreme southern Ontario.

CONOCEPHALUS NIGROPLEURUM (Bruner)

1891. *Xiphidium nigropleurum* Bruner, Can. Ent. *23*:58.

Xiphidium nigropleurum; Walker, 1902, Rept. ent. Soc. Ont. *32*:85-86.

Xiphidium nigropleura [*sic*]*; Walker,* 1904, Can. Ent. *36*:341; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301.

Conocephalus nigropleurus [*sic*]; *Blatchley,* 1920, Orth. N.E. Amer.:577; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117.

Conocephalus nigropleurum; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:136; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:19.

Localities:

Arner; Brockville; Chatham; Kingsville; Malden Centre; Point Pelee; Rondeau; Toronto; Turkey Point; Vineland; Walpole Island, St. Clair River.

C. nigropleurum is not a common species but is found quite widely in southern Ontario.

CONOCEPHALUS ATTENUATUS (Scudder)

1869. *Xiphidium attenuatum* Scudder, Trans. Amer. ent. Soc. *2*:305.

Xiphidium attenuatum; Walker, 1902, Rept. ent. Soc. Ont. *32*:85-87; 1902, *Ibid. 32*:109; 1904, Can. Ent. *36*:341.

Conocephalus attenuatus; Blatchley, 1920, Orth. N.E. Amer.:579; *Hebard,* 1931, Proc. Acad. nat. Sci. Philad. *83*:201; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:117; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:19.

Localities:

Amherstburg; Arner; Brockville; Malden Centre; Picton; Point Pelee; Rondeau; Toronto; Walpole Island, St. Clair River.

Females of *C. attenuatus* have exceptionally long ovipositors. This species is found throughout southern Ontario and in southwestern Quebec.

CONOCEPHALUS SALTANS (Scudder)

1871. *Xiphidium saltans* Scudder, Rept. U.S. geol. Surv. Nebr.:249.

Xiphidium saltans; Fletcher, 1903, Rept. ent. Soc. Ont. *33*:98; 1904, *Ibid. 34*:97; *Walker,* 1904, Can. Ent. *36*:340.

Xiphidion saltans; Walker in Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301.

Conocephalus viridifrons; Blatchley, 1920, Orth. N.E. Amer.:583.

Conocephalus saltans; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:138; 1928, *Ibid. 80*:295; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:294.

Localities:

Islington, York County; Toronto; Turkey Point.

This species is at the eastern limit of range in southern Ontario, and is not common there.

Family Phaneropteridae

Subfamily Phaneropterinae

Scudderia Stål

1873. *Scudderia* Stål. Recens. Orth. *1*:41.

SCUDDERIA SEPTENTRIONALIS (Audinet-Serville)

1839. *Phaneroptera septentrionalis* Audinet-Serville, Hist. nat. Ins. Orth.:416.

Scudderia septentrionalis; Urquhart, 1940, Can. Field-Nat. *54*:102.

Locality:

Guelph.

The record of Urquhart (1940) is the only one for this species from Ontario. The specimen, a male, is in the Royal Ontario Museum, Toronto. The Lyman Entomological Museum also has a male specimen from the same locality.

SCUDDERIA PISTILLATA Brunner von Wattenwyl

1878. *Scudderia pistillata* Brunner von Wattenwyl, Monogr. Phan.:240.

Scudderia pistillata; Walker, 1902, Rept. ent. Soc. Ont. *32*:89; 1904, Can. Ent. *36*:327; 1906, Rept. ent. Soc. Ont. *36*:67; 1909, Can. Ent. *41*:208; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301; *Piers,* 1918, Trans. N.S. Inst. Sci. *14*:312; *Blatchley,* 1920, Orth. N.E. Amer.:467; *Urquhart,* 1940, Can. Field-Nat. *54*:102-104; 1941, Univ. Toronto Stud. biol. Ser. *48*:117; *Walker,* 1956, Rept. ent. Soc. Ont. *86*:38; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:5.

Phaneroptera pistillata; Hebard, 1925, Proc. Acad. nat. Sci. Philad. 77:125; 1928, *Ibid. 80*:293.

Localities:

Brockville; Burke's Island, Lake Huron; Constance; DeGrassi Point, Lake Simcoe; Dwight, Muskoka Region; East River, Nipissing District; Eldorado; Fort William; Grand Bay, Lake Nipigon; Guelph; Hawthorn; Jarvis Lake; Johnston Harbour, Lake Huron; Lancaster; Leg Lake; Macdiarmid; Mer Bleue; Mindemoya, Manitoulin Island; Norway Bay; Norway Point, Lake of Bays; Ottawa; Parry Sound; Rosegrove; Sesikinika; Smoke Lake, Algonquin Park; Southampton; St. Mary's; Sudbury; Timagami; Tobermory, Bruce Peninsula; Toronto; Trenton; Wellington.

This species, the 'Broad-winged false katydid', is the most abundant species of the genus in Ontario. It is widespread throughout eastern Canada. During the day, males sun themselves on the tops of bushes in pastures and meadows and their stridulation is a famaliar sound in late August in these locations.

SCUDDERIA CURVICAUDA (DeGeer)

1773. *Locusta curvicauda* DeGeer, Mém. Hist. Ins. Orth.:446.

Phaneroptera curvicauda; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:69.

Scudderia curvicauda; Walker, 1904, Can. Ent. *36*:326; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301; *Urquhart,* 1940, Can. Field-Nat. *54*:103-104; 1941, Contrib. R. Ont. Mus. Zool. *20*:21; 1941, Univ. Toronto Stud. biol. Ser. *48*:117; *Judd,* 1960, Can. Ent. *92*:242.

Localities:

Algonquin Park; Arner; Aylmer; Bala; Brockville; Byron Bog; Constance Bay; DeGrassi Point, Lake Simcoe; Essex County; Go Home Bay; Golden Lake; Hawthorn; Inglewood; Jarvis Lake; Kahshe Lake; Kingsville; Lefroy, Simcoe County; Macdonald's Falls; Macdiarmid; Marmora; Mer Bleue; Mindemoya, Manitoulin Island; Muskoka; Ottawa; Picton; Pittsburgh Camp; Ragged Rapids, Severn River; Sphagnum Bay; Tobermory; Toronto; Turkey Point; Vineland.

Next to *S. pistillata*, this species is the most common member of the genus in eastern Canada.

SCUDDERIA TEXENSIS Saussure and Pictet

1897. *Scudderia texensis* Saussure and Pictet, Biol. centr. Amer. Orth.:328.

Scudderia texensis; Walker, 1902, Rept. ent. Soc. Ont. *32*:109; 1904, Can. Ent. *36*:325; *Blatchley,* 1920, Orth. N.E. Amer.:466; *Urquhart,* 1940, Can. Field-Nat. *54*:102; 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:22; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:278; *Walker,* 1956, Rept. ent. Soc. Ont. *86*:38; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:9.

Phaneroptera texensis; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:126-127.

Localities:

Amherstburg; Arner; Brockville; Colchester; DeGrassi Point, Lake Simcoe; Essex; Guelph; Kingsville; Lancaster; LaSalle; Malden Centre; MacGregor; Niagara Falls; Oxley; Point Pelee; Port Rowan; Sarnia; Summerstown; Tecumseh; Trenton; Turkey Point; Vineland; Walpole Island, St. Clair River.

S. texensis, has a more general southerly distribution than *pistillata, curvicauda* and *furcata,* and is found only in the southern parts of Ontario.

SCUDDERIA FURCATA FURCATA Brunner von Wattenwyl

1878. *Scudderia furcata* Brunner von Wattenwyl, Monogr. Phan.:239.

Scudderia furcata; Walker, 1904, Can. Ent. *36*:328; 1906, Rept. ent. Soc. Ont. *36*:65, 67; 1909, Can. Ent. *41*:209; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301; *Blatchley,* 1920, Orth. N.E. Amer.:473; *Urquhart,* 1940, Can. Field-Nat. *54*:102-103; 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid, 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:21; *Fox,* 1953, Rept. ent. Soc. Ont. *83*:53; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:278.

Phaneroptera furcata; Hebard, 1928, Proc. Acad. nat. Sci. Philad. *80*:293.

Localities:

Arner; Bell's Corners; Blackburn; Bolton; Brockville; Bruce Peninsula; Chatham; Constance Bay; DeGrassi Point, Lake Simcoe; Dwight, Muskoka; Frank's Bay, Lake Nipissing; Gainesville; Go Home Bay; Guelph; Highland Creek; Ingersoll; Johnston Harbour, Bruce County; Kingsville; Lancaster; Leamington; Little Eagle Harbour, Bruce County; North Bay; Ottawa; Point Pelee; Port Stanley; Rondeau; Sarnia; Severn River; Summerstown Tobermory Toronto; Trenton; Wilcox Lake.

A second subspecies, *S. f. furcifera* Scudder, occurs in the southwestern United States. *S. f. furcata* has the widest distribution of any species in the genus, ranging from coast to coast in Canada. It is rather common, as the records of localities in Ontario indicate.

SCUDDERIA FASCIATA Beutenmuller

1894. *Scudderia fasciata* Beutenmuller, Bull. Amer. Mus. nat. Hist. *6*:251.

Scudderia fasciata; Urquhart, 1942, Can. Ent. *74*:97.

Locality:

Turkey Point.

This species has been reported only once in Ontario.

Amblycorypha Stål

1873. *Amblycorypha* Stål, Recens. Orth. *1*:40.

AMBLYCORYPHA OBLONGIFOLIA (DeGeer)

1773. *Locusta oblongifolia* DeGeer, Mém. Hist. Ins. *3*:445.

Phylloptera (Amblycorypha) oblongifolia; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70.

Amblycorypha oblongifolia; Walker, 1904, Can. Ent. *36*:329; *Fletcher,* 1908, Rept. ent. Soc. Ont. *38*:131; *Walker,* 1913, Rept. ent. Soc. Ont. *43*:32; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:301; *Gibson,* 1920, Rept. ent. Soc. Ont. *50*:133; *Blatchley,* 1920, Orth. N.E. Amer.:478; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:128; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:21; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:280.

Localities:

Arner; Colchester; Hamilton; Harrow; Kingsville; Niagara Glen; Niagara River; Ottawa; Point Pelee; Rondeau; Summerstown; Toronto; Trenton; Turkey Point; Vineland; Wainfleet; Walpole Island, St. Clair River; Windsor.

A. oblongifolia is a relatively common species living on tall plants and shrubs. As the green colour provides good camouflage, it, like most of the Phaneropteridae, is more often heard than seen. The males stridulate at night and also in the afternoon. Walker (1904) described the sound as "very harsh and scraping in character". A genetically based colour phase of this species sometimes occurs, in which the individuals are entirely pink. So far as we know, no pink specimen has been found in Canada.

Family Pseudophyllidae

Subfamily Pseudophyllinae

Pterophylla Kirby

1828. *Pterophylla* Kirby, Intro. Ent. 5 ed.,:218.

PTEROPHYLLA CAMELLIFOLIA (Fabricius)

1775. *Locusta camellifolia* Fabricius, Syst. ent. Ins.:283.

Phylloptera myrtifolia; F. Walker, 1872, Can. Ent. *4*:30.

Platyphyllum concavum; Saunders, 1887, Can. Ent. *19*:29; *Caulfield,* 1888, Rept. ent. Soc. Ont. *18*:70.

Cyrtophyllus perspicillatus; Walker, 1904, Can. Ent. *36*:330; 1913, Rept. ent. Soc. Ont. *43*:32.

Pterophylla camellifolia; Blatchley, 1920, Orth. N.E. Amer.:498; *Hebard,* 1931, Proc. Acad. nat. Sci. Philad. *83*:196; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:15.

Pterophylla camellifolia camellifolia; Hebard, 1941, Trans. Amer. ent. Soc. *67*:205; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:281.

Localities:

Harrow; London; Niagara-on-the-Lake; Point Pelee.

The true "katydid" is found in Canada only in the southern part of the Niagara peninsula. It is heard more often than it is seen owing to its habit of living high up in trees.

SUBORDER CAELIFERA

SUPERFAMILY TRIDACTYLOIDEA

Family Tridactylidae

Subfamily Tridactylinae

Tridactylus Olivier

1789. *Tridactylus* Olivier, Encyc. Meth. Dict. Ins. Orth. *4*:26.

TRIDACTYLUS APICALIS Say

1825. *Tridactylus apicialis* [*sic*] Say, J. Acad. nat. Sci. Philad. *4*:310. [emend. Burmeister, 1838, Handb. Ent. *2*:741].

Tridactylus apicalis; Walker, 1904, Can. Ent. *36*:143; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:302; *Blatchley,* 1920, Orth. N.E. Amer.:657; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:154; 1929, *Ibid. 81*:425; *Urquhart,* 1939, Can. Field-Nat. *51*:28; 1940, *Ibid. 54*:106; 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:22; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:328.

Localities:

Humber River; Point Pelee; Port Rowan; Toronto; York Mills.

This is yet another species known in Canada only from southern Ontario. It is usually found in muddy places along streams.

TRIDACTYLUS MINUTUS Scudder

1862. *Tridactylus minutus* Scudder, Bost. J. nat. Hist. *7*:425.

Tridactylus minulus [*sic*]; *Urquhart,* 1940, Can. Field-Nat. *54*:106.

Tridactylus minutus; Walker and Urquhart, 1940, Can. Ent. *72*:16; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:22.

Localities:

Morpeth and Port Rowan.

The only known Canadian localities from which this tiny insect has been recorded are those given above. It is one of the smallest of all Orthoptera. It has habits similar to those of *T. apicalis* and is frequently found with that species.

SUPERFAMILY TETRIGOIDEA

Family Tetrigidae

Subfamily Tetriginae

Nomotettix Morse

1894. *Nomotettix* Morse, Psyche *7*:150.

NOMOTETTIX CRISTATUS CRISTATUS (Scudder)

1862. *Batrachidea cristata* Scudder, Bost. J. nat. Hist. *7*:478.

Batrachidea cristata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Nomotettix cristatus; Walker, 1902, Can. Ent. *34*:253; *Fletcher,* 1909, Rept. ent. Soc. Ont. *39*:113; *Blatchley,* 1920, Orth. N.E. Amer.:157; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:195.

Nomotettix borealis Walker, 1909, Can. Ent. *41*:173.

Nomotettix cristatus cristatus; Rehn and Grant, 1955, Proc. Acad. nat. Sci. Philad. *107*:6, 9-11, 19, 21-22; 1961, Monogr. Acad. nat. Sci. Philad. *12*:37-38, 44; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Localities:

Bala; Bell's Corners; Diamond Lake, Timagami District [Type locality of *N. borealis* Walker]; Go Home Bay; Klock; Nipissing District; Macdiarmid; Osgood; Point au Baril; Toronto.

N. c. cristatus is somewhat variable and Walker's *N. borealis* was based upon decidedly atypical specimens. Although not common, this insect should occur in all except northern Ontario. There are four additional subspecies known from various areas of the United States, but none of these occurs in Canada.

TETRIX SUBULATA (Linnaeus)

1761. *Gryllus subulatus* Linnaeus, Fauna Suecia *2*:236.

Tettix granulata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Tettix granulatus; Walker, 1898, Can. Ent. *30*:123; 1902, *Ibid., 34*:253; 1906, Rept. ent. Soc. Ont. *36*:66; 1909, Can. Ent. *41*:174; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Acrydium granulatum; Gilbert, 1937, Rept. ent. Soc. Ont. *67*:65.

Acrydium subulatum; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:23.

Tetrix subulata; Rehn and Grant, 1955, Proc. Acad. nat. Sci. Philad. *107*:148-154, 158-159, 161; 1961, Monogr. Acad. nat. Sci. Philad. *12*:26, 44, 53.

Localities:

Attawapiskat, 52° N.; Black Rapids; Bradford; Charlton; Constance Bay; Favourable Lake, 53° N.; Fort Albany, 52° N.; Fort Severn; Fort William; Hawthorn; Island Lake, Algonquin Park; Jock River; Johnston Harbour; Lake Abitibi; Lake of Two Rivers, Algonquin Park; Marmora; Merivale; Mer Bleue; Moose Factory; Muskoka; Nipigon; North River, Algonquin Park; Obatika Portage; Ogoki; Ottawa; Owen Sound; Point Pelee; Port Rowan; Rainy River; Renfrew County; Sarnia; Six-mile Lake; Simcoe Lake, Algonquin Park; Southampton; Stoke's Bay; Strathoy; Timagami; Tobermory; Toronto; Wabinash Bay, Lake Nipigon.

This common species occurs throughout Ontario and all across Canada. It is one of the few circumboreal Orthoptera.

TETRIX BRUNNERII Bolívar

1887. *T*[*ettix*] *brunnerii* Bolívar, Ann. Soc. ent. Belg. *31*:259, 266.

Tettix brunneri; Fletcher, 1909, Rept. ent. Soc. Ont. *39*:113; *Blatchley,* 1920, Orth. N.E. Amer.:165.

Tetrix brunneri; Walker, 1909, Can. Ent. *41*:174; *Rehn and Grant,* 1956, Proc. Acad. nat. Sci. Philad. *108*:99-101, 103-104, 106, 108-110; 1961, Monogr. Acad. nat. Sci. Philad. *12*:44, 48-49, 51.

Localities:

Diamond Lake; Favourable Lake, 53° N.; Fort Severn; Fraserdale; Hawthorn; Hudson Bay; Malden Centre; Macdiarmid; Merivale; North River, Algonquin Park; Point Pelee; Port Rowan; Sarnia; Southampton; Timagami Falls; Toronto [coll. 1895]; Turkey Point; Vineland.

A northern species, near the southern limits of its range in Ontario, *T. brunneri* is not common. It extends into the United States only in the northern Great Lakes region and in extreme northern New York. It resembles *T. subulata,* and it is possible that some specimens reported as that species should properly be referred to *T. brunneri.*

TETRIX ORNATA (Say)

1824. *Acrydium ornatum* Say, Amer. Ent. *1*:pl. 5.

Tettix ornata; F. Walker, 1872, Can. Ent. *4*:31; *Caulfield,* 1888, Rept. ent. Soc. Ont. *18*:71.

Tettix triangularis; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Tettix ornatus; Walker, 1898, Can. Ent. *30*:122; 1902, *Ibid. 34*:253; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Tettix acadicus; Walker, 1902, Can. Ent. *34*:253; 1906, Rept. ent. Soc. Ont. *36*:66; *Fletcher,* 1909, *Ibid. 39*:113.

Tettix ornatus triangularis; Walker, 1902, Can. Ent. *34*:253; *Fletcher,* 1906, Rept. ent. Soc. Ont. *36*:103.

Tettix hancocki; Walker, 1902, Can. Ent. *34*:253.

Tettix hancocki abbreviatus; Walker, 1902, Can. Ent. *34*:253.

Tettix handcocki [*sic*]; *Walker,* 1906, Rept. ent. Soc. Ont. *36*:66.

Tetrix acadicus; Walker, 1909, Can. Ent. *41*:175.

Tetrix hancocki; Walker, 1909, Can. Ent. *41*:175.

Tettix hencocki [*sic*]; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Acrydium ornatum; Blatchley, 1920, Orth. N.E. Amer.:167-168; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:47-48; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:23; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Acrydium acadicum; Blatchley, 1920, Orth. N.E. Amer.:167-168; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:47-48.

A[*crydium*] *ornatum hancocki; Blatchley,* 1920, Orth. N.E. Amer.:167-168.

Acrydium acadicum acadicum; Hebard, 1928, Proc. Acad. nat. Sci. Philad. *80*:222; 1934, Ill. nat. Hist. Surv. Bull. *20*:167.

Tetrix acadicus acadicus; Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:197-198.

Tetrix ornatus; Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:197-198.

Tetrix ornata ornata; Rehn and Grant, 1956, Trans. Amer. ent. Soc. *82*:132, 136, 138; 1961, Monogr. Acad. nat. Sci. Philad. *12*:57.

Tetrix ornata hancocki; Rehn and Grant, 1956, Trans. Amer. ent. Soc. *82*:125, 131, 141-142; 1961, Monogr. Acad. nat. Sci. Philad. *12*:57.

Localities:

Bell's Corners; Blackburn; Bruce Peninsula; Burke Falls; Charlton; DeGrassi Point, Lake Simcoe; Diamond Lake; Dwight, Muskoka District; Eglington; Favourable Lake; Fort William; Fraserdale; Gull Lake; Hastings County; Hawthorne; Kirkwood Twp.; Lambton; Lake Nipissing; Little Eagle Harbour, Bruce County; Malden Centre; Marmora; Merivale; North Bay; North River, Algonquin Park; Osgoode; Ottawa; Point Pelee; Port Rowan; Prince Edward County; Rouge River; Sarnia; Smoky Falls, Algonquin Park; Southampton; Spencerville; St. Martin's Falls, Albany River; Sudbury; Timagami; Toronto; Turkey Point; Vineland; Wyebridge.

This tetrigid is extremely variable, which accounts for the use of so many names in the literature. After studying this species the senior author believes that but a single species without recognizable subspecies occurs in Canada. The so-called subspecies, *ornata* and *hancocki,* recognized by Rehn and Grant (1956, 1961) are distributed geographically (and ecologically) in such a manner that they cannot be considered as subspecies in the generally accepted sense (see Rehn and Grant 1956, Maps, pp. 129, 130). Grant (personal communication, 1966) has also discarded the subspecies concept for populations of this species.

TETRIX ARENOSA ANGUSTA (Hancock)

1896. *Tettix angustus* Hancock, Trans. Amer. ent. Soc. *23*:238.

Tettix obscurus; Walker, 1902, Can. Ent. *34*:253; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Tettix gibbosus; Walker, 1902, Can. Ent. *34*:253.

Acrydium arenosum obscurum; Blatchley, 1920, Orth. N.E. Amer.:169; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:23; 1941, Univ. Toronto Stud. biol. Ser. *50*:31.

Acrydium arenosum angustum; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:48; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:118.

Tetrix arenosus angustus; Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:199.

Tetrix arenosa angusta; Rehn and Grant, 1956, Trans. Amer. ent. Soc. *82*:124, 127, 133, 139; 1961, Monogr. Acad. nat. Sci. Philad. *12*:63, 68.

Localities:

Agincourt; Bolton; DeGrassi Point, Lake Simcoe; Eglinton; Goderich; Grimsby; Marmora; Miner's Bay; Owen Sound; Point Pelee; Prince Edward County; Rondeau Park; Sarnia; Singhampton; Toronto.

The typical subspecies, *T. arenosa arenosa* (Burmeister, 1838) is found only far to the south of the Canadian border with the United States of America. *T. a. angusta* has wide distribution in Canada from Ontario to the east coast. In the past it has been confused by some authors with *T. ornata,* but the recorded occurrences in Ontario appear to be correct.

Paratettix I. Bolívar

1887. *Paratettix* I. Bolívar, Ann. Soc. ent. Belg. *31*:195, 270.

PARATETTIX CUCULLATUS (Burmeister)

1838. *T*[*ettix*] *cucullata* Burmeister, Handb. Ent. *2*:658.

Tettix cucullata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Paratettix cucullatus; Walker, 1898, Can. Ent. *30*:123; 1902, *Ibid. 34*:254; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.: 299; *Blatchley,* 1920, Orth. N.E. Amer.:176; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:49; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:31, 1941, Contrib. R. Ont. Mus. Zool. *20*:23; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:200; *Rehn and Grant,* 1957, Proc. Acad. nat. Sci. Philad. *109*:266, 271, 272; 1961, Monogr. Acad. Sci. Philad. *12*:103-105.

Localities:

Cape Hope; Chatham; Don Valley; Emdale; Lampton; Point Pelee; Prince Edward County; Toronto; Turkey Point; York Mills.

This is another southern species, extending only as far north as southern Ontario and possibly southern Quebec.

Subfamily Batrachideinae

Tettigidea Scudder

1862. *Tettigidea* Scudder, Bost. J. nat. Hist. *7*:476.

TETTIGIDEA LATERALIS LATERALIS (Say)

1824. *Acrydium laterale* Say, Amer. Ent. *1*:10.

Tettigidea lateralis; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:200-201.

Tettigidea polymorpha; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Tettididea parvipennis; Walker, 1898, Can. Ent. *30*:123; 1902, *Ibid. 34*:254; 1906, Rept. ent. Soc. Ont. *36*:66; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:299.

Tettigidea parvipennis pennata; Walker, 1902, Can. Ent. *34*:254.

Tettigidea lateralis parvipennis; Blatchley, 1920, Orth. N.E. Amer.:184; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:118; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:23.

Tettigidea lateralis lateralis; Rehn and Grant, 1958, Trans. Amer. ent. Soc. 85:22-24, 26-27, 33, 40, 52, 55; 1961, Monogr. Acad. nat. Sci. Philad. *12*:103-105.

Localities:

Arner; Bell's Corners; Black Creek, Toronto; Bolton; Brockville; DeGrassi Point, Lake Simcoe; Detongue Portage; Eglinton; Grimsby; High Park, Toronto; Kew Beach, Toronto; Kingsville; Lancaster; Leamington; Lefroy; Marmora; Meaford; Medford; Mer Bleue; Miner's Bay; Minette; North Bay; North River, Algonquin Park; Osgoode; Ottawa; Owen Sound; Point Pelee; Port Hope; Ridgeway; Spencerville; Strathroy; Sudbury; Turkey Point; Vineland; Wellington; Wheatley; York Mills.

All Ontario specimens are considered by Rehn and Grant (1958, 1961) to be either atypical or intermediate between *T. lateralis lateralis* and *T. lateralis cazieri* Rehn and Grant, 1958. The latter subspecies is generally distributed from Nebraska to Arizona, while the former is eastern, the typical form occurring from New Jersey to Florida and Texas.

SUPERFAMILY ACRIDOIDEA

Family Acrididae

Subfamily Romaleinae

Romalea Audinet-Serville

1831. *Romalea* Audinet-Serville, Ann. Sci. nat. *22*:280.

ROMALEA MICROPTERA (Palisot de Beauvois)

1805. *Acridium micropterum* Palisot de Beauvois, Ins. Rec. Afr. Amer.:146.

Adventive only.

The distribution of *R. microptera* is confined to the states bordering the Gulf of Mexico and north to the Atlantic coast of North Carolina in the United States. The species is used extensively in classrooms and laboratories in schools and colleges in North America. The sole Canadian record, from the banks of the Detroit River, apparently resulted from the dumping of living specimens used as fish bait by American sport fishermen.

Subfamily Oxyinae

Oxya Audinet-Serville

1831. *Oxya* Audinet-Serville, Ann. Sci. nat., Paris *22*:264, 286.

OXYA sp., [probably *O. intricata* (Stål)]

1860. *Acrydium (Oxya) intricatum* Stål, Eugenies Resa, Orth.:335.

Adventive only.

This insect has not been reported previously in North America, and is here recorded as a casual adventive. A single male was taken from a commercial aircraft at Malton airport, November 8, 1965.

Females of the genus *Oxya* can be separated readily by means of a key, but no such key exists for males which are at present nearly impossible to determine to species (Willemse, 1956).

O. intricata is found in China, Formosa, Java, Ceylon and the Philippines. Since the native habitat of the genus *Oxya* is subtropical to tropical, it could not become established in Canada.

Subfamily Cyrtacanthacridinae, s.str.

Schistocerca Stål

1873. *Schistocerca* Stål, Recens. Orth. *1*:64.

SCHISTOCERCA AMERICANA (Drury)

1773. *Gryllus americana* Drury, Illus. nat. Hist. *1*:128, pl. 49, fig. 2.

Acridium americanum; Moffat, 1895. Can. Ent. *27*:52.

Schistocerca americana; Walker, 1897, Can. Ent. *29*:89; 1899, *Ibid. 31*:29; 1902, *Ibid. 34*:256; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:314; *Urquhart,* 1939, Can. Field-Nat. *53*:24-25; *Vickery and Kevan,* 1964, Can. Ent. *96*:1555.

Schistocerca americana americana; Hebard, 1931, Proc. Acad. nat. Sci. Philad. *83*:169; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:29.

Localities:

Billings Bridge; Essex County; Jordan Station; London; Point Pelee; Ruthven; Toronto.

This species is rare in Canada. The few specimens captured in southern Ontario were almost certainly stray migrants. The single female specimen (in the Academy of Natural Sciences of Philadelphia) collected at the most northerly recorded locality, Billings Bridge, near Ottawa, 8 Aug., 1954, by W. Matthewman, may have been an accidental introduction, similar to the case of a specimen found in imported celery at Ste. Anne de Bellevue, Quebec, in 1955 (Vickery and Kevan, 1964). Mr. Matthewman's field notes (personal communication) indicate, however, that the locality he visited on the date in question was farmland.

SCHISTOCERCA EMARGINATA (Scudder)

1872. *Acridium emarginatum* Scudder, Fin. Rept. U.S. geol. Surv. Nebr.:250.

Schistocerca alutacea; Urquhart, 1942, Can. Ent. *74*:98.

Schistocerca lineata; Hubbell, 1960, Misc. Publ. Mus. Zool. Univ. Mich. *116*:77.

Schistocerca emarginata; Vickery and Kevan, 1964, Can. Ent. *96*:1555-1556.

Locality:

Grand Bend.

S. emarginata has been recorded only once from Ontario. It is a migrant species and does not breed in Canada.

Subfamily Catantopinae, s. str.

Melanoplus Stål

1873. *Melanoplus* Stål, Recens. Orth. *1*:79.

MELANOPLUS VIRIDIPES Scudder

1897. *Melanoplus viridipes* Scudder, Proc. U.S. nat. Mus. *20*:255.

Melanoplus viridipes; Walker and Urquhart, 1940, Can. Ent. *72*:18; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:29.

Localities:

Leamington; Maynooth.

Leamington is the only literature record for this species but the Royal Ontario Museum also has a specimen from Maynooth. The specimens from Leamington are stated by Walker and Urquhart (1940) to be intermediate between typical *viridipes* and *viridipes eurycercus* Hebard, 1930. The species was considered to be rare in dry, woodlot pastures.

MELANOPLUS ISLANDICUS Blatchley

1898. *Melanoplus islandicus* Blatchley, Psyche *8*:196.

Melanoplus abortivus Walker, 1898, Can. Ent. *30*:90-92.

Melanoplus islandicus; Walker, 1899, Can. Ent. *31*:36; 1901, *Ibid. 33*:22; 1902, Rept. ent. Soc. Ont. *32*:89; 1902, Can. Ent. *34*:257; 1906, Rept. ent. Soc. Ont. *36*:66; 1909, Can. Ent. *41*:208; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:389; *Hebard,* 1937, Trans. Amer. ent. Soc. *63*:164; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:258.

Melanoplus mancus islandicus; Hebard, 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:34.

Localities:

Algoma; Aurora; DeGrassi Point, Lake Simcoe [Type locality of *M. abortivus* Walker]; Fort William; Giant's Tomb; Gilford; Gloucester Pool, near Georgian Bay; Island Lake, Algonquin Park; Johnston Harbour, Bruce County; Klock, Nipissing District; Lake Nipigon; Little Eagle Harbour, Bruce County; Niagara Glen; North Bay; North River, Algonquin Park; Orient Bay; portage between Lakes Esnogami and Kabinakagami; Ragged Rapids, Severn River; Smoke Lake, Algonquin Park; Sparrow Lake; Stonecliffe; Timagami; Tobermory; Toronto; Turkey Point; Vineland; Whisky Falls, Algonquin Park; Whitemouth River.

Blatchley's name *islandicus* appeared in print only a very short time before *abortivus* of Walker. This was somewhat unfortunate since *islandicus* was described from only a few specimens, whereas *abortivus* was described more adequately and from a long series of specimens from a number of localities. The name *islandicus* is not appropriate, but nevertheless must be used.

MELANOPLUS HURONI Blatchley

1898. *Melanoplus huroni* Blatchley, Psyche *8*:195.

Melanoplus altitudinum; Fletcher, 1908, Rept. ent. Soc. Ont. *38*:131; *Walker,* 1909, Can. Ent. *41*:207.

Melanoplus dodgei huroni; Blatchley, 1920, Orth. N.E. Amer.:408; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:101; 1928, *Ibid. 80*:272.

Melanoplus huroni; Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:257.

Localities:

Favourable Lake, 53° N.; Fort William; Kirkland; Klock, Nipissing District; Macdiarmid; Nipigon; Smoke Lake, Algonquin Park; Sudbury.

This species is generally found in open clearings in coniferous forests, although Brooks (1958) reported it from parklands, far removed from evergreen trees, south of Saskatoon, Saskatchewan.

MELANOPLUS PUNCTULATUS PUNCTULATUS Scudder

1862. *Caloptenus punctulatus* Scudder, Bost. J. nat. Hist. *7*:465.

Melanoplus punctulatus; Walker, 1899, Can. Ent. *31*:34-35; 1901, *Ibid. 33*:22-23; 1902, *Ibid. 34*:258; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto. Reg.:301; *Blatchley,* 1920, Orth. N.E. Amer.:452; *Hebard,* 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:35; *Rehn,* 1946, Proc. Acad. nat. Sci. Philad. *98*:245-51.

Localities:

Brockville; Constance Bay; DeGrassi Point, Lake Simcoe; Highland Creek; High Park, Toronto; Marmora; Ottawa; Queen's Park, Toronto; Wilcox Lake; Woodstock.

M. p. puctulatus is an arboreal species frequently found on white pine, although some of the High Park, Toronto, specimens were taken on white oak (Walker, 1901). *M. p. arboreus*, Scudder, 1897, another recognized subspecies, occurs in the southeastern part of the United States.

MELANOPLUS BIVITTATUS (Say)

1825. *Gryllus bivittatus* Say, J. Acad. nat. Sci. Philad. *4*:308.

Caloptenus bivittatus; F. Walker, 1872, Can. Ent. *4*:30.

Melanoplus femoratus; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Scudder,* 1896, *Ibid. 26*:65; *Walker,* 1899, Can. Ent. *31*:34; 1902, *Ibid. 34*:258.

Melanoplus bivittatus; Fletcher, 1894, Rept. ent. Soc. Ont. *24*:12; 1896, *Ibid. 26*:31; *Scudder,* 1896, *Ibid. 26*:65; *Walker,* 1901, Can. Ent. *33*:22; 1902, *Ibid. 34*:258; *Jarvis,* 1906, *Ibid. 38*:349; *Walker,* 1909, *Ibid. 41*:208; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto. Reg.:301; *Gilbert,* 1936, Rept. ent. Soc. Ont. *66*:61; 1937, *Ibid. 67*:65; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:30; *MacNay,* 1951, Rept. ent. Soc. Ont. *81*:109; 1954, *Ibid. 84*:124; 1956, *Ibid. 86*:106; *Guppy,* 1958, Can. Ent. *90*:524-525; *Brooks,* 1958, Can. Ent. Supp. *9*:21-22; *James,* 1959, Rept. ent. Soc. Ont. *89*:53.

Melanoplus bivittatus femoratus; Walker, 1906, Rept. ent. Soc. Ont. *36*:67.

'Two-striped grasshopper'; *Fletcher,* 1897, Rept. ent. Soc. Ont. *27*:60.

Localities:

Algonquin Park; Arner; Barry's Bay; Bell's Corners; Blackburn; Bowesville; Brule Lake; Burke's Island, Lake Huron; Chatham; Chatterton; Clear Lake; Coe Hill, Hastings County; Colchester; Constance Bay; DeGrassi Point, Lake Simcoe; Essex; Fort Erie; Fort William; Goderich; Go Home Bay; Guelph; Hastings County; Johnston's Harbour, Bruce County; Killaloe; Kingsmere; Kingsville; Lake of the Woods; Lake Muskoka; Little Eagle Harbour, Bruce County; Marysville; Manitoulin Island; Niagara; Nipigon; North Bay; Northumberland County; Osgoode; Ottawa; Owen Sound; Palmer Rapids; Picton; Point Pelee; Renfrew County; Rockcliffe; Rondeau Park; Rosegrove; Ruthven; Sarnia; Smoky Falls, near Kapuskasing; Southampton; Sparrow Lake; Stokes Bay, Lake Huron; Timagami; Tobermory; Toronto; Tweed; Walpole Island, St. Clair River; Wellington; Westmeath; Windfall; Windsor.

Melanoplus bivittatus, the 'Two-striped grasshopper', is often recorded as an economically important grasshopper in Ontario. With *M. femurrubrum* it shares the distinction of being the most destructive species in the Province. Most of the references above describe damage to crops or control measures taken against this species.

MELANOPLUS DAWSONI (Scudder)

1875. *Pezotettix dawsoni* Scudder, Dawson's Rept. Geol. 49th Parallel:343.

Melanoplus dawsoni; Walker, 1899, Can. Ent. *31*:31; 1902, *Ibid. 34*:257; *Fletcher,* 1903, Rept. ent. Soc. Ont. *33*:98; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:393; *Hebard,* 1928, Proc. Acad. nat. Sci. Philad. *80*:103; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:65; *Brooks,* 1958, Can. Ent. Supp. *9*:24.

Localities:

Hastings County; Klock, Nipissing District; Macdonald's Falls, Severn River; Manitoulin Island; Northumberland County; Point au Baril; Rainy River; Renfrew County; Severn River; Toronto.

The eastern limit of the range of *M. dawsoni* is in Ontario. The species is normally brachypterous but may sometimes be macropterous. It is not known whether the macropterous form has been recorded in Ontario. No macropterous specimen has been seen by the authors. The species seems to prefer bush or scrub areas on sandy soils.

MELANOPLUS DIFFERENTIALIS DIFFERENTIALIS (Thomas)

1871. *Caloptenus differentialis* Thomas, Proc. Acad. nat. Sci. Philad. *1871*:149.

Melanoplus differentialis; Walker and Urquhart, 1940, Can. Ent. *72*:18; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:30.

Localities:

Colchester; Point Pelee.

This species, 'the Differential grasshopper', has been recorded in Canada only from extreme southern Ontario, although the authors have at hand a male specimen supposedly collected in Montreal in 1957. The specimens recorded in the literature, collected in 1938, are in the collection of the Royal Ontario Museum. Two additional females taken at Point Pelee in 1954 are in the Canadian National Collection, Ottawa. Another subspecies, *M. d. nigricans* Cockerell, 1917, is found only in the United States.

MELANOPLUS CONFUSUS Scudder

1897. *Melanoplus confusus* Scudder, Proc. U.S. nat. Mus. *20*:339.

Melanoplus minor; Walker, 1899, Can. Ent. *31*:33; 1902, Can. Ent. *34*:258; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto. Reg.:300.

Melanoplus confusus; Blatchley, 1920, Orth. N.E. Amer.:435; *Hebard,* 1928, Proc. Acad. nat. Sci. Philad. *80*:106; *Smith,* 1965, Can. J. Zool. *43*:180.

Localities:

Brockville; Chatterton; Lampton; near Port Dover; Toronto; Turkey Point.

Ontario marks the eastern limit of distribution of this species. It is not common in the Province.

MELANOPLUS FEMURRUBRUM FEMURRUBRUM (DeGeer)

1773. *Acrydium femur rubrum* DeGeer, Mém. Hist. nat. Ins. *3*:498, pl. 42, fig. 5.

Melanoplus femur-rubrum; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Fletcher,* 1889, *Ibid. 19*:10; *Bethune,* 1893, *Ibid. 23*:11; *Fletcher,* 1894, *Ibid. 24*:12; 1896, *Ibid. 26*:31; 1897, *Ibid. 27*:60; *Walker,* 1899, Can. Ent. *31*:32; *Hutt,* 1899, Rept. ent. Soc. Ont. *29*:98; *Walker,* 1902, Can. Ent. *34*:257; 1906, Rept. ent. Soc. Ont. *36*:67-68; *Jarvis,* 1907, *Ibid. 37*:111; *Walker,* 1909, Can. Ent. *41*:207; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Caesar,* 1915, Rept. ent. Soc. Ont. *45*:46; *Cosens,* 1916, *Ibid. 46*:16; *Gilbert,* 1937, *Ibid. 67*:65; *Walker and Urquhart,* 1940, Can. Ent. *72*:16; *Twinn,* 1946, Rept. ent. Soc. Ont. *76*:50; *MacNay,* 1948, *Ibid. 78*:73; 1949, *Ibid. 79*:68; 1950, *Ibid. 80*:60; 1951, *Ibid. 81*:109; *Fox,* 1953, *Ibid. 83*:53; *MacNay,* 1954, *Ibid. 84*:124; 1956, *Ibid. 86*:106; 1957, *Ibid. 87*:87; *Guppy,* 1958, Can. Ent. *90*:524-525; *Rehn,* 1963, Proc. Acad. nat. Sci. Philad. *115*:29.

Caloptenus femur-rubrum; Kilman, 1899, Rept. ent. Soc. Ont. *29*:90.

Melanoplus femur rubrum [*sic*]; *Jarvis,* 1906, Can. Ent. *38*:349.

Melanoplus femur-rubrum femur-rubrum; Hebard, 1928, Proc. Acad. nat. Sci. Philad. *80*:275; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:29.

Melanotus [*sic, Melanoplus*] *femur-rubrum; Ross and Caesar,* 1932, Rept. ent. Soc. Ont. *62*:11.

Melanoplus februm-rubrum [*sic*]; *MacNay,* 1953, Rept. ent. Soc. Ont. *83*:72.

Melanoplus femurrubrum femurrubrum; Smith, 1965, Can. J. Zool. *43*:180.

Melanoplus femurrubrum; Mook and Davies, 1966, Can. Ent. *98*:913.

'Red-legged grasshopper'; *Dearness,* 1897, Rept. ent. Soc. Ont. *27*:23.

Localities:

Arner; Bear Island; Burke's Island, Lake Huron; Calpa; Chatham; Chatterton; Clarksburg; DeGrassi Point, Lake Simcoe; Essex County; Fort William; Goderich; Guelph; Hamilton; Hastings County; Johnston Harbour, Bruce County; Lake Muskoka; Lanark County; Little Eagle Harbour, Bruce County; Manitoulin Island; Niagara; Norfolk County; North Bay; North River, Algonquin Park; Northumberland County; Ottawa; Owen Sound; Peterborough County; Point Pelee; Port Hope; Prince Edward County; Renfrew County; Rondeau; Sarnia; Southampton; Stoke's Bay, Lake Huron; Tobermory; Toronto; Walkerton; Walpole Island, St. Clair River.

This species, the 'Red-legged grasshopper', causes more plant injury in Ontario than any other grasshopper. *M. f. femurrubrum* and *M. bivittatus* together rank first as economic species of Orthoptera in the Province. *M. f. propinquus* Scudder, 1897, the only other subspecies, occurs in the southeastern part of the United States, while *M. f. femurrubrum* is found over most of the remainder of the continent.

MELANOPLUS BOREALIS BOREALIS (Fieber)

1853. *Caloptenus borealis* Fieber, Lotos, *3*:120.

Pezotettix borealis; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71.

Melanoplus borealis; Scudder, 1896, Rept. ent. Soc. Ont. *26*:64.

Melanoplus extremus; Walker, 1899, Can. Ent. *31*:33; 1901, *Ibid. 33*:21; 1902, *Ibid. 34*:257; *Fletcher,* 1908, Rept. ent. Soc. Ont. *38*:131, *Walker,* 1909, Can. Ent. *41*:207.

Melanoplus borealis borealis; Brooks, 1958, Can. Ent. Supp. *9*:22-23.

Localities:

Algoma; Bala; Beaver Lake; Big Piskwanish, 52° N.; Camp Billie Bear, Muskoka; Fort Albany; Fort Severn; Fort William; Go Home Bay; Heyden, Hudson Bay; Inland Lake; James Bay; Lake of the Woods; Mer Bleue; Minden; Moose Factory; Nipigon; Portage, Lake Kabingkagami and Matawishqua River Rosegrove; Rupert House; Sesekinika; Stony Lake, Peterborough County.

The distribution of this northern grasshopper presumably extends farther south into Ontario than the records indicate. *M. b. borealis* occurs earlier in the season than most species of *Melanoplus*. It largely disappears by the time the common *M. f. femurrubrum* and *M. s. sanguinipes* begin to appear in the adult stage. Although normally brachypterous, occasional individuals are reported with fully developed wings. Three additional subspecies are recognized, *M. b. stupefactus* (Scudder, 1876), *M. b. palaceus* Fulton, 1930, and *M. b. utahensis* Scudder, 1897, all of which occur south of the Canadian border.

MELANOPLUS FASCIATUS (F. Walker)

1870. *Caloptenus fasciatus* F. Walker, Cat. Derm. Salt. Brit. Mus. *4*:680.

Caloptenus fasciatus; F. Walker, 1872, Can. Ent. *4*:31.

Melanoplus fasciatus; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Scudder,* 1896, *Ibid. 26*:64; *Walker,* 1899, Can. Ent. *31*:31-32; 1902, Rept. ent. Soc. Ont. *32*:

89; 1902, Can. Ent. *34*:257; 1906, Rept. ent. Soc. Ont. *36*:67; 1909, Can. Ent. *41*:207; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:110; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:29; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:5.

Localities:

Albany River; Attawapiskat, 52° N.; Bala; Bell's Corners; Brockville; Buckshot Lake, Addington County; Constance Bay; Canoe Lake, Algonquin Park; DeGrassi Point, Lake Simcoe; Diamond Lake; Favourable Lake, 53° N.; Fort William; Go Home Bay; Johnston Harbour, Bruce County; Kirkland Lake; Klock, Nipissing District; Lake of the Woods; Little Eagle Harbour, Bruce County; Macdiarmid; Nipigon; North River, Algonquin Park; Onakawana, 50° 35' N.; Point Pelee; Prince Edward County; Rondeau Park; Severn River; Smoke Lake; St. Martin's Falls, Lower Albany River; Stony Lake, Peterborough County; Sudbury; Timagami District; Tobermory; Toronto.

M. fasciatus is found from coast to coast, across northern Canada, and throughout Ontario. It is found among heath plants, usually associated with *Vaccinium* species. It has not been recorded as a pest.

MELANOPLUS SANGUINIPES SANGUINIPES (Fabricius)

1798. *Gryllus sanguinipes* Fabricius, Suppl. ent. Syst.:195.

Melanoplus atlanis; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:71; *Fletcher,* 1889, *Ibid. 19*:109; 1894, *Ibid. 24*:12; 1896, *Ibid. 26*:31; *Scudder,* 1896, *Ibid. 26*:64; *Fletcher,* 1897, *Ibid. 27*:66; *Scudder,* 1897, Proc. U.S. nat. Mus. *20*:180-181; *Walker,* 1899, Can. Ent. *31*:30; 1902, *Ibid. 34*:257; 1903, Rept. ent. Soc. Ont. *33*:41; 1906, *Ibid. 36*:66; 1909, Can. Ent. *41*:205; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Gibson,* 1914, Rept. ent. Soc. Ont. *44*:16; 1915, *Ibid. 45*:14; *Caesar,* 1915, *Ibid. 45*:46; *Gibson,* 1916, *Ibid. 46*:11; 1916, *Ibid. 46*:156-158; *Blatchley,* 1920, Orth. N.E. Amer.:415.

Melanoplus angustipennis [*nec* Dodge]; *Gilbert,* 1936, Rept. ent. Soc. Ont. *66*:61.

Melanoplus mexicanus mexicanus [*nec* Saussure]; *Gilbert,* 1936, Rept. ent. Soc. Ont. *66*:62; 1937, *Ibid. 67*:65; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:29; *Pfadt,* 1949, Univ. Wyo. agr. exp. Sta. Bull. *290*:5, 7; *MacNay,* 1949, Rept. ent. Soc. Ont. *79*:68; *Fox,* 1953, *Ibid. 83*:53; *MacNay,* 1956, *Ibid. 86*:106.

Melanoplus mexicanus [*nec* Saussure]; *Walker and Urquhart,* 1940, Can. Ent. *72*:16; *MacNay,* 1948, Rept. ent. Soc. Ont. *78*:73; *James,* 1959, *Ibid. 89*:53.

Melanoplus mexicanus atlanis; MacNay, 1951, Rept. ent. Soc. Ont. *81*:109.

Melanoplus bilituratus atlanis; Brooks, 1958, Can. Ent. Supp. *9*:20-21.

Localities:

Bear Island; Bowesville; Castleton; Chatterton; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Essex County; Fort William; Goderich; Hastings County; Heyden; Johnston Harbour, Bruce County; Kenora; Rat Portage (Kenora); Lake Muskoka; Lanark County; LaSalle; Leamington; Little Eagle Harbour, Bruce County; Manitoulin Island; Nipigon; North Bay; North River, Algonquin Park; Northumberland County; Ottawa; Owen Sound; Peterborough County; Picton; Point Pelee; Renfrew County; Rondeau; Sarnia; Searchmont; Severn River; Southampton; Staples; Sudbury; Tobermory; Toronto; Westmeath.

This species, the 'Lesser migratory grasshopper', is the main grasshopper pest of western Canada, but in Ontario it ranks fourth after *Melanoplus f. femurrubrum, M. bivittatus* and *Camnula pellucida.* It has such a potential for increase that it may become a pest of major proportions in any season. Many of the references cited above describe economic injury caused by this pest to crops in Ontario.

Gurney (1962) discovered that the type of *Gryllus sanguinipes* Fabricius, 1798, was conspecific with the 'Lesser migratory grasshopper' of North America, so that *sanguinipes,* which has priority, should be used instead of *bilituratus* which has frequently been employed in recent years. A submission has been made by Kevan and Vickery (1965) to the International Commission of Zoological Nomenclature in order to stabilize the name of this important economic species.

Other subspecies, *M. s. vulturnus* Gurney and Brooks, 1959, and *M. s. defectus* Scudder, 1897, occur only in the eastern and southwestern United States respectively.

MELANOPLUS BRUNERI Scudder

1897. *Melanoplus bruneri* Scudder, Proc. U.S. nat. Mus. *20*:164.

Melanoplus bruneri; Walker, 1902, Can. Ent. *34*:256; *Fletcher,* 1903, Rept. ent. Soc. Ont. *33*:98; *Walker,* 1906, *Ibid. 36*:66; 1909, Can. Ent. *41*:205; *Blatchley,* 1920, Orth. N.E. Amer.:413; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:114; 1928, *Ibid. 80*:285; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:258; *Brooks,* 1958, Can. Ent. Supp. *9*:23-24.

Localities:

Dwight, Muskoka District; Fort William; Kirkland Lake; Nipigon; Onakawana, 50° 35' N.

Records for the first two above localities and Nipigon were published by Walker (1902, 1906, 1909); other authors merely repeated them. This is a northern species, usually collected in forested areas. It is rare in Ontario. The specimens from Kirkland Lake and Onakawana, not previously recorded in the literature, are in the Royal Ontario Museum.

MELANOPLUS KEELERI LURIDUS (Dodge)

1876. *Caloptenus luridus* Dodge, Can. Ent. *8*:11.

Melanoplus collinus; Walker, 1899, Can. Ent. *31*:33-34; 1902, *Ibid. 34*:258.

Melanoplus luridus; Walker, 1906, Rept. ent. Soc. Ont. *36*:67; 1909, Can. Ent. *41*:208; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300.

Melanoplus keeleri luridus; Blatchley, 1920, Orth. N.E. Amer.:438; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:115; 1928, *Ibid. 80*:286; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:29.

Localities:

Arner; Aurora; Big Joe Lake; Brockville; Constance Bay; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; 5 miles south of Grand Bend; near Gravenhurst; Hawk Lake, north of Lake Superior; Kenora; Marmora; Lake Muskoka; Nipigon; North Bay; North River, Algonquin Park; Point Pelee; Ragged Rapids, Severn River; Rondeau Park; Sarnia; Severn River; Summerstown; Ten Mile Point, Manitoulin Island; Toronto; Turkey Point; Wasaga Beach.

The typical subspecies *M. k. keeleri* (Thomas, 1874) occurs in the southeastern United States. *M. k. luridus* is known in Canada from Nova Scotia to Alberta, usually on sandy soils. It is uncommon, but not rare, and has not been regarded as being of economic importance.

MELANOPLUS STONEI Rehn

1904. *Melanoplus stonei* Rehn, Ent. News *15*:85.

Melanoplus packardii [*nec* Scudder]; *Gibson,* 1915, Rept. ent. Soc. Ont. *45*:148.

Melanoplus stonei; Blatchley, 1920, Orth. N.E. Amer.:432; *Hebard,* 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:38; 1936, N. Dak. agr. Coll. exp. Sta. tech. Bull. *284*:49; *Walker and Urquhart,* 1940, Can. Ent. *72*:18; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:9.

Localities:

DeGrassi Point, Lake Simcoe; Fort William; Kirkland Lake; Orient Bay, Lake Nipgon; Sandy Island, Lake Nipissing; Wasaga Beach, Georgian Bay.

M. stonei has an odd, disjunct distribution in northern Canada, occurring in northern Manitoba, northern Ontario and in the Lake St. John region of Quebec. In Manitoba it occurs with *M. packardi* Scudder, a species which it resembles in appearance and activity. This probably explains the very logical error made by Walker (Gibson, 1915) in determining the specimen from Fort William as *M. packardi*.

MELANOPLUS ANGUSTIPENNIS ANGUSTIPENNIS (Dodge)

1877. *Caloptenus angustipennis* Dodge, Can. Ent. *9*:111.

Melanoplus coccineipes; Scudder, 1896, Rept. ent. Soc. Ont. *26*:64 [*nomen nudum*]; 1897, Proc. U.S. nat. Mus. *20*:304 [original description of *M. coccineipes*]; 1900, Proc. Davenport Acad. nat. Sci. *8*:56; *Walker,* 1902, Can. Ent. *34*:257.

Melanoplus angustipennis; Walker, 1909, Can. Ent. *41*:207; *Blatchley,* 1920, Orth. N.E. Amer.:427; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:36, 118; 1928, *Ibid. 80*:288.

Melanoplus angustipennis coccineipes; Gibson, 1911, Rept. ent. Soc. Ont. *41*:119.

[*non*] *Melanoplus angustipennis* [*nec* Dodge = *M. sanguinipes*]; *Gilbert,* 1936, Rept. ent. Soc. Ont. *66*:61.

Melanoplus angustipennis angustipennis; Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:263; *Brooks,* 1958, Can. Ent. Supp. *9*:20.

Localities:

Fort William; Nipigon; Sudbury; Toronto.

This subspecies is northern in distribution. The other subspecies, *M. a. impiger* Scudder, 1897, occurs in the southeastern United States. *M. a. angustipennis* is usually found in sandy areas. It is not common in Ontario, which is the eastern limit of distribution of the subspecies.

Dendrotettix Packard

1890. *Dendrotettix* Packard, Rept. U.S. ent. Comm. *5*:214.

DENDROTETTIX QUERCUS Packard

1890. *Dendrotettix quercus* Packard, Rept. U.S. ent. Comm. *5*:214.

Dendrotettix quercus; Urquhart, 1942, Can. Ent. *74*:97-98; *Friauf,* 1957, Florida Ent. *40*:133.

Locality:

Turkey Point.

D. quercus was found in Red oak forest by Urquhart, August 25, 1940 (1 ♂, 2 ♀♀). One specimen is in the collection of the Academy of Natural Sciences of Philadelphia, the other two are deposited in the Royal Ontario Museum. No additional specimen has been found in Canada. Urquhart (1942) reported that his material was atypical in colour and gave a description. Friauf (1957) repeated Urquhart's record.

Boonacris Rehn and Randell

1962. *Boonacris* Rehn and Randell, Trans. Amer. ent. Soc. *88*:110.

[Named after Daniel Boone, and thus misspelled as originally proposed. Emendation does not seem to be called for under the Code].

BOONACRIS GLACIALIS CANADENSIS (E. M. Walker)

1903. *P[odisma] glacialis Canadensis* E. M. Walker, Can. Ent. *35*:300.

Podisma glacialis; Scudder, 1896, Rept. ent. Soc. Ont. *26*:63; 1897, Proc. U.S. nat. Mus. *20*:100; *Walker,* 1899, Can. Ent. *31*:36; *Scudder,* 1900, Proc. Davenport Acad. nat. Sci. *8*:52; *Walker,* 1902, Can. Ent. *34*:256.

P[odisma] glacialis Canadensis Walker, 1903, Can. Ent. *35*:300.

Podisma glacialis canadensis; Walker, 1906, Rept. ent. Soc. Ont. *36*:66; 1909, Can. Ent. *41*:205; *Blatchley,* 1920, Orth. N.E. Amer.:343; *Hebard,* 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:40.

Boonacris glacialis canadensis; Rehn and Randell, 1962, Trans. Amer. ent. Soc. *88*:112, 152; 1963, Proc. Acad. nat. Sci. Philad. *115*:24.

Localities:

Cache Lake, Algonquin Park; swamp near Churchill; Fort William; Gunter; Kirkland Lake; Klock, Nipissing District; Macdiarmid; Maynooth; Muskoka; North Bay; North River, Algonquin Park [Type locality]; Portage, Lake Kabingkagami-Matawishqua River; Port Sydney; Smoky Falls, near Kapuskasing; Smoke Lake, Algonquin Park; South Bay, Lake Nipigon; Sudbury; Timagami; Tobermory; Whisky Falls, Algonquin Park; Windy Lake Siding, C.P.R., near Sudbury.

The typical subspecies occurs in Quebec, but not in Ontario. Elsewhere in Canada, it has been reported only from Prince Edward Island (Walker, 1915), although it may well occur in New Brunswick. *B. g. canadensis* Walker is found in scattered locations throughout northern Ontario.

BOONACRIS VARIEGATA (Scudder)

1897. *Podisma variegata* Scudder, Proc. U. S. nat. Mus. *20*:97, 101.

Podisma variegata; Scudder, 1897, Proc. U.S. nat Mus. *20*:102; *Walker,* 1899, Can. Ent. *31*:29-30; *Scudder,* 1900, Proc. Davenport Acad. nat. Sci. *8*:52; *Walker,* 1902, Can. Ent. *34*:256; 1902, Rept. ent. Soc. Ont. *32*:89; *Blatchley,* 1920, Orth. N.E. Amer.:344.

Podisma glacialis variegata; Walker, 1903, Can. Ent. *35*:300; *Gibson,* 1915, Rept. ent. Soc. Ont. *45*:148.

Zubovskya glacialis variegata; Walker in Urquhart (ed.), 1957, Changes Fauna Ont.:5.

Boonacris variegata; Rehn and Randell, 1962, Trans. Amer. ent. Soc. *88*:162.

Localities:

Swamp near Churchill; DeGrassi Point, Lake Simcoe; Guelph Junction; Guilford; Macdiarmid; Muskoka; North River, Algonquin Park; Sabine Twp., Hastings County; Tobermory.

In Canada, *B. variegata* is found in many of the same localities as is *B. glacialis canadensis,* so that it cannot be regarded as a subspecies of *glacialis* as it was by Walker (1903). It is a valid species, as indicated by Rehn and Randell (1962).

Paroxya Scudder

1877. *Paroxya* Scudder, Proc. Bost. Soc. nat. Hist. *19*:28.

PAROXYA HOOSIERI (Blatchley)

1892. *Pezotettix hoosieri* Blatchley, Can. Ent. *24*:31.

Paroxya floridana [*nec* Thomas, 1874]; *Walker,* 1902, Can. Ent. *34*:258; 1902, Rept. ent. Soc. Ont. *32*:109.

Paroxya hoosieri; Walker and Urquhart, 1940, Can. Ent. *72*:18; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *50*:30; 1941, Contrib. R. Ont. Mus. Zool. *20*:30; *Judd,* 1956, Rept. ent. Soc. Ont. *86*:27.

Localities:

Arner; Kingsville; Point Pelee.

These localities mark the northern limit for the species. It is not known elsewhere in Canada.

Subfamily Oedipodinae

Arphia Stål

1873. *Arphia* Stål, Recens. Orth. *1*:113.

ARPHIA SULPHUREA (Fabricius)

1781. *Gryllus sulphurea* Fabricius, Spec. Ins. *1*:369.

Arphia sulphurea; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1899, Can. Ent. *30*:258; 1902, *Ibid. 34*:255; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:253-254; *Hebard,* 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:27; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:25.

Arphia xanthoptera; Walker in Gibson, 1910, Rept. ent. Soc. Ont. *40*:126.

Localities:

Bothwell; Grand Bend; London; Nipigon; Ottawa; Port Dover; Port Rowan; Rondeau; Sarnia; Sudbury; Toronto; Turkey Point.

A. sulphurea is a spring species, most abundant in June and July as it winters in the nymphal stage. It occurs in dry areas in pastures, fields, and scrub bush-land. It is an eastern species, not found west of Ontario. The Toronto record of Walker *in* Gibson (1910) may be incorrect although the identification is probably reliable. It is based on a specimen found in a collection and labelled "coll. Toronto, 1880"; the specimen has not been examined by the present authors.

ARPHIA CONSPERSA Scudder

1875. *Arphia conspersa* Scudder, Proc. Bost. Soc. nat. Hist. *17*:514.

Arphia conspersa; Walker and Urquhart, 1940, Can. Ent. *72*:17.

Localities:

Favourable Lake; Fergus Falls; Rat Portage (Kenora).

From Ontario, there is but a single published record of this species, Favourable Lake (53° North latitude), although it occurs in forest clearings and grasslands throughout the southern Prairie provinces. The Academy of Natural Sciences of Philadelphia has specimens from the other two localities noted.

ARPHIA PSUEDONIETANA PSEUDONIETANA (Thomas)

1870. *Tomonotus pseudonietanus* Thomas, Proc. Acad. nat. Sci. Philad. *1870*:82.

Arphia tenebrosa; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1902, Can. Ent. *34*:255.

Arphia pseudonietana; Walker, 1909, Can. Ent. *41*:177; *Blatchley*, 1920, Orth. N.E. Amer.:251; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:69; 1928, *Ibid. 80*:234; *Walker and Urquhart,* 1940, Can. Ent. *72*:17.

Arphia pseudonietana pseudonietana Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:225.

Localities:

Grand Bend; Kincardine; Leg Lake; Nipigon; Ottawa; Point Edward; Sudbury.

Another subspecies, *A. p. crassa* Bruner, 1905, is recognized, but is not Canadian, occurring in Arizona and Mexico. *A. p. pseudonietana* is usually found in dry grassland.

Chortophaga Saussure

1884. *Chortophaga* Saussure, Mém. Soc. phys. Hist. nat. Genève *28*:43.

CHORTOPHAGA VIRIDIFASCIATA (DeGeer)

1773. *Acrydium viridifasciatum* DeGeer, Mém. Hist. nat. Ins. *3*:498.

Tragocephala infuscata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70.

Tragocephala infuscata viridifasciata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70.

Chortophaga viridifasciata; Walker, 1898, Can. Ent. *30*:258; 1902, *Ibid. 34*:255; 1906, Rept. ent. Soc. Ont. *36*:76; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:256; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:72; 1928, *Ibid. 80*:235; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:35; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:25; 1953, Rept. ent. Soc. Ont. *83*:53.

Localities:

Almonte; Amherstburg; Arner; Bell's Corners; Blackburn; Burke's Falls; Chatterton; Clear Lake; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Essex; Fenelon Falls; Giant's Tomb; Goderich; Grimsby; Hamilton; Hastings County; Honey Harbour; Kettleboil; Komoka; Limerick Forest, near Oxford Station; Manitoulin Island; Marmora; Mer Bleue; Miner's Bay; North of Lake Superior; New Liskeard; Northumberland County; Ottawa; Point Pelee; Port Rowan; Renfrew County; Rondeau; Severn; Spencerville; St. Williams; Toronto; Turkey Point; Walpole Island, St. Clair River; Wasaga; Wellington; Wheatley.

C. viridifasciata is a common species which spends the winter as a nymph. It is one of the first orthopterans to appear in the spring. It occurs in two colour phases, green and brown, females being predominantly green and males predominantly brown. Green males are rather rare. In Canada, the species is known from British Columbia to Nova Scotia, but not in Prince Edward Island or Newfoundland.

Encoptolophus Scudder

1875. *Encoptolophus* Scudder, Proc. Bost. Soc. nat. Hist. *17*:478.

ENCOPTOLOPHUS SORDIDUS SORDIDUS (Burmeister)

1838. *Oedipoda sordida* Burmeister, Handb. Ent. *2*:643.

Encoptolophus sordidus; Walker, 1898, Can. Ent. *30*:259; 1899, *Ibid. 31*:36; 1901, *Ibid. 33*:20; 1902, *Ibid. 34*:255; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.: 260; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:75; *MacNay,* 1949, Rept. ent. Soc. Ont. *79*:68; 1950, *Ibid. 80*:60; 1956, *Ibid. 86*:106; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:7; *James,* 1959, Rept. ent. Soc. Ont. *89*:50.

Encoptolophus sordidus sordidus; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:25; *Smith,* 1965, Can. J. Zool. *43*:180.

Localities:

Arner; Bell's Corner's; Brockville; Chatterton; Cottam; Constance Bay; DeGrassi Point, Lake Simcoe; Essex; Goderich; Hamilton; Marmora; Marysville; Mer Bleue; Minden; Niagara Falls; Osgoode; Ottawa; Point Pelee; Picton; Queenston Heights; Rondeau Park; Sarnia; Scarboro; Southampton; South Woodslee; Spencerville; Summerstown; Toronto; Turkey Point; Vineland; Wheatley; Whitby; Windsor.

E. s. sordidus occurs from Ontario and Quebec southward. Another subspecies, *E. s. costalis* (Scudder, 1862) occurs in the Prairie provinces and adjacent

areas in the United States of America. *E. s. sordidus* is common on dry, grassy locations during the fall. Adults appear later in the season than any other of our common grasshoppers.

Camnula Stål

1873. *Camnula* Stål, Recens. Orth. *1*:114.

CAMNULA PELLUCIDA (Scudder)

1862. *Oedipoda pellucida* Scudder, Bost. J. nat. Hist. 7:472.

Camnula pellucida; Walker, 1898, Can. Ent. *30*:259; 1902, *Ibid. 34*:255; 1906, Rept. ent. Soc. Ont. *36*:66; 1909, Can. Ent. *41*:177; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Gibson,* 1914, Rept. ent. Soc. Ont. *44*:16; *Caesar,* 1915, *Ibid. 45*:16; *Gibson,* 1916, *Ibid. 46*:11; 1916, *Ibid. 46*:156-158; *Blatchley*, 1920, Orth. N.E. Amer.:262; *Caesar,* 1923, Rept. ent. Soc. Ont. *53*:37-38; *Ross,* 1924, *Ibid. 54*:62; *Gilbert,* 1936, *Ibid. 66*:61; 1937, *Ibid. 67*:65; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:48, 68; 1941, Contrib. R. Ont. Mus. Zool. *20*:26; *MacNay,* 1948, Rept. ent. Soc. Ont. *78*:73; 1949, *Ibid. 79*:68; 1950, *Ibid. 80*:59; 1951, *Ibid. 81*:109; *Fox,* 1953, *Ibid. 83*:52; *MacNay,* 1956, *Ibid. 86*:106; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100; *Smith,* 1965, Can. J. Zool. *43*:180.

Localities:

Barry's Bay; Bell's Corners; Bowesville, near Ottawa; Byron; Chatterton; Clear Lake; DeGrassi Point, Lake Simcoe; Essex County; Fort William; Golden Lake; Goderich; Hastings County; Jarvis Lake; Johnston Harbour, Bruce County; Killaloe; Kirkwood Twp.; Lake Muskoka; Lanark County; Little Eagle Harbour, Bruce County; Manitoulin Island; Marmora; Nipigon; North Bay; North River, Algonquin Park; Norway Point, Lake of Bays; Owen Sound; Palmer Rapids; Peterborough County; Point Pelee; Prince Edward County; Renfrew County; Rondeau; Sarnia; Severn River; Southampton; Stokes Bay; Sudbury; Timagami; Tobermory; Toronto; Walpole Island, St. Clair River.

Camnula pellucida, the 'Clear-winged' or 'Roadside' grasshopper, is known in every province of Canada. It is a common grass feeder, usually in somewhat drier situations, and is economically one of the most important species of Orthoptera in Canada. In Ontario it ranks third after *Melanoplus f. femurrubrum* and *M. bivittatus*. Many of the references above describe outbreaks of this pest.

Pardalophora Saussure

1884. *Pardalophora* Saussure, Mém. Soc. Phys. Hist. nat. Genève *28*:576.

PARDALOPHORA APICULATA (Harris)

1835. *Locusta apiculata* Harris, *in* Hitchcock, Rept. geol. Mass. *2*:576.

Aedipoda [*sic, Oedipoda*] *corallina; Harrington,* 1884, Rept. ent. Soc. Ont. *14*:17.

Hippiscus phoenicoptera [*nec* Burmeister, 1838]; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70.

Hippiscus tuberculatus [Beauvois, 1805, *nec* Fabricius, 1775]; *Walker*, 1898, Can. Ent. *30*:260; 1902, *Ibid. 34*:255; 1909, *Ibid. 41*:178; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.: 300.

Hippiscus apiculatus; Blatchley, 1920, Orth. N.E. Amer.:265.

Pardalophora apiculata; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:76; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:26; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:231.

Localities:

Charlton; Diamond Lake, Timagami District; Fraserdale; Hudson Bay; Humber; Lake Abitibi (Low Bush); Lake of Two Rivers, Algonquin Park; Lake

Sasajewan, Algonquin Park; London; Macdiarmid; Marmora; New Post; Nipigon; North Bay; Ottawa; Rondeau; Sault Ste. Marie; Toronto.

Pardalophora apiculata is rather localized in its distribution in Ontario. Brooks (1958) reported a subspecies, as yet undescribed, from forested areas in the Prairie provinces. This has not yet been investigated further, but, if it proves to be a valid subspecies, the entity found in Ontario would then be known as *P. apiculata apiculata.*

Dissosteira Scudder

1876. *Dissosteira* Scudder, Ann. Rept. U.S. Chief Engineers 1876, app. *JJ*:511.

DISSOSTEIRA CAROLINA (Linnaeus)

1758. *Gryllus (Locusta) carolina* Linnaeus, Syst. Nat. Ed. 10 *1*:433.

Dissosteira carolina; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1898, Can. Ent. *30*:260; 1902, *Ibid, 34*:255; *Fletcher,* 1902, Rept. ent. Soc. Ont. *32*:54-55; *Walker,* 1906, *Ibid. 36*:76; 1909, Can. Ent. *41*:178; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Fyles,* 1914, Rept. ent. Soc. Ont. *44*:47; *Blatchley,* 1920, Orth. N.E. Amer.:273; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:81; 1928, *Ibid. 80*:247; *Gilbert,* 1936, Rept. ent. Soc. Ont. *66*:61; 1937, *Ibid. 67*:65; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:26; *Twinn,* 1946, Rept. ent. Soc. Ont. *76*:50; *MacNay,* 1950, *Ibid. 80*:60; *Fox,* 1953, *Ibid. 83*:53; *Smith,* 1965, Can. J. Zool. *43*:180.

Localities:

Arden; Arner; Barry's Bay; Bell's Corners; Bear Island; Bobcaygeon; Cache Lake, Algonquin Park; Castleton; Cayuga; Cedarvale; Chatham; Chatterton; DeGrassi Point, Lake Simcoe; Eglington; Essex; Glen Major; Goderich; Gravenhurst; Gull Lake; Hamilton; Hastings County; Kenora; Kent County; Killaloe; Lake Muskoka; Marmora; Meaford; Mindemoya, Manitoulin Island; Muskoka; New Glasgow; North Bay; North River, Algonquin Park; Northumberland County; Osgoode; Ottawa; Owen Sound; Palmer Rapids; Picton; Point Pelee; Port Credit; Rat Portage (Kenora); Renfrew County; Rondeau; Sarnia; Severn River; Smoke Lake, Algonquin Park; Southampton; Spencerville; Tillsonburg; Tobermory; Toronto; Trenton; Walpole Island, St. Clair River; Wardsville; Wellington.

This large species, the 'Carolina grasshopper', with distinctive black hind wing with a yellow border, is probably the most well recognized grasshopper in Canada, and indeed throughout North America. It is most commonly found near inhabited areas, or, at least, seldom far away from the activities of man, such as roads, railways, cuttings, quarries, etc., where vegetation is sparse and the substrate exposed and sandy or gravelly.

Spharagemon Scudder

1875. *Spharagemon* Scudder, Proc. Bost. Soc. nat. Hist. *17*:469.

SPHARAGEMON BOLLI BOLLI Scudder

1875. *Spharagemon bolli* Scudder, Proc. Bost. Soc. nat. Hist. *17*:469.

Spharagemon bolli; Walker, 1898, Can. Ent. *30*:261; 1902, *Ibid. 34*:256; 1906, Rept. ent. Soc. Ont. *36*:65-66; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:277; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:82; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:65; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:26; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:8.

Localities:

Arner; Bala; Bell's Corners; Brockville; Chatterton; Coe Hill; Constance Bay; DeGrassi Point, Lake Simcoe; Dwight, Muskoka District; Hastings County; Manitoulin Island; Marmora; Northumberland County; Ottawa; Point Pelee; Port McNicholl; Prince Edward County; Rainy River; Renfrew County; Rondeau Park; Sarnia; Smoke Lake, Algonquin Park; Southampton; Sparrow Lake; Stony Lake, Peterborough County; Spencerville; St. Anne's Island, Lambton County; Toronto; Wasaga Beach, Georgian Bay; Wheatley.

Another subspecies, *S. b. inoratum* Morse, 1895, is recognized from New Mexico. *S. b. bolli* is relatively common in sandy areas in all except extreme eastern and far northern Ontario.

SPHARAGEMON COLLARE COLLARE (Scudder)

1872. *Oedipoda collare* Scudder, U.S. geol. Surv. Nebr. Final Rept. *3*:250.

Spharagemon collare; Walker and Urquhart, 1940, Can. Ent. *72*:17; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:236.

Spharagemon collare collare; Urquhart, 1941, Contrib. R. Ont. Mus. Zool. *20*:28.

Locality:

Southampton, Bruce County.

This insect has been found in Ontario only at Southampton. Most authors do not recognize subspecies in *S. collare,* but Walker and Urquhart (1940) pointed out differences in the size and in the distribution in Ontario between the specimens from Southampton and others which had previously been recorded as *S. c. wyomingianum* (Thomas) — see below. Pending further investigation, subspecific names are retained here for these populations.

SPHARAGEMON COLLARE WYOMINGIANUM (Thomas)

1872. *Oedipoda wyomingiana* Thomas, Ann. Rept. U.S. geol. Surv. Terr. *5*:462.

Spharagemon collare wyomingianum; Walker, 1901, Can. Ent. *33*:20; 1902, Can. Ent. *34*:256; *Walker and Urquhart,* 1940, Can. Ent. *72*:17; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:26; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:8; *Smith,* 1965, Can. J. Zool. *43*:180.

Localities:

Chatterton; DeGrassi Point, Lake Simcoe; Grand Bend; Point Edward; Lake Huron; Osgoode; Marmora; Point Pelee; Rondeau Park; Turkey Point.

This subspecies is stated to be smaller, with smaller and narrower tegmina, than specimens of *S. c. collare* from northern Lake Huron and from the Prairie provinces. In Ontario it is found only at the western end of the southern peninsula. The relationships of the populations of *S. collare* require additional investigation.

Scirtetica Saussure

1884. *Scirtetica* Saussure, Mém. Soc. Phys. nat. Genève *28*:135.

SCIRTETICA MARMORATA MARMORATA (Harris)

1841. *Locusta marmorata* Harris, Rept. Ins. Mass. inj. Veg.:145.

Scirtetica marmorata; Walker, 1898, Can. Ent. *30*:261-262; 1899, *Ibid. 31*:36; *Scudder,* 1900, Proc. Davenport Acad. nat. Sci. *8*:38; *Walker,* 1902, Can. Ent. *34*:255; *Blatchley,* 1920, Orth. N.E. Amer.:285.

Scirtetica marmorata marmorata; Hebard, 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:30.

Localities:

Frank's Bay, Lake Nipissing; Go Home Bay; near Gravenhurst; Karsh Lake; Lake Muskoka; Leg Lake; Macdonald's Falls, Severn River; Nobel; Pittsburg Camp; Point au Baril; Ragged Rapids, Severn River; Sparrow Lake; Waubaushene.

S. m. marmorata, a handsome, mottled insect, is very localized in distribution. This subspecies is also known from New England, New Jersey and Michigan. Another subspecies, *S. m. picta* (Scudder, 1877) occurs from North Carolina south to Florida and Mississippi, according to Blatchley (1920).

Trimerotropis Stål

1873. *Trimerotropis* Stål, Recens. Orth. *1*:118.

TRIMEROTROPIS HURONIANA E. M. Walker

1902. *Trimerotropis huroniana* E. M. Walker, Can. Ent. *34*:6.

Trimerotropis huroniana Walker, 1902, Can. Ent. *34*:6; 1902, *Ibid. 34*:256; 1902, Rept. ent. Soc. Ont. *32*:109; *Blatchley,* 1920, Orth. N.E. Amer.:298; *Walker and Urquhart,* 1940, Can. Ent. *27*:18; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:9.

Localities:

DeGrassi Point, Lake Simcoe; Giant's Tomb Island, Georgian Bay; Southampton [Type locality]; Wasaga Beach, Georgian Bay.

Walker (1957) stated that, prior to 1935, this species had been displaced all along the shore of Georgian Bay by *T. maritima interior* Walker, and it apparently no longer occurs at Southampton, the type locality. Its present distribution is unknown, but presumably it persists at least in some localities around Lake Simcoe or the Muskoka Lakes. The holotype and allotype are in the Royal Ontario Museum.

TRIMEROTROPIS MARITIMA INTERIOR E. M. Walker

1898. *Trimerotropis maritima interior* E. M. Walker, Can. Ent. *30*:262.

Trimerotropis maritima interior Walker, Can. Ent. *30*:262; 1902, *Ibid. 34*:2; *Hebard,* 1932, Univ. Mich. agr. exp. Sta. tech. Bull. *85*:31; *Walker and Urquhart,* 1940, Can. Ent. *72*:17; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:28; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:238.

Tri*merotropis maritima; Walker,* 1902, Can. Ent. *34*:256; 1902, Rept. ent. Soc. Ont. *32*:89; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:294; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:10.

Localities:

Bayfield; DeGrassi Point, Lake Simcoe; Goderich; Kincardine; Kingsville; Point Edward; Point Pelee; Port Rowan; Port Stanley; Ridgeway; Rondeau Park; near Sarnia; Southampton; Tecumseh; Toronto [Type locality]; Toronto Island; Walpole Island, St. Clair River.

Walker was not very sure that this population warranted subspecific status, as is shown by his subsequent references to Ontario specimens merely as *T. maritima* (Harris, 1841). He did not even include this subspecies when listing the deposition of types of species named by him (Walker, 1914). However, the holotype and allotype are in the Royal Ontario Museum and are clearly marked as such (they are dated July 22, 1896). Other authors (see above) have continued to use Walker's *interior* as a valid name, although Blatchley (1920:294) stated that he regarded it as being "wholly unnecessary".

The known range of *interior* has been extended to Saskatchewan (Hebard, 1932) and Manitoba and Saskatchewan (Froeschner, 1954). White (1949) states that *T. m. interior* is a clearly defined subspecies and the name is therefore retained here until such time as a more detailed study can be made to determine the actual status of the populations involved. The typical subspecies, *T. m. maritima,* does not occur in Ontario and is found on the Atlantic coast of the United States southward to Florida.

TRIMEROTROPIS VERRUCULATUS (Kirby)

1837. *Locusta verruculata* Kirby, Richardson Faune Boreale Amer. *4*:250.

Trimerotropis verruculata; Caulfield, 1888, Rept. ent. Soc. Ont. *18*:70.

Circotettix verruculatus; Walker, 1898, Can. Ent. *30*:263; 1902, *Ibid. 34*:256; *Fletcher,* 1902, Rept. ent. Soc. Ont. *32*:54-55; *Walker,* 1906, Rept. ent. Soc. Ont. *36*:66; 1909, Can. Ent. *41*:178; *Blatchley,* 1920, Orth. N.E. Amer.:300; *Hebard,* 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:32; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:65; *Walker,* 1956, Rept. ent. Soc. Ont. *86*:38; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:5.

Localities:

Aurora; Bradford; Burke's Falls, Peterborough County; Burke's Island, Lake Huron; Churchill; Credit Forks; DeGrassi Point, Lake Simcoe; Dwight; Favourable Lake, 53° N.; Fort William; near Gilford; Gravenhurst; Hasting County; Jackfish; Johnston Harbour, Bruce County; Lake Muskoka; Little Eagle Harbour, Bruce County; Low Bush, Lake Abitibi; Macdiarmid, Lake Nipigon; Macdonald's Falls, Severn River; Midland; Mindemoya, Manitoulin Island; Molson; Nobel; North Bay; North River, Algonquin Park; Northumberland County; Onakawana; Ottawa; Owen Sound; Ragged Rapids, Severn River; Rainy River; Rat Portage (Kenora); Renfrew County; Serpent River, Algoma District; Smoky Falls, near Kapuskasing; Stokes Bay, Lake Huron; Stony Lake, Peterborough County; Southampton; Thessalon; Timagami; Tobermory; near Tomico, Nipissing District.

Long placed in the genus *Circottetix,* this species has been shown, on the basis of cytological study by White (1951), to belong in *Trimerotropis. T. verruculatus* is found from coast to coast in Canada. It is by far the most widespread species in the genus. The exact type locality is unknown, but it is certainly in Canada and could well be northern (?) Ontario.

Stethophyma Fischer

1853. *Stethophyma* Fischer, Orth. Eur. *297*:453.

STETHOPHYMA GRACILE (Scudder)

1862. *Arcyptera gracile* Scudder, Can. Nat. and Geol. *7*:463.

Mecostethus gracilis; Walker, 1898, Can. Ent. *30*:126; 1902, *Ibid. 34*:255; 1909, *Ibid. 41*:177; *Blatchley,* 1920, Orth. N.E. Amer.:241.

Stethophyma gracile; Hebard, 1925, Proc. Acad. nat. Sci. Philad. *77*:64; *Walker in* Urquhart (ed.), 1957, Changes Fauna Ont.:5.

Localities:

Aurora; Churchill, Simcoe County; DeGrassi Point, Lake Simcoe; Fort William; Go Home Bay; Kirkland Lake; Manitoulin Island; Marmora; Mer Bleue; Nipigon; Nobel; Pittsburg Camp.

This graceful grasshopper is found in swamp areas across Canada from the east coast to Alberta. Like those of many other oedipodines, the males stridulate in flight, producing a crackling sound which can be heard at a distance of about 50 feet.

STETHOPHYMA LINEATUM (Scudder)

1862. *Arcyptera lineata* Scudder, Bost. J. nat. Hist. *7*:462.

Mecostethus lineatus; Walker, 1898, Can. Ent. *30*:125; 1902, *Ibid. 34*:255; 1906, Rept. ent. Soc. Ont. *36*:65-66; 1909, Can. Ent. *41*:176; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.: 240.

Stethophyma lineatum; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *50*:31; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:217; *Walker in* Urquhart, (ed.), 1957, Changes Fauna Ont.: 5.

Localities:

Arner; Aurora; Bala; DeGrassi Point, Lake Simcoe; Dwight; Fort William; Go Home Bay; 8 miles east of Latchford; Nipigon; Pittsburg Camp; Point Pelee; Redmond Swamp, Byron; Sarnia; Smoke Lake, Algonquin Park; Stokes Bay, Bruce County; Sudbury; Timagami; Tomico, Nipissing District; Wasaga Beach; Whitchurch.

The distribution of *S. lineatum* is somewhat similar to that of *S. gracile* but does not extend so far north or west in Canada. The species occurs throughout northern Ontario. It is found in low, wet meadows, and, according to Blatchley (1920), is more abundant in swamps bordering lakes or tamarack swamps.

Subfamily Gomphocerinae[6]

Pseudopomala Morse

1896. *Pseudopomala* Morse, Psyche *7*:325.

PSEUDOPOMALA BRACHYPTERA (Scudder)

1862. *Opomala brachyptera* Scudder, Bost. J. nat. Hist. *7*:454.

Pseudopomala brachyptera; Walker and Urquhart, 1940, Can. Ent. 72:16; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. 20:24; Judd, 1956, Rept. ent. Soc. Ont. *86*:27.

Localities:

Arner; Point Pelee.

Urquhart (1941) reported *P. brachyptera* as rare in marshy areas near Lake Erie. The only records from Ontario (or Canada) are from the localities mentioned.

Metaleptea Brunner von Wattenwyl

1893. *Metaleptea* Brunner von Wattenwyl, Ann. Mus. Civ. Stor. Nat. Genova *33*:118.

METALEPTEA BREVICORNIS BREVICORNIS (Johannson *in* Linnaeus)

1764. *Gryllus brevicornis* Johannson *in* Linnaeus, Amoen. Acad. *6*:398.

Tryxalis brevicornis; Walker, 1902, Rept. ent. Soc. Ont. *32*:86; 1902, *Ibid. 32*: 109; 1902, Can. Ent. *34*:254; *Blatchley,* 1920, Orth. N.E. Amer.:199; *Hebard,* 1922, Trans. Amer. ent. Soc. *48*:105.

Metaleptea brevicornis; Urquhart, 1941, Contrib. R. Ont. Mus. Zool. *20*:24; *Judd,* 1956, Rept. ent. Soc. Ont. *86*:27.

Metaleptea brevicornis brevicornis; Froeschner, 1954, Iowa St. Coll. J. Sci. *29*:205.

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[6]Formerly included in the Acridinae *sens. lat.* or Truxalinae *sens. str.* The former subfamily is now restricted to *Acrida* and numerous related (mainly tropical) genera, while the latter now contains only *Truxalis* and one or two African genera closely related to it (Uvarov, 1966).

Localities:

Arner; Point Pelee.

M. b. brevicornis is another species which occurs in Canada only in southern Ontario. It is rare.

Orphulella Giglio-Tos

1894. *Orphulella* Giglio-Tos, Boll. Mus. zool. anat. comp. Torino *9*(184):8.

ORPHULELLA SPECIOSA (Scudder)

1862. *Stenobothrus speciosus* Scudder, Bost. J. nat. Hist. *7*:458.

Orphula aequalis; Walker, 1898, Can. Ent. *30*:125.

Orphulella speciosa; Walker, 1902. Can. Ent. *34*:254; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:229; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:60; 1928, *Ibid. 80*:228; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:65; *Gurney,* 1940, Ent. Amer. *20*:94, 136;*Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:24; *Smith,* 1965 ,Can. J. Zool. *43*:180.

Localities:

Arden; Arner; Belle River; Brockville; Chatterton; Constance Bay; DeGrassi Point, Lake Simcoe; Essex; Hastings County; Mactier; Manitoulin Island; Northumberland County; Ottawa; Picton; Point Pelee; Renfrew County; Rondeau; Sarnia; Toronto; Turkey Point; Wasaga Beach, Georgian Bay; Wheatley; Windsor.

This small, slant-faced grasshopper occurs in two colour phases, green and brown, although the green phase seems to predominate. It is relatively common throughout southern Ontario. It is not a pest species.

ORPHULELLA PELIDNA PELIDNA (Burmeister)

1838. *Gomphocerus pelidnus* Burmeister, Handb. Ent. *2*:650.

Orphulella pelidna; Walker, 1902, Rept. ent. Soc. Ont. *32*:87; 1902, *Ibid. 32*:109; 1902, Can Ent. *34*:254; *Blatchley,* 1920, Orth. N.E. Amer.:226; *Gurney,* 1940, Ent. Amer. *20*:119, 125; *Urquhart,* 1941, Contrib. R. Ont. Mus. Zool. *20*:24.

Localities:

Point Edward; Port Rowan; Sarnia; St. Clair River; Turkey Point.

O. p. pelidna, like *O. speciosa,* occurs in both green and brown colour phases. In Ontario its distribution is restricted to the extreme southern part. Another subspecies, *O. p. desereta* Scudder, 1899, occurs in British Columbia.

Neopodismopsis Bei-Bienko

1932. *Neopodismopsis* Bei-Bienko, Eos, Madr. *8*:56.

NEOPODISMOPSIS ABDOMINALIS (Thomas)

1873. *Chrysochraon abdominalis* Thomas, Rept. U.S. geol. Surv. Terr. *5*:74.

Chloealtis abdominalis; Walker, 1902, Can. Ent. *34*:254; *Fletcher,* 1906, Rept. ent. Soc. Ont. *36*:102-103; *Walker,* 1909, Can. Ent. *41*:176; 1911, Can. Ent. *43*:304; *Blatchley,* 1920, Orth. N.E. Amer.:219; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:58.

Chrysochraon abdominalis; Hebard, 1928, Proc. Acad. nat. Sci. Philad. *80*:228; 1932, Univ. Minn. agr. exp. Sta. tech. Bull. *85*:25.

Neopodismopsis abdominalis; Hebard, 1936, N. Dak. agr. Coll. exp. Sta. tech. Bull. *284*:31; *Rehn,* 1952, Ent. News *63*:30.

Localities:

Attawapiskat, 52°N.; Constance Bay; DeGrassi Point, Lake Simcoe; Fort William; Kaministiqua River; Kirkland Lake; Klock, Nipissing District; Macdonald's Falls, Severn River; Nipigon; Nobel; Sesekinika; Smoke Lake, Algonquin Park; Sudbury.

N. abdominalis seems to prefer mountainous forested areas, although it is not confined to such regions. It is often found in clearings in scrubby woods (Walker, 1909).

Chloealtis Harris

1841. *Chloealtis* Harris, Rept. Ins. Mass. inj. Veg.:148.

CHLOEALTIS CONSPERSA Harris

1841. *Locusta (Chloealtis) conspersa* Harris, Rept. Ins. Mass. inj. Veg.:149.

Chloealtis conspersa; Caulfield, 1888. Rept. ent. Soc. Ont. *18*:70; *Walker,* 1898, Can. Ent. *30*:124; 1902, *Ibid. 34*:254; 1906, Rept. ent. Soc. Ont. *36*:76; 1909, Can. Ent. *41*:176; *Walker in* Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.:216; *Hebard,* 1925, Proc. Acad. nat. Sci. Philad. *77*:58; *Urquhart,* 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:24; *Froeschner,* 1954, Iowa St. Coll. J. Sci. *29*:214.

Chloealtis conspersa prima; Walker, 1902, Can. Ent. *34*:254.

Localities:

Arner; Brule Lake; near Churchill; Clear Lake; Constance Bay; DeGrassi Point, Lake Simcoe; Fort William; Goderich; Kingsville; Klock, Nipissing District; Lake Nipissing; Nipigon; North Bay; North River, Algonquin Park; Palmer Rapids; Point Pelee; Prince Edward County; Rat Portage (Kenora); Rondeau; Sarnia; Severn River; Smoke Lake, Algonquin Park; Toronto; Turkey Point.

C. conspersa occurs in small numbers over a wide range, including all but extreme northern Ontario. It is most often found in thickets, hedges, fence rows and on the edges of wooded areas. It is normally short-winged, but a few macropterous individuals have been found. Morse (1896) named these *C. c. prima,* but this name has no subspecific validity.

Chorthippus Fieber

1852. *Chorthippus* Fieber *in* Kelch, Grundl. Orth. Oberschles:1.

CHORTHIPPUS CURTIPENNIS (Harris)

1841. *Locusta (Chloealtis) curtipennis* Harris, Rept. Ins. Mass. inj. Veg.:149.

Stenobothrus curtipennis; F. Walker, 1872, Can. Ent. *4*:31; *Caulfield,* 1888, Rept. ent. Soc. Ont. *18*:70; *Walker,* 1898, Can Ent. *30*:126; 1902, *Ibid. 34*:254; 1906, Rept. ent. Soc. Ont. *36*:66; 1909, Can. Ent. *41*:176.

Chorthippus curtipennis; Walker in Faull (ed.), 1913, Nat. Hist. Toronto Reg.:300; *Blatchley,* 1920, Orth. N.E. Amer.: 235; *Gilbert,* 1937, Rept. ent. Soc. Ont. *67*:65; *Vickery,* 1964, Can. Ent. *96*:1537-1548.

Chorthippus longicornis; Urquhart, 1941, Univ. Toronto Stud. biol. Ser. *48*:119; 1941, *Ibid. 50*:31; 1941, Contrib. R. Ont. Mus. Zool. *20*:25.

Chorthippus eurtipennis [*sic*]; *Martin,* 1965, Proc. ent. Soc. Ont. *95*:100.

Localities:

Amherstburg; Arner; Attawapiskat, 52° N.; Bala; Bell's Corners; Belle River; Blackburn; Black Sturgeon Lake; Blytheswood; Brockville; Chatham; Clear Lake; Constance Bay; DeGrassi Point, Lake Simcoe; East River, Nipissing

District; Eglinton; Favourable Lake, 53° N.; Fort William; Gananoque; Goderich; Go Home Bay; Gull Lake; Hastings County; Johnston Harbour, Bruce County; Kingsville; Kirkland Lake; Kirkwood Twp.; Klock, Nipissing District; Lake Muskoka; Little Eagle Harbour, Bruce County; Malden Centre; Marmora; Mer Bleue; Mindemoya, Manitoulin Island; Minett, Muskoka District; Niagara; Nipigon; North Bay; Northumberland County; Norway Point, Lake of Bays; Onakawana, 50° 35' N.; Osgoode; Ottawa; Owen Sound; Palmer Rapids; Pittsburg Camp; Point Pelee; Poverty Bay, Parry Sound District; Ragged Rapids, Severn River; Rainy River; Renfrew County; Rondeau Park; Rosseau, Muskoka District; Sarnia; Searchmont; Sesekinika; Severn River; Shawanaga, Georgian Bay; Smoky Falls, near Kapuskasing; Smoke Lake, Algonquin Park; Southampton; Spencerville; St. Martins Falls, Albany River; Stonecliffe; Stony Point; Sudbury; Timagami; Tobermory; Toronto; Trenton; Turkey Point; Vineland; Walpole Island, St. Clair River; Wheatley; White Lake.

C. curtipennis is a common, widely distributed species found in every province of Canada. Hebard (1936) synonymized *curtipennis* under an Old World species name, *longicornis* Latreille. This latter was subsequently shown to be a *nomen dubium,* since the description applied equally to two European species. The type is lost and the name *longicornis* was suppressed by the International Commission on Zoological Nomenclature (1961) following a submission to the Commission by Kevan (1960). Vickery (1964) then showed that North American *Chorthippus* are not conspecific with any species from the Old World and the name *curtipennis* Harris was reinstated.

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Summary

All of the orthopteroid insects known to occur or to have been found in Ontario, including those native to the Province and established aliens, as well as casual adventives, are listed. Previous literature references, synonomy, localities and appropriate comments are given for each species. The total of 127 species are categorized as follows: Dermaptera — 5, established aliens and native — 3, adventive — 2; Isoptera — 2, established alien — 1, adventive — 1; Blattodea — 11, established aliens and native — 7, adventive — 4; Mantodea — 2 established aliens; Phasmatodea — 1 native; Orthoptera — 106, native or established (including *Metrioptera roeseli*) — 102, adventive (including 2 casual migrants) — only from Ontario. *Nemobius macdunnoughi* Urquhart, 1938, is placed in synonomy under *N. carolinus* Scudder, 1877.

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SOME OBSERVATIONS ON VECTORS AND TRANSMISSION OF TOBACCO ETCH VIRUS

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Introduction

The tobacco etch virus increased in economic importance from 1947 to 1964. Initial appearance of the virus closely followed the beginning of serious infestations of burley tobacco by the green peach aphid in Essex and Kent Counties in 1947. Stover reported the occurrence of TEV and other aphid-borne viruses of tobacco from 1949 to 1951 and McKeen reported a serious outbreak of TEV in peppers in 1950. More recent epidemics occurred in 1951, 1955, 1958, 1962 and 1964. Stover suggested that the early potato crop might be an important reservoir of TEV in Ontario and that the green peach aphid probably transported the disease to tobacco. Because of the epidemic of 1958 research was initiated to clarify the source of the virus and to determine the relation of vectors to its transmission into the burley tobacco crop. A brief report by McKeen and Boyce (1960) was made of the existence of ground cherry as an overwintering host in Ontario.

Transmission Tests of Potential Vectors Other Than Aphids

Examination of tobacco and ground cherry revealed that a number of insects were commonly found on both species of plants. Attempts to obtain transmission in the laboratory with the greenhouse whitefly, the two spotted spider mite, the potato flea beetle, the potato leaf hopper, the cercopid, *Philaenus spumarius* (L.), the fulgorid, *Acanalonia bivittata* Say and the membracids *Stictocephalus bubalus* (Wlk.), *S. taurina* (Fitch) and *S. diceros* (Say) produced negative results. All of the above insects were found utilizing *P. heterophylla* as a host. The three membracids developed through nymphal stages to adults on *P. heterophylla* and both nymphs and adults were tested for ability to transmit TEV. None of the tests with the insect species listed above resulted in transmission of the virus to tobacco.

Transmission of Tobacco Etch Using the Green Peach Aphid and the Potato Aphid

Field studies soon established that four of six previously reported aphid vectors occurred on burley tobacco in Essex County. The most abundant of these were the green peach aphid, the potato aphid and the bean aphid, *Aphis fabae*. *Aphis nasturtii,* though present, was rare.

Tests were conducted in a greenhouse to determine the ability of the green peach aphid and the potato aphid to transmit TEV to tobacco, *Physalis* and potato, variety Irish Cobbler.

A stock of etch-infected green peach aphid was obtained from a sample taken from infected post-harvest suckers of burley tobacco. This stock was maintained in a cage by periodic transfer to potted Harrow Velvet tobacco plants, as found necessary. An etch-infected stock of the potato aphid was obtained from the inflorescence of an etch-infected burley plant. Attempts to maintain the potato aphid stock on tobacco were unsuccessful. However, when this stock was transferred to potted *Physalis* derived from seed and held in a cage, no further difficulty was encountered.

Virus free stocks of both species were obtained by transferring apterae, deposited on moist filter paper by apterous viviparae, to the respective host plants mentioned above, then testing for freedom from virus by several transfers to Harrow Velvet tobacco. In no case were any of the apterae of either species obtained in this manner found to be infected with etch.

Transmission tests were made by inoculating plants with infected aphids which were removed by fumigation after four days and then recolonizing with non-infected aphids. Subsequently 15 aphids were transferred on a portion of leaf tissue in a small boat of aluminum foil to each test plant. The aphids were allowed to transfer of their own accord rather than by using a brush. Usually most of the aphids moved from the original leaf portion to the test plant within two days.

Using the transfer technique described and the green peach aphid as vector the following results were obtained: (a) transfer of TEV from tobacco to tobacco 80 per cent successful (10 tests), (b) transfer of TEV from tobacco to *Physalis* 100 per cent successful (3 tests), (c) from *Physalis* to tobacco 100 per cent (6 tests), (d) from tobacco to potato 100 per cent (5 tests) and (e) from potato to tobacco 100 per cent (5 tests).

In similar tests using the potato aphid as vector successful transmission of etch was obtained as follows: (a) tobacco to tobacco 60 per cent (10 tests), (b) tobacco to *Physalis* 80 per cent (10 tests), (c) *Physalis* to tobacco 73 per cent (15 tests) and (d) tobacco to potato none (7 tests). The virus was transmitted also from potato to tobacco in one test.

The tests clearly indicate the ability of both the green peach and potato aphids to transmit etch between tobacco, *Physalis* and potato, except that no transmission from tobacco to potato was obtained with the potato aphid. The transmission tests suggest that the green peach aphid may be, in general, a more efficient vector than the potato aphid.

Association of the Green Peach Aphid and the Potato Aphid with Tobacco and *P. heterophylla* in Nature

During the years 1960 to 1964, inclusive, the populations of the green peach aphid and the potato aphid on burley tobacco were sampled in large tobacco plots. Sampling was accomplished by collecting all winged aphids from the middle third area of tobacco plants three times per week. Plants were sampled at random for

15 minutes in each corner of the plot, beginning when the first alates were detected by daily observation and continuing until the virus was first detected. The four samples were combined for each collection date to provide the relation of samples to one man hour for each collection period. In turn the numbers of the two species, obtained for the total collections each year, were related to the severity of infection by TEV by visual rating (Table I).

TABLE I. No. of aphids collected per man hour from burley tobacco from time of first appearance in crop to time of appearance of TEV.

Year	*M. euphorbiae*	*M. persicae*	Severity of TEV
1960	48	210	Moderate
1961	16	72	Light
1962	76	90	Heavy
1963	2	2	Very light
1964	106	184	Heavy

The samplings suggested that the total populations of the two species of aphids were related to the severity of TEV infection. Also, it appeared that if the ratio of the green peach aphid to the potato aphid was less than 2:1 and populations were large, as in 1962 and 1964, heavy infections occurred. Such a relation between the two species suggests that the potato aphid is more important in introducing the virus into the crop.

From the beginning of July to mid-October 1959 to 1964 three groups of *P. heterophylla* totalling 100 plants located on and adjacent to the Research Station, Harrow were examined at bi-weekly intervals for aphids. At no time were alate or apterous green peach aphids found but, on several occasions, alates, apterae or cast nymphal skins of the potato aphid were observed in this host in small numbers.

An attempt was made in 1960 to determine more precisely the numbers of the green peach and potato aphids occurring on *P. heterophylla* during the portion of the season when the virus might be expected to be picked up by aphids to provide the first infection of tobacco. A total of 12 potted *Physalis* plants grown from seed collected in 1959 were set in the soil at the east and west ends of rows of early and late tomatoes and eggplant adjacent to a mixed planting of tobacco and pepper. These plants were placed in position on May 31 and were examined for aphids as frequently as possible usually at intervals of two to three days but occasionally four to six days. From June 1 to July 6, when the first tobacco plant infected with etch was discovered on the Station a total of 28 alate and 88 apterous forms of the potato aphid were found on the plants. However, during the same period only one alate and no apterae of the green peach aphid were seen on the trap plants.

The evidence obtained from this experiment by no means provides conclusive evidence that contact of the potato aphid with *Physalis* is more frequent than by the green peach aphid. The former aphid species utilizes *Physalis* as a host, at least to some extent, whereas the latter apparently does not. Accordingly, the potato aphid may remain on the host plant longer whereas the green peach aphid may alight and take off quickly again thus not being encountered on the plant as frequently.

Since apterae of the potato aphid were deposited and developed on *Physalis,* it may be expected that the subsequent production of virus-carrying alatae from infected *Physalis* could occur at any time that conditions were appropriate.

An event of this nature was closely observed on the Research Station, Harrow. Initial infection by etch of single plants in a large field of burley tobacco was observed on one plant on July 6 and on a second plant on July 11, in the outside row. In both instances etch-infected *Physalis* plants were located across a roadway immediately to the west of the infected plants.

The *Physalis* near the infested tobacco plants discovered July 6 was naturally infested with viviparous apterae of the potato aphid. Before July 6 to July 18 only 2 apterae and one alate of the potato aphid remained on this plant. Between July 6 and July 20 considerable etch infection of tobacco plants appeared near each of the two tobacco plants originally found to be infected. Subsequently, infection became widespread down wind from the original infested plants.

Discussion

Only the potato aphid *M. euphorbiae,* has been closely linked in nature with the reservoir hosts of the virus and the aphid colonized them to a certain extent each year, such taking place only on plants well protected from the wind by crops such as alfalfa, oats, corn and tall grasses and by weeds in waste areas and peach orchards.

It would seem that the apparently closer association of the potato aphid than the green peach aphid with *Physalis* may afford a greater opportunity for the former species to acquire etch, through visits of migrant alates and through the production of additional alates on etch infected *Physalis* plants and to transmit the disease to tobacco.

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A COMPARATIVE STUDY OF GASTRIC CAECA IN ADULT AND LARVAL STAGES OF BARK BEETLES (COLEOPTERA: SCOLYTIDAE)

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Introduction

Taxonomic studies of any group of insects should not be restricted to examination of the anatomy of the adult stages only, but should encompass as many approaches as possible including ecological studies to determine life histories and behaviour, physiology, biochemistry, genetics, and cytology. In the same

respect, anatomical studies should be expanded to cover the immature stages as well as the adults. For a number of years I have been studying the immature stages of bark beetles to see if their characteristics can be used to augment classifications of the family Scolytidae previously derived from the form of the adults alone (Thomas 1957, 1960, 1965). Emphasis has been on external anatomy, but recently it was noticed that there appeared to be some differences in the type, number, and arrangement of the diverticula of the alimentary canal. A survey of representatives of a number of genera confirmed this. It is my intention in this paper to compare briefly the types of diverticula or gastric caeca located on the midgut of the alimentary canal of the larvae and adults of a number of bark beetles. Consideration will be given to the possible application of these characters to current taxonomic problems in the family Scolytidae.

Methods

Whenever possible, the midgut was removed immediately after the specimens were killed in 70% alcohol. Each larva, immersed in a small dish of alcohol, was grasped with two pairs of forceps, one about the thorax and the other about the anal region. By tearing the integument at the anus, the entire gut up to the ventriculus could usually be extracted with all the gastric caeca intact. The same procedure was used with the adults, although it was also possible to expose their midgut by pulling the body apart at the junction of the pro- and mesonota. Several specimens could be treated per minute using this method, but it could not be used with specimens preserved for some time because the internal structures became too fragile. In such cases, tedious dissection requiring upwards of thirty minutes per specimen was required, and in most cases the midgut could not be uncoiled to reveal all the details.

The number of gastric caeca of each type was recorded, and a few of the midguts from each species were mounted on slides. The image of the midgut was projected through a compound microscope onto a paper-covered glass screen and a direct tracing made on the paper. This provided an outline drawing very quickly with all parts in proportion, and the minute details were then added by direct observation of the specimen. This method was described by Thomas and Gardiner (1962).

Species Examined

The 83 species of bark-beetles representing 27 genera examined in this study are listed in Table I according to subfamilies and tribes. The tribal groupings are according to the preliminary classification of Scolytoid beetles published by Wood (1961). Wherever possible, the arrangement of tribes under subfamilies follows that given by Leng (1920).

TABLE I. Species of Bark Beetles and Stages Examined.

Subfamily	Tribe	Species	Stage	
			Adult	Larva
Scolytinae	Scolytini	*Scolytus dentatus* Bright		X
		Scolytus mali Bechst.	X	X
		Scolytus multistriatus (Marsh.)	X	X
		Scolytus piceae (Sw.)	X	X
		Scolytus rugulosus Ratz.		X
		Scolytus tsugae (Sw.)	X	X

Subfamily	Tribe	Species	Stage	
			Adult	Larva
Hylesininae	Crypturgini	*Crypturgus borealis* Sw.	X	X
	Hypoborini	*Liparthrum arizonicum* Wood	X	X
	Polygraphini	*Polygraphus rufipennis* (Kby.)	X	X
	Hylurgini	*Dendroctonus adjunctus* (Bland.)	X	X
		Dendroctonus brevicomis Lec.	X	X
		Dendroctonus frontalis Dz.	X	X
		Dendroctonus murrayanae Hopk.	X	X
		Dendroctonus obesus (Mann.)	X	X
		Dendroctonus ponderosae Hopk.	X	X
		Dendroctonus pseudotsugae Hopk.	X	X
		Dendroctonus simplex Lec.	X	X
		Dendroctonus terebrans (Oliv.)	X	X
		Dendroctonus valens Lec.	X	X
		Blastophagus piniperda (L.)		X
		Hylurgopinus rufipes (Eichh.)	X	X
	Hylesinini	*Chramesus hicoriae* Lec.	X	X
		Chramesus aspericollis Sch.		X
		Phloeotribus piceae (Sw.)	X	X
		Phloeosinus canadensis Sw.	X	X
		Phloeosinus aciculatus Bruck	X	X
		Leperisinus aculeatus (Say)	X	X
		Leperisinus criddlei Sw.	X	X
	Hylastini	*Hylastes fulgidus* Blkm.	X	
		Hylastes nitidus Blkm.	X	
		Hylastes porculus Lec.	X	X
		Hylurgops alternans Chap.	X	X
		Hylurgops pinifex (Fitch)	X	X
		Hylurgops planirostrus Chap.	X	X
Ipinae	Xyloterini	*Xyloterinus politus* (Say)		X
		Trypodendron betulae Sw.	X	X
		Trypodendron lineatum (Oliv.)	X	X
		Trypodendron retusum (Lec.)	X	X
		Trypodendron rufitarsis (Kby.)	X	X
		Dendrotrypum aceris (Niisima)		X
	Corthylini	*Gnathotrichus materiarius* (Fitch)	X	X
		Gnathotrichus retusus Lec.	X	X
		Gnathotrichus sulcatus Lec.	X	X
		Gnathotrichus nitidifrons Hopk.	X	X
	Pityophthorini	*Conophthorus coniperda* (Sz.)	X	X
		Conophthorus flexilis Hopk.		X
		Conophthorus lambertianae Hopk.		X
		Conophthorus monophyllae Hopk.		X
		Conophthorus ponderosae Hopk.	X	X
		Conophthorus radiatae Hopk.		X
		Conophthorus resinosae Hopk.	X	X
		Conophthorus sp.	X	X
		Pityophthorus puberulus Lec.	X	X
		Pityophthorus sp.	X	X
		Pityoborus intonsus Wood	X	
		Pseudopityophthorus micans Wood	X	X

Subfamily	Tribe	Species	Stage Adult	Stage Larva
	Ipini	*Pityogenes hopkinsi* Sw.	X	X
		Pityogenes plagiatus (Lec.)	X	X
		Ips amiskwiensis G. Hopp.		X
		Ips avulsus (Lec.)	X	X
		Ips bonanseai (Hopk.)	X	X
		Ips borealis Sw.	X	X
		Ips calligraphus (Germ.)	X	
		Ips concinnus (Mann.)		X
		Ips confusus (Lec.)	X	X
		Ips cribricollis (Eichh.)	X	X
		Ips emarginatus (Lec.)	X	
		Ips grandicollis (Eichh.)	X	X
		Ips lecontei Sw.	X	X
		Ips mexicanus Hopk.	X	X
		Ips perroti Sw.	X	X
		Ips perturbatus (Eichh.)	X	X
		Ips pini (Say)	X	X
		Ips plastographus (Lec.)	X	X
		Pityokteines sparsus Lec.	X	X
		Orthotomicus caelatus (Eichh.)	X	X
		Orthotomicus erosus Woll.		X
		Orthotomicus latidens (Lec.)	X	X
	Xyleborini	*Anisandrus* sp.	X	X
	Dryocoetini	*Dryocoetes affaber* (Mann.)	X	X
		Dryocoetes autographus (Ratz.)	X	X
		Dryocoetes betulae Hopk.	X	X
		Dryocoetes confusus Sw.	X	X

Types and Distribution of Gastric Caeca

The gross anatomy of the alimentary canal of the larva of *Ips pini* is shown in Fig. 1. The adult structure is similar, with the addition of a well-developed proventriculus anterior to the ventriculus. This can be considered as the generalized structure for most scolytids. The midgut, beginning at the anterior end of the ventriculus and extending to the point of origin of the Malpighian tubules, usually bears one or more types of diverticula hereafter referred to as gastric caeca or simply as caeca. There are two main types of caeca, globular and elongate, both of which can be seen in Fig. 1. Only the species of *Gnathotrichus* lacked caeca entirely in both the larvae and adults; *Trypodendron* larvae had caeca around the anterior end of the ventriculus only, and the remaining species had caeca on the tubular portion of the midgut between the ventriculus and the Malpighian tubules. In the following text, the types and distribution of caeca are described briefly. The average number of caeca followed by the range (in brackets) is given opposite some species to clarify the text of the description.

Scolytus spp.	Larvae	Adult
Scolytus dentatus	16 (14-18)	—
" *mali*	11 (7-17)	35 (32-38)
" *multistriatus*	8 (5-12)	18 (12-28)
" *piceae*	9 (6-14)	17 (11-20)
" *rugulosus*	4 (2-7)	—
" *tsugae*	9 (4-14)	—

Larvae of these species of *Scolytus* have elongate caeca arranged in three longitudinal rows on the midgut (Fig. 2) and varying greatly in number. Adults of only three of these species were available, but the arrangement of caeca in all three is similar, an irregular row or band on opposite sides of the midgut (Fig. 3). *S. mali* has approximately twice as many per row as the other two species.

Crypturgus borealis

This species has a row of 4-6 semi-globular or partially elongate caeca on either side of the midgut with 1 or 2 (usually 1) long, thin, caeca located in front of each row and separated from the shorter ones (Fig. 4). The structure and arrangement is similar in the adult, with the semi-globular caeca being slightly longer.

Liparthrum arizonicum

The larva has a row of globular caeca on either side of the midgut, each row preceded by a single elongate caecum (Fig. 5). The structure and arrangement are similar for the adult, with an average of 14 globular caeca compared with an average of 12 in the larva.

Polygraphus rufipennis

The larva has a band of semi-globular caeca, average 30 (range 24-40), on either side of the midgut with a more or less linear group of longer caeca, average 8 (range 5-12), anterior to the band (Fig. 6). In some specimens the caeca at the anterior end of the band are more elongate than those comprising the larger part of the band. There is usually, but not always, a space separating the large band from the anterior group. The structure and arrangement of the caeca in the adult (Fig. 7) is essentially similar to that of the larvae. There are an average of 31 (range 21-50) globular caeca in the band and 8 (range 4-12), elongate caeca in the anterior group. In the anterior group, they may be irregularly scattered around the circumference of the midgut.

Dendroctonus spp.	Larva	Adult
Dendroctonus adjunctus	10 (6-13) per band	21 (15-24) per band
" *brevicomis*	5 (3- 8) " "	21 (18-25) " "
" *frontalis*	8 (6-12) " "	17 (8-33) " "
" *ponderosae*	36 (25-50) " "	120-150 approx. total
" *murrayanae*	65 (55-85) " "	140-190 " "
" *obesus*	67 (70-80) " "	125-200 " "
" *pseudotsugae*	60 (43-70) " "	90-110 " "
" *simplex*	60 (50-75) " "	70-105 " "
" *terebrans*	65 (50-70) " "	125-150 " "
" *valens*	68 (55-75) " "	125-150 " "

Caeca in the larvae and adults of the genus *Dendroctonus* are elongate and arranged either in a band on opposite sides of the midgut, or tend to be distributed about the circumference when the number is large. In this latter case, only an approximation of the total number per specimen rather than per band is given in the list of species.

The larvae of *brevicomis* have the caeca in an irregular row (Fig. 8), and the slightly larger number in *adjunctus* (Fig. 10) and *frontalis* (Fig. 11) is arranged in a band or group on either side of the midgut. The arrangement and number for the adults of the three species are similar, the caeca being in two bands as in *brevicomis* (Fig. 9).

D. ponderosae (Fig. 12) has the next largest number of larval caeca, an average of 36 (range 25-50), in a band. In the adults (Fig. 13) they range from 120-150, distributed about the circumference of the gut with a slight concentration on opposite sides.

The final group of species have an average of 60 or more caeca per band in the larvae, frequently over 75 as in *obesus* (Fig. 14) and *valens* (Fig. 16). The total number of caeca in adults of *pseudotsugae* and *simplex* ranges from approximately 70-110, with a much larger number, 125-200, for adults of *obesus* (Fig. 15), *murrayanae, terebrans,* and *valens* (Fig. 17).

Blastophagus piniperda

A few larvae were obtained from Israel, but their condition precluded many dissections. It was determined, however, that the elongate caeca are arranged in two broad bands of approximately 75-100 each, similar to the condition in larvae of *Dendroctonus, Hylurgops* and *Hylastes.*

Hylurgopinus rufipes

The caeca are elongate and arranged in an irregular row on either side of the midgut. Larvae (Fig. 18) have an average of 17 (range 15-22) per row. The number in the adults (Fig. 19) is smaller, an average of 12 (range 8-15), but they are more regularly arranged, and are slightly longer than those of the larvae.

Chramesus hicoriae
" *aspericollis*

The larvae have a row of caeca, average 7 (range 5-9), on either side of the midgut (Fig. 20). The posterior ones are small, semi-globular, gradually becoming elongate anteriorly. The adults have a number of elongate caeca of varying lengths, average 20 (range 16-24), grouped on one side only (Fig. 21). One specimen of a larva of *C. aspericollis* was available and the caecal pattern in it was similar to the other species with 5 caeca on one side and 6 on the other.

Phloeotribus piceae

The larva has a row of globular caeca, average 8 (range 6-10) preceded by 2 or 3 (usually 2) elongate caeca on either side of the midgut (Fig. 22). They are not as uniformly globular in the adult, and are distributed in three rows of 5 to 8 each (Fig. 23) on one-half of the circumference of the midgut (Fig. 24). The anterior group of elongate caeca is also on one side of the midgut.

Phloeosinus canadensis
" *aciculatus*

The gastric caeca of the larvae are elongate and are arranged in a row on either side of the midgut, averaging 14 (range 10-17) (Fig. 25). The bases of the caeca usually do not touch, and the caeca decrease slightly in diameter and length at the anterior end of the row. The adult caeca are similar to those of the larvae, although the arrangement within the rows is more regular, and they are slightly more numerous, average 16 (range 12-21).

Leperisinus aculeatus
" *criddlei*

The gastric caeca of these species are similar in structure and arrangement. The larval caeca are semi-elongate or semi-globular, and are arranged in a single row on either side of the midgut. *L. aculeatus* (Fig. 26) has a mean of 13 (range 9-19) per row, whereas *criddlei* has a mean of only 10 (range 8-14). The adult caeca are also distributed in a single row on either side of the midgut. Again the average number of 8 per row (range 5-11) in *aculeatus* (Fig. 15) exceeds the average of 4 (range 3-5) found in *criddlei.*

Hylurgops spp.	Larva	Adult
Hylurgops pinifex	52 (42-68)	37 (25-60)
" *planirostrus*	43 (36-52)	44 (34-57)
" *alternans*	45 (35-50)	25 (21-41)

The three species of *Hylurgops* have elongate caeca in a row or band on opposite sides of the midgut. The band reduces to a more or less single line of 3-12 anteriorly in the larva (Fig. 28). The larvae of *pinifex* have the largest average number of caeca per band exceeding those in the other two species. The arrangment of the adult caeca tends toward a row, and the caeca are not as closely grouped as in the larvae (Fig. 29). *H. alternans* has the fewest caeca, with the range of the other two species being relatively close.

Hylastes porculus
" *fulgidus*
" *nitidus*

Both larvae and adults have elongate caeca arranged in an irregular row on opposite sides of the midgut. The line is fairly uniform posteriorly, but the arrangement becomes irregular anteriorly and, in some adult specimens, the caeca partially encircle the midgut. The larvae of *porculus* (Fig. 30) have a mean of 19 (range 14-24) caeca with a larger number, an average of 31 (range 26-36) per row in the adults (Fig. 31). Only adults of the other two species were available, and these averaged 35 (range 25-42) caeca per row.

Trypodendron betulae
" *lineatum*
" *lineatum*
" *rufitarsis*

Xyloterinus politus
Dendrotrypum aceris

The structure of the alimentary canal of the larvae of the four species of *Trypodendron* and *X. politus,* and *D. aceris* has been described previously (Thomas, 1960). Caeca, when present, are globular and form a ring about the anterior end of the ventriculus (Fig. 32). The development is variable, some specimens having uniformly-sized caeca, others have them of different sizes, and some specimens have none. None of the six specimens of *D. aceris* larvae examined had caeca. Adults of the species of *Trypodendron* only were available, and these have a pair of elongate caeca anterior to the point of origin of the Malpighian tubules (Fig. 33).

Gnathotrichus materiarius
" *retusus*

G. sulcatus
G. nitidifrons

No caeca are present in either the larval or adult stages. The midgut of the larva is smooth, whereas that of the adult is covered with small papillae.

Conophthorus spp.	Larva		Adult	
	Globular	Elongate	Globular	Elongate
Conophthorus coniperda	36 (30-44)	- 3 (2-5)	37 (25-46)	- 8 (5-12)
" *flexilis*	41 (34-45)	- 4 (2-5)	41 (31-51)	- 7 (6-11)
" *lambertianae*	37 (29-42)	- 4 (3-5)		
" *monophyllae*	26 (20-30)	- 3 (2-4)		
" *ponderosae*	42 (28-59)	- 3 (1-5)		
" *radiatae*	42 (32-52)	- 3 (2-4)		
" *resinosae*	36 (25-49)	- 4 (2-5)	33 (23-50)	- 7 (4-10)
" sp. (ex jack pine)	37 (30-45)	- 4 (3-5)	31 (25-40)	- 6 (5- 7)

The gastric caeca of the larvae and adults of the species in this genus are similar in structure. The globular caeca are arranged in an irregular band on opposite sides of the midgut (Figs. 34 and 35), preceded by a group of 3 or 4 elongate ones. These elongate caeca are usually in a continuous row in the adult, partially encircling the midgut, rather than in two groups as in the larva, and the figures listed above are totals, not the average number shown for the larvae.

Pseudopityophthorus micans

The caeca are of the same general type as in the genus *Conophthorus*. There are fewer globular caeca in the larval stage, an average of 17 (range 9-23), and they tend towards linear arrangement (Fig. 36). This is particularly evident when only a few caeca are present. The elongate caeca average 3 (range 1-4) per side. The average number of globular caeca in the adult is slightly smaller than in *Conophthorus,* an average of 24 (range 18-30) per side. There appears to be less scatter in the band, possibly because of fewer caeca. The elongate caeca are in a group on one side of the midgut and average 10 (range 9-14) in number.

Pityophthorus puberulus

Pityophthorus sp.

The caeca are globular and elongate as in the preceding two genera. The globular ones are in a narrow band in the larvae of *puberulus* (Fig. 37) averaging 13 (range 9-16) per band. There is an average of 20 (range 17-26) in the other species. Both species have an average of two elongate caeca anterior to each band of globular caeca. The adult caeca are also in a band along opposite sides of the midgut, averaging 22 (range 18-25) per band in *puberulus* (Fig. 39). The elongate caeca averaging 3 (range 2-5), are in a single group spread over one-half of the circumference of the midgut. Only one adult specimen of the second species was available. It has 25-26 globular and a group of 5 elongate caeca.

Pityoborus intonsus

Adults only were available. These conform to the typical Pityophthorini pattern with the globular caeca in a band on either side of the midgut, an average of 24 ((19-29) in each of the two bands. The elongate caeca are in one group, average 6 (range 4-8), anterior to the globular type usually occupying one-half of the circumference of the midgut.

Pityogenes spp.	Larva		Adult	
	Globular	Elongate	Globular	Elongate
Pityogenes hopkinsi	14 (9-17)	- 2 (2-3)	12 (10-14)	- 6 (5-7)
" *plagiatus*	10 (7-12)	- 3 (2-3)	10 (7 -14)	- 6 (4-8)

The type and arrangement of gastric caeca are similar in both species with only minor differences in numbers. A single row of globular caeca on either side of the midgut is preceded by a group of elongate ones in the larvae (Fig. 39). Larvae of *hopkinsi* have slightly more globular caeca than *plagiatus*. The arrangement of the globular caeca in the adult (Fig. 40) is similar in both species. The elongate caeca are located in a single group on one side of the midgut more frequently than in separate groups as they are in the larvae.

Ips spp.

Because of the larger number of distinct groups of caeca in the genus *Ips,* the data are presented in a separate table. Column 1 of Table II refers to the natural groups of species according to Hopping (1963).

The typical pattern in larvae of the genus *Ips* (Fig. 41) is a row of globular caeca on either side of the midgut, each row preceded by two groups of elongate

caeca, designated as first and second groups, the second being the most cephalad. The globular caeca may be strictly lineal, or the row may become irregular tending to double, particularly at the anterior end. The adults (Fig. 42) have a similar arrangement of globular caeca. Some adults have the elongate caeca in the first group on opposite sides of the midgut, but in most cases these have merged to form one group, and the figures in Table II represent the total caeca for the group. The second group is divided into three relatively distinct subgroups spaced about the circumference of the midgut. One subgroup usually has fewer caeca than the other two.

The two species in Group I, *concinnus* and *mexicanus,* differ from the remaining *Ips* species in that the second elongate group is lacking in the larvae (Fig. 43). The only differences I found among the remaining species were in numbers of caeca, and these occurred mostly in the adults. No characteristics of the gastric caeca that might be correlated with any particular natural grouping other than Group I are apparent. Usually, when the number of globular caeca is large, they are crowded at the anterior end of each row into a band 2-3 wide (Fig. 44) in contrast to the more lineal and regular arrangement in species with a smaller number as in Fig. 42.

Pityokteines sparsus

Both the larvae and adults have a similar pattern, a row of globular caeca on either side of the midgut preceded by a group of elongate caeca as in Fig. 45. The average number of globular ones is 9 (range 7-12) for the larvae and 8 (range 7-10) for the adults. The elongate caeca average 2 (range 1-3) and 3 (range 2-4) for larvae and adults respectively.

Orthotomicus spp.	Larva		Adult	
	Globular	Elongate	Globular	Elongate
Orthotomicus caelatus	14 (10-17)	- 4 (2-7)	16 (10-22)	- 4 (2- 7) (2 groups)
" *erosus*	14 (12-18)	- 5 (4-6)		
" *latidens*	12 (10-14)	- 2 (1-3)	16 (14-17)	- 9 (9-10) (1 group)

The pattern of gastric caeca in this genus is very similar to that in the genus *Ips* except that only one anterior group of elongate caeca is present in both larvae and adults. The globular caeca in the larvae are in a row along opposite sides of the midgut, each row preceded by a group of elongate caeca (Fig. 46). In the adult (Fig. 47) the elongate caeca tend to merge on one side to form one group instead of two, and in such cases, the total number is, of course, higher than the average figure of 4 given for separate groups. In this respect the situation is similar to the first anterior group in *Ips.*

Anisandrus sp.

The larvae have a row of globular caeca, average 4 (range 3-5), on either side of the midgut, each row preceded by a single elongate caecum (Fig 50). The adults have 2-4 semi-globular caeca per row also preceded by a single elongate one (Fig. 51). The elongate caecum is slightly branched in some specimens, and some specimens have no gastric caeca.

Dryocoetes spp.	Larva		Adult	
	Globular	Elongate	Globular	Elongate
Dryocoetes affaber	9 (7-11)	- 2 (2-3)	11 (7-12)	- 2 (2-3)
" *autographus*	10 (7-13)	- 2 (1-2)	8 (7-10)	- 4 (3-6)
" *betulae*				
" *confusus*				

TABLE II. Distribution of caeca in the genus *Ips*

Group	Species	Larva			Adult			
		Globular	Elongate Group		Globular	Elongate Group		
			1st	2nd		1st	2nd	
I	*concinnus* (2 spec.)	12(10-14)	4(3-5)					
	mexicanus	14(10-19)	4(2-7)		21(14-29)	14(7-22)	3(2-5)	
II	*emarginatus* (1 spec.)				60(57-64)	21	2	2	4
III	*plastographus*	21(16-28)	5(3-8)	4(3-6)	51(33-72)	12(6-23)	7(6-10)	5(2- 8)	8(4-14)
IV	*pini*	16(13-21)	5(3-7)	1(1-3)	34(25-46)	14(10-17)	7(5-10)	3(2- 3)	7(6- 8)
	avulsus	13(11-15)	4(3-5)	2(1-3)	17(10-25)	9(6-14)	3(1- 6)	2(0- 3)	3(1- 5)
	bonanseai	16(13-19)	4(3-6)	2(1-4)	26(13-28)	8(6-11)	3(2- 6)	2(1- 3)	3(2- 4)
V	*perroti*	13(11-19)	4(4-5)	1(1-1)	23(15-30)	6(4- 9)	1(0- 2)	1(1- 2)	1(1- 3)
VI	*perturbatus*	18(15-23)	5(3-7)	2(0-3)	23(18-30)	10(7-13)	5(5- 6)	3(3- 5)	5(3- 6)
VII	*borealis*	15(13-18)	3(2-4)	2(1-3)	15(9-21)	5(2- 9)	3(1- 5)	1(1- 2)	2(1- 5)
VIII	*amiskwiensis* (1 spec.)	14(13-15)	(3-4)	(2-3)					
IX	*confusus*	21(19-25)	6(5-8)	4(2-5)					
	lecontei	14(12-18)	5(3-7)	3(0-5)	46(31-61)	15(9-18)	9(7-10)	3(1- 6)	9(7-11)
	cribricollis	17(14-20)	4(3-6)	3(1-5)	30(22-36)	11(9-14)	5(3- 7)	4(3- 4)	6(5- 8)
	grandicollis	21(17-24)	5(3-7)	2(1-3)	50(42-64)	21(17-27)	8(7-10)	2(1 3)	9(6-11)
X	*calligraphus* (1 spec.)				82(77-87)	11	7	8	9

TABLE III: DISTRIBUTION OF CAECA IN THE FAMILY SCOLYTIDAE

Subfamily	Tribe	Genera	Species	Types of Gastric Caeca									
				Globular only		Globular + Elongate		Elongate only		Intermediate		None	
				A	L	A	L	A	L	A	L	A	L
SCOLYTINAE –	SCOLYTINI	1	6					●	●				
HYLESININAE –	CRYPTURGINI	1	1			●	●						
	HYPOBORINI	1	1			●	●						
	POLYGRAPHINI	1	1					●			●		
	HYLURGINI	3	12					●	●				
	HYLESININI	4	7					●	●		●		
	HYLASTINI	2	6					●	●				
IPINAE –	XYLOTERINI	3	6		●			●					
	CORTHYLINI	1	4									●	●
	PITYOPHTHORINI	4	12			●	●						
	IPINI	4	22			●	●						
	XYLEBORINI	1	1			●	●						
	DRYOCOETINI	1	4			●	●						
		27	83										

A – Adult L – Larva

The pattern of gastric caeca is the same for the four species although the number of specimens of *betulae* and *confusus* was only sufficient to show the similarity to the other two species. The larva of *autographus* (Fig. 52) has a row of globular caeca on opposite sides of the midgut, each row preceded by a small group of elongate caeca. The adult has the same arrangement, but there are a few more elongate caeca. These also have a tendency to merge into one group occupying about one-half of the circumference of the midgut.

Discussion

The different types of gastric caeca and the patterns of distribution have been described and illustrated for 83 species of bark beetles representing 27 genera. Can this information be applied to taxonomic problems and if so at what level?

When the caecal arrangements of the species are viewed in terms of tribal or subfamily characteristics (Table III), it is evident that there is a tendency towards certain types of caeca within the tribes forming a subfamily. However, there is enough variability to limit definite conclusions in this regard and, in addition, only one genus has been examined in several of the tribes. At the subfamily and tribal levels then, gastric caeca could be used as useful taxonomic tools only when considered with other characters.

At the species level, the type and arrangement of caeca is, in most cases, similar in both larval and adult stages although differences in number occur. The chief contradiction to this is in the genus *Trypodendron,* tribe Xyloterini, which has globular caeca in the larvae and elongate ones in the adult. The other two exceptions are more relative than absolute. Caeca of larvae of *Polygraphus rufipennis,* tribe Polygraphini, and of *Chramesus hicoriae,* tribe Hylesinini, are considered atypical of an easily recognized globular or elongate type, and so are classed as intermediate. In addition to the close anatomical agreement between stages, there is also good agreement as to types of caeca between species of the same genus.

I have been unable, as yet, to determine if the caecal pattern can be used effectively at the species level, although differences in the number of gastric caeca between species do occur. For instance, 10 of the 14 species in the genus *Dendroctonus* were examined. Three species, *brevicomis* (Figs. 8, 9), *adjunctus* (Fig. 10), and *frontalis* (Fig. 11), have small numbers of gastric caeca, particularly in the larvae, and the remainder have large numbers of caeca as in *obesus* (Figs. 14 and 15). Differences in the numbers of caeca occur among species in the genera *Ips, Hylurgops,* and *Leperisinus* as well.

In particular cases, the caecal patterns can be used to support classifications arrived at by other methods, and to indicate a need for further study in other directions. As evidence of this, consider the following situation. Hopping (1963) revised the North American species of the genus *Ips* and in so doing transferred *I. latidens* to the genus *Orthotomicus* as *O. latidens.* Wood (1966) believes that the chief character of the adult on which Hopping based his transfer of *latidens* from *Ips* is too unreliable, and accordingly he places it back in *Ips.* I examined the gastric caeca of 16 species of *Ips* and, in 14 of them, the caecal pattern is of the general type shown for *I. pini* (Figs. 41 and 42). Note particularly the two groups of elongate caeca. On the other hand, in two species of *Orthotomicus* that I examined, *caelatus* and *erosus,* the larvae have only one group of elongate caeca as shown in Fig. 46. The adults of *caelatus* (Fig. 47) similarly have only one group of elongate caeca but, unfortunately no adults of *erosus* were suitable for dissection. The caecal pattern of *O. latidens,* both in the larva (Fig. 48) and in the adult (Fig. 49), also shows only the one anterior group of elongate caeca and therefore conforms to the pattern found in the genus *Orthotomicus* rather than in

the genus *Ips*. This would seem to be good evidence substantiating Hopping's decision. Schedl (1964) grouped most of the genera of the tribe Ipini into the one genus *Ips* De Geer in preparing a revision of the Scolytidae. Wood (1966) thinks that a more detailed and extensive study of all possible anatomical parts showing variation should be completed before such a step is taken, but he indicates that, following this, some of the genera in the tribe, including *Orthotomicus,* will almost certainly fall into synonomy. In the meantime, he prefers to recognize them as distinct genera. The characteristics of the gastric caeca of *Orthotomicus* and *Ips* as described in this paper certainly should be one of the variable factors considered in such a study, as well as other features of the anatomy of the larvae and pupae that are currently under study.

This study has indicated a feature of the genus *Ips* which is worthy of further consideration. Larvae of *I. mexicanus* (Fig. 45) and *I. concinnus* have only one anterior group of elongate caeca, and, in this respect, are similar to members of the genus *Orthotomicus*, and quite different than the remainder of the *Ips* species examined. Perhaps this variation is sufficient to warrant re-examination of the generic status of these two species from additional points of view.

Studies of the internal anatomy may have some application at the family level. Larvae of the families Scolytidae and Curculionidae cannot be separated morphologically except in particular instances where only a few species in each family are involved. The characters found useful in these situations have failed when applied to entire families. This factor, as well as certain aspects of adult morphology, has prompted some workers, notably Crowson (1955) to question the status of the two families as presently constituted. Chararas (1957) did a comparative study of the anatomy of species of Cossonini (Curculionidae) and Scolytidae, including the internal anatomy. The gastric caeca in the larvae and adults of the seven species of bark beetles represented the same types and patterns that I found. He also found that there was only the elongate type in the Cossonini compared to the two types in Scolytidae. The gastric caeca in species of *Pissodes* (Curculionidae) as well as the weevil *Sternochaetus lapathi* (L.) that I have examined are also the elongate type. It is possible that a more extensive coverage of additional species of weevils and bark beetles would be useful in determining the relationships between these families. Perhaps such a study might also be of some help in the vexing problem of deciding if a certain specimen is a bark beetle or a weevil.

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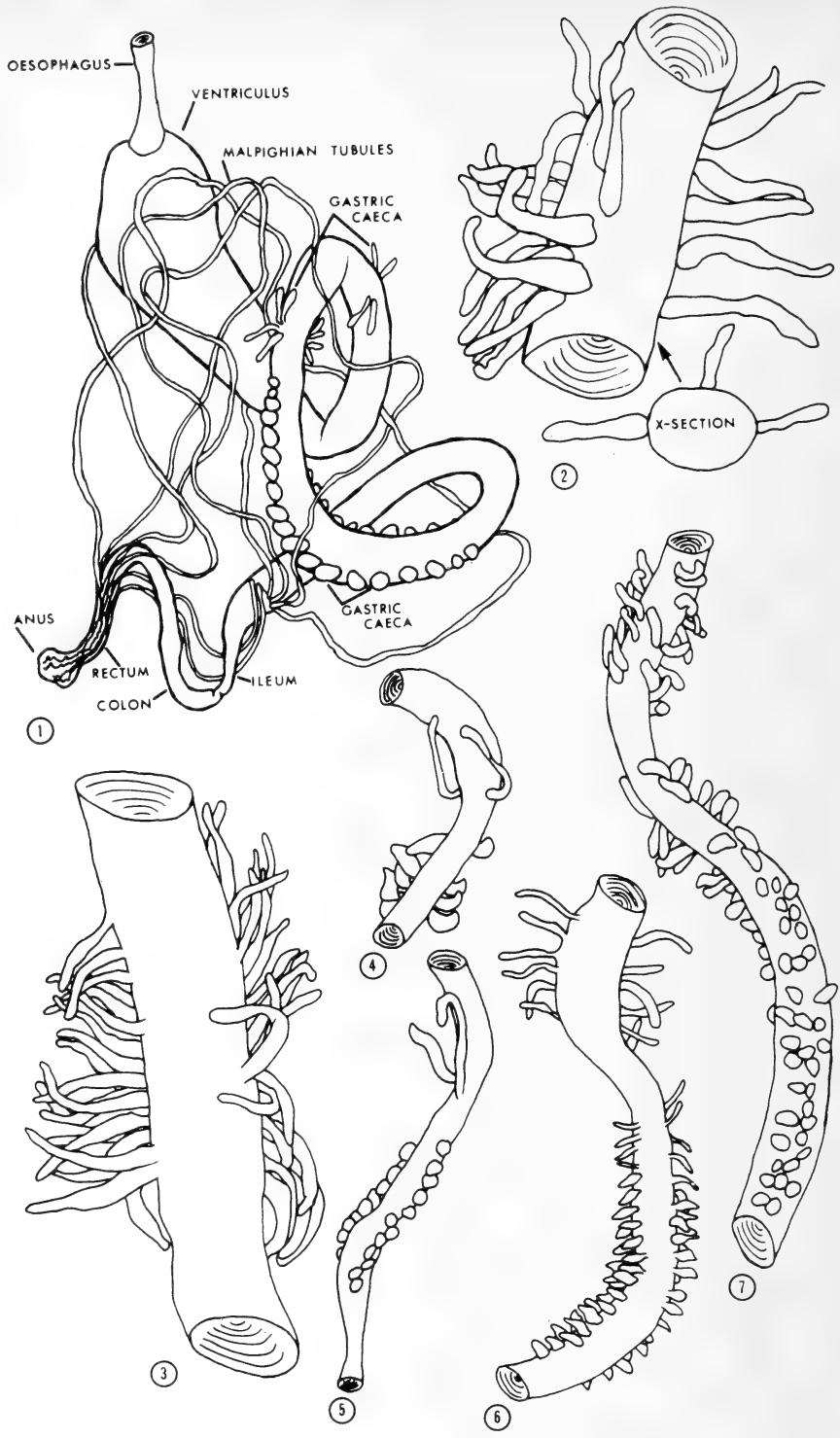
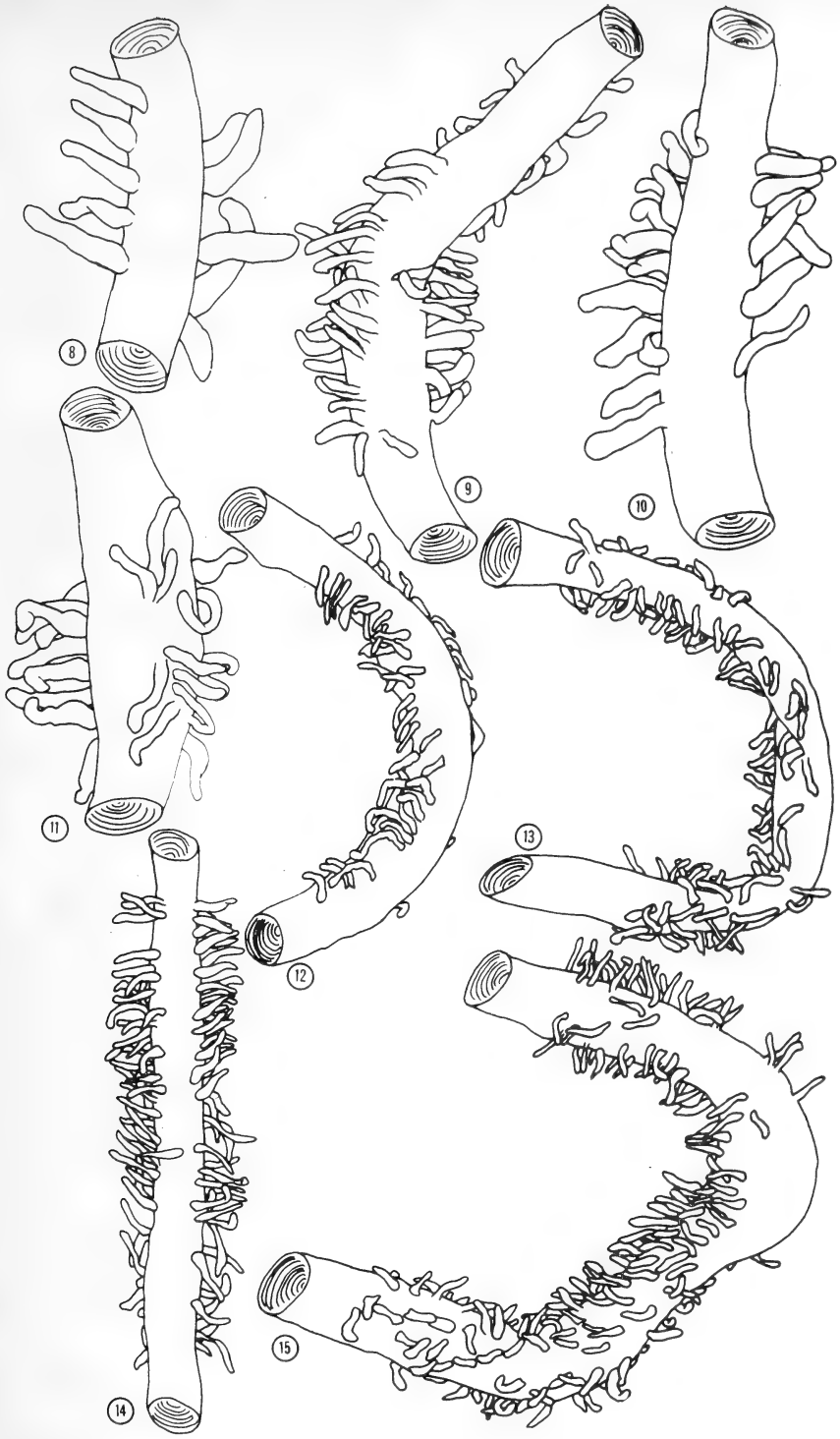
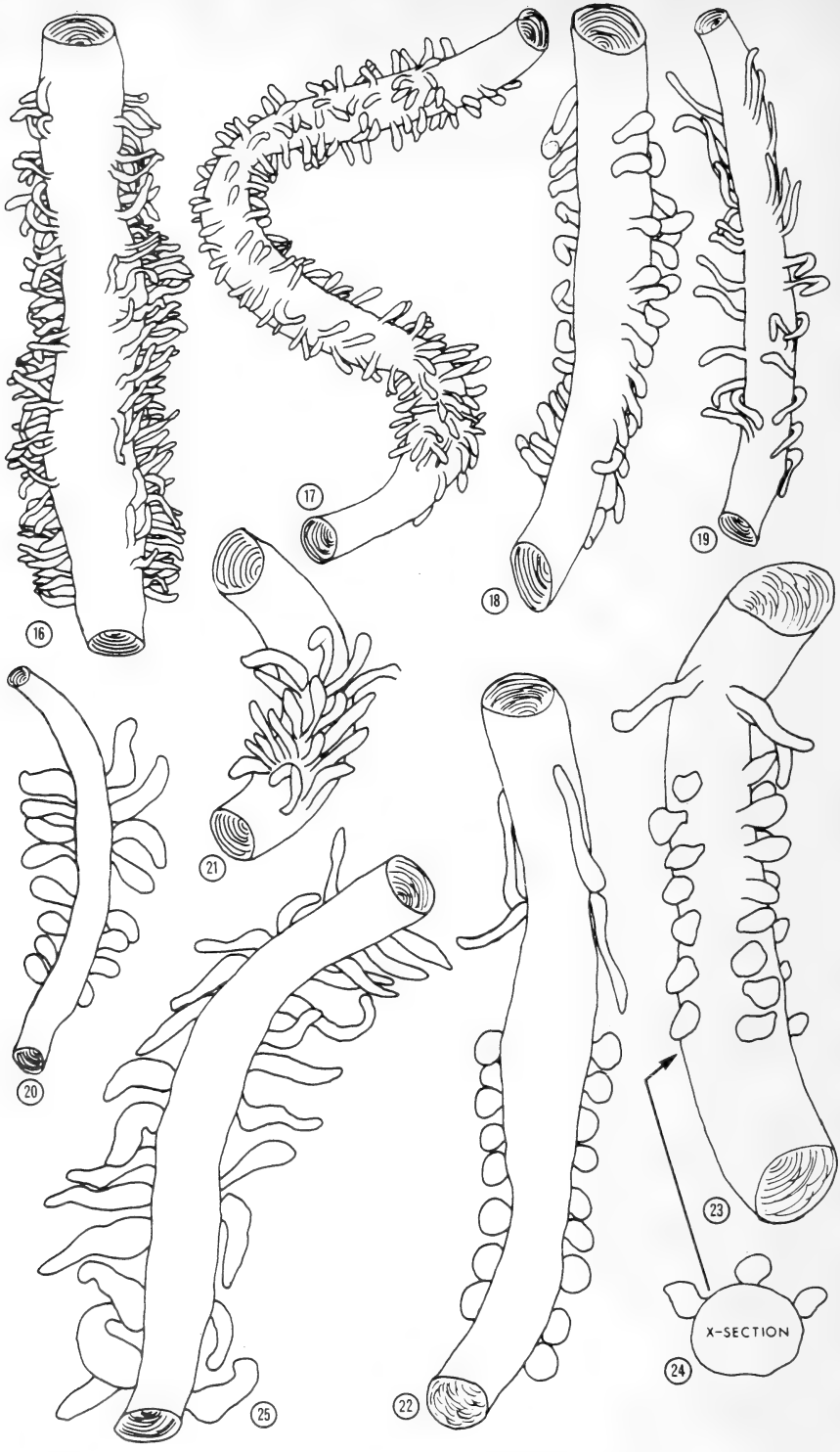


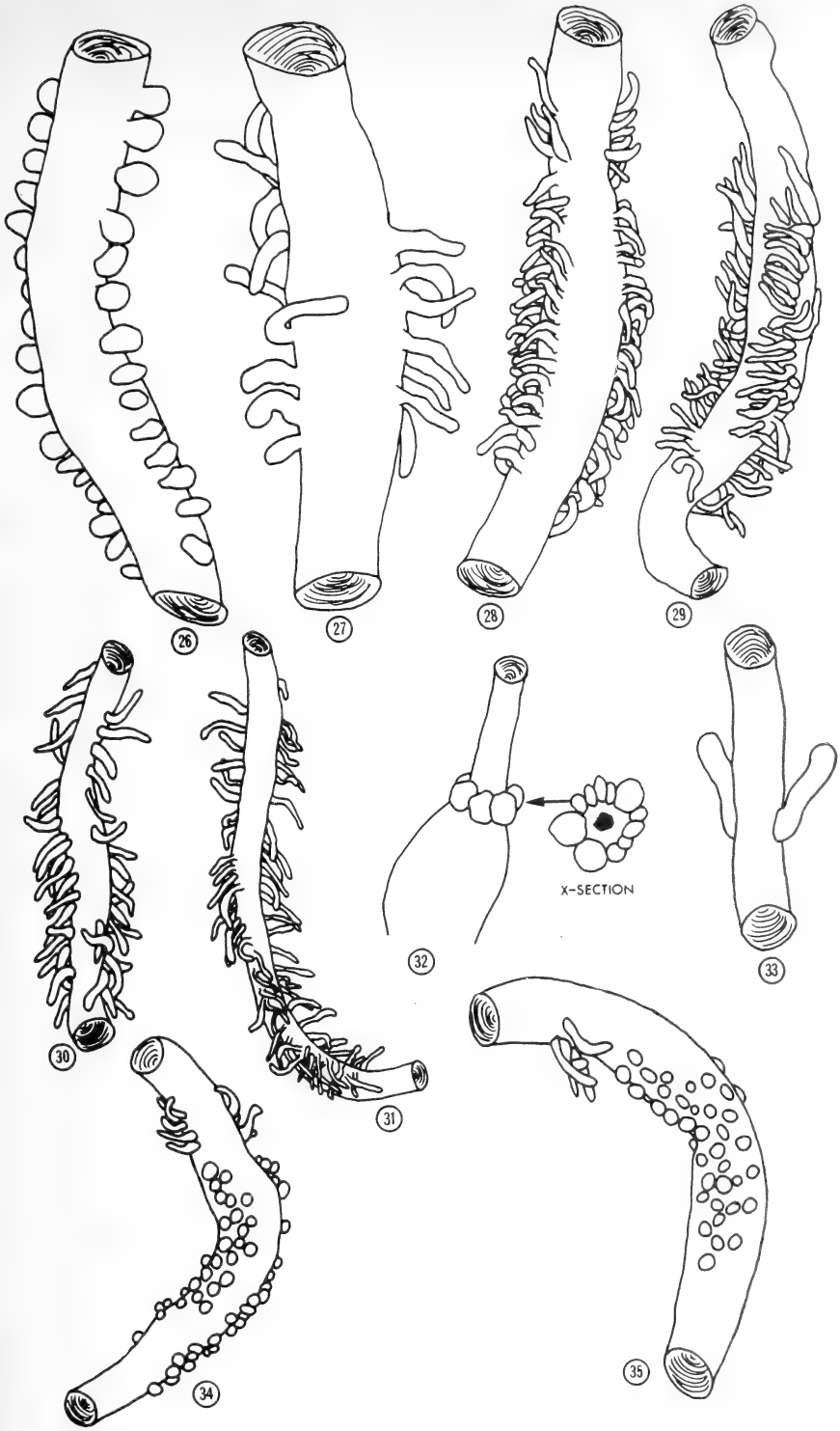
FIGS. 1-7. 1, Entire alimentary canal of larva of *Ips pini*. 2-7, Gastric caeca on midgut: 2-3, *Scolytus multistriatus*, 2, larva, 3, adult; 4, *Crypturgus borealis* larva; 5, *Liparthrum arizonicum* larva; 6-7, Polygraphus rufipennis; 6, larva, 7, adult.



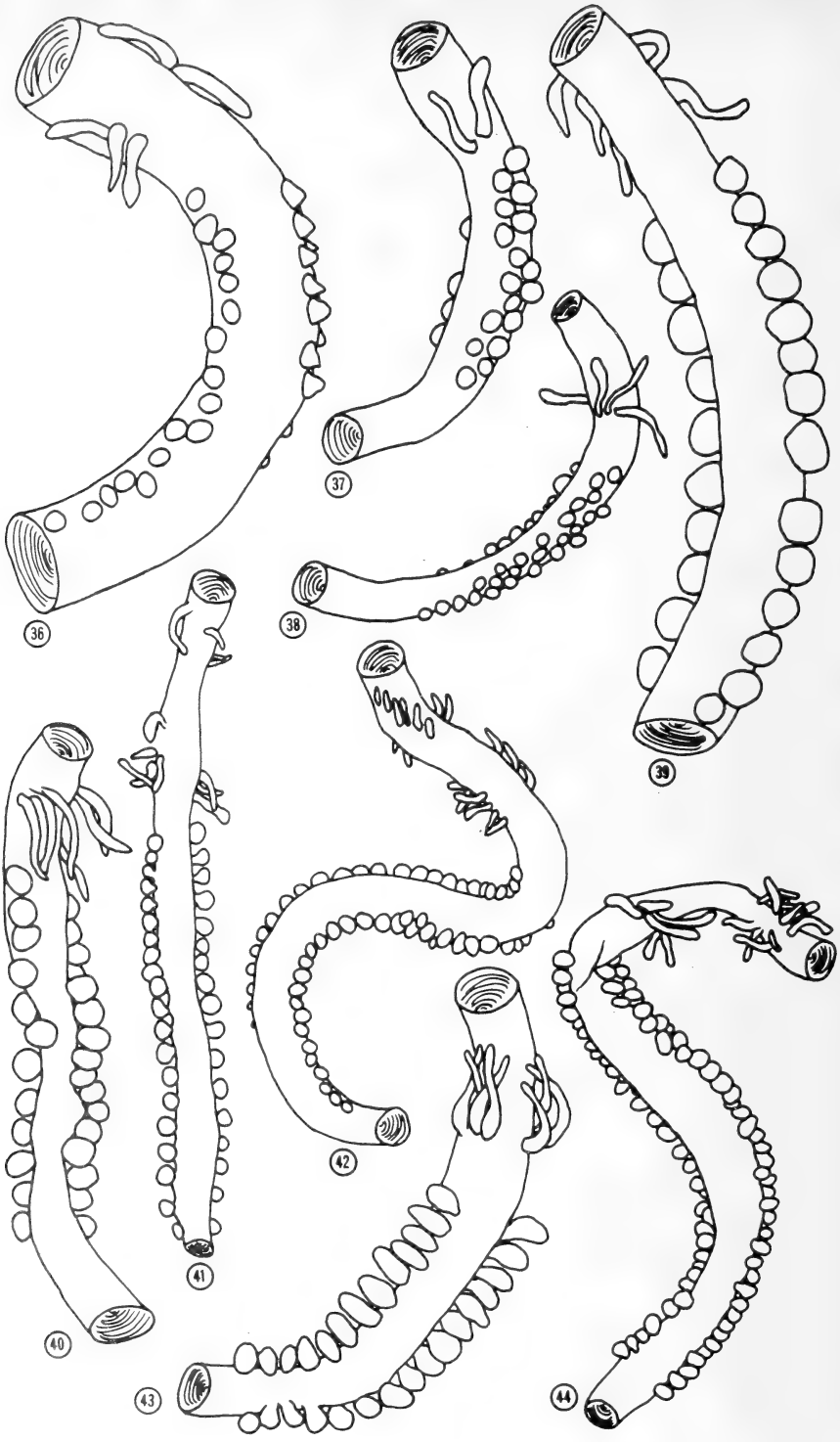
FIGS. 8-15. Gastric caeca on midgut: 8-9, *Dendroctonus brevicomis,* 8, larva, 9, adult; 10, *Dendroctonus adjunctus* larva; 11, *Dendroctonus frontalis* larva; 12-13, *Dendroctonus ponderosae,* 12, larva, 13, adult; 14-15, *Dendroctonus obesus,* 14, larva, 15, adult.



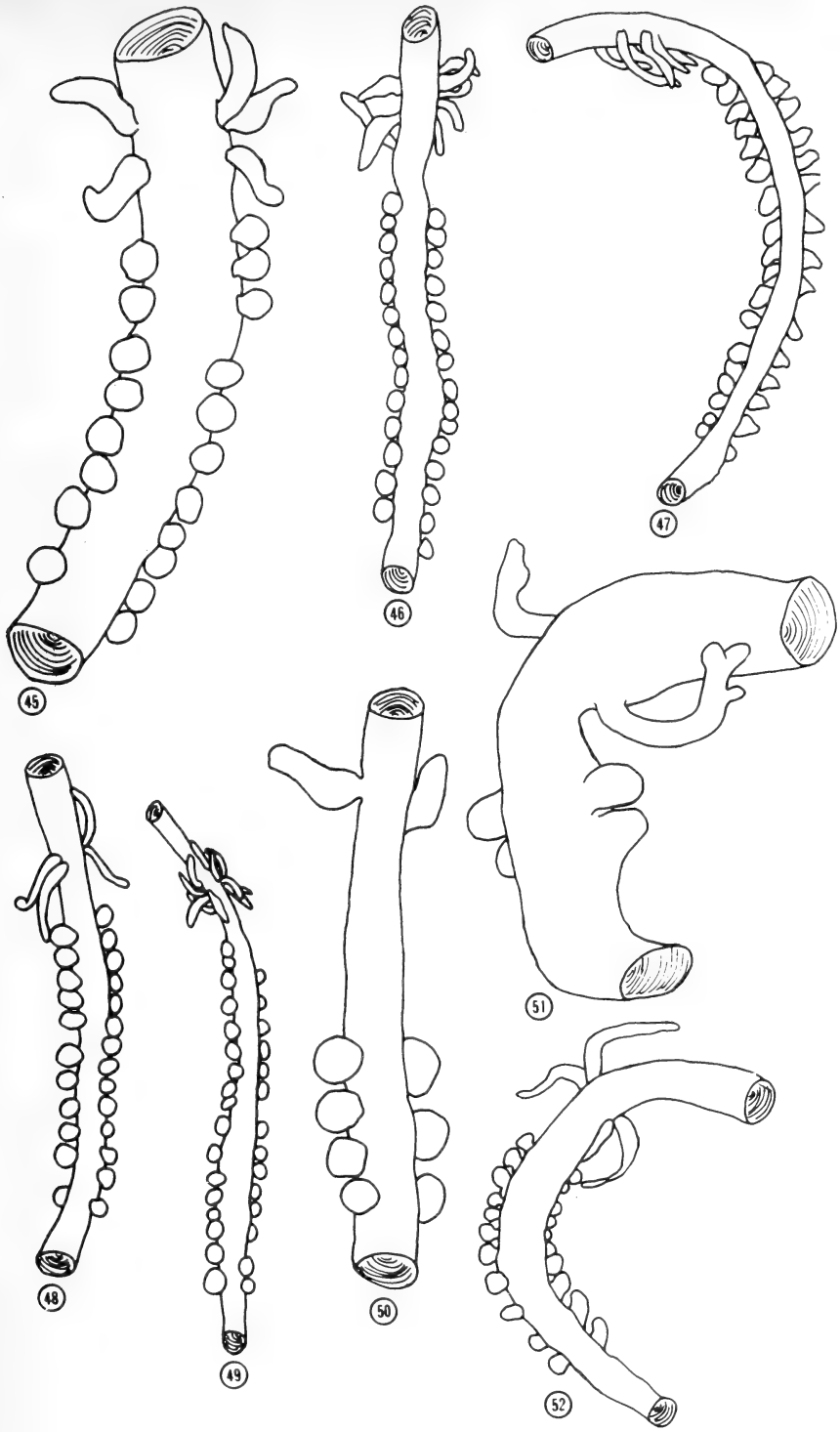
FIGS. 16-25. Gastric caeca on midgut: 16-17, *Dendroctonus valens,* 16, larva, 17, adult; 18-19, *Hylurgopinus rufipes,* 18, larva, 19, adult; 20-21, *Chramesus hicoriae,* 20, larva, 21, adult; 22-24, *Phloeotribus piceae,* 22, larva, 23-24, adult; 25, *Phloeosinus canadensis* larva.



FIGS. 26-35. Gastric caeca on midgut: 26-27, *Leperisinus aculeatus,* 26, larva, 27, adult; 28-29, *Hylurgops pinifex,* 28, larva, 29, adult; 30-31, *Hylastes porculus,* 30, larva, 31, adult; 32-33, *Trypodendron lineatum,* 32, larva, 33, adult; 34-35, *Conophthorus coniperda,* 34, larva, 35, adult.



FIGS. 36-44. Gastric caeca on midgut: 36, *Pseudopityophthorus micans,* larva; 37-38, *Pityophthorus puberulus,* 37, larvae, 38, adult; 39-40, *Pityogenes hopkinsi,* 39, larva, 40, adult; 41-42, *Ips pini,* 41, larva, 42, adult; 43, *Ips mexicanus,* larva; 44, *Ips grandicollis,* adult.



FIGS. 45-52. Gastric caeca on midgut: 45, *Pityokteines sparsus,* larva; 46-47, *Orthotomicus caelatus,* 46, larva, 47, adult; 48-49, *Orthotomicus latidens,* 48, larva, 49, adult; 50-51, *Anisandrus* sp., 50, larva, 51, adult; 52, *Dryocoetes autographus,* larva.

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A STUDY OF THE POPULATION OF INSECTS EMERGING AS ADULTS FROM SPETTIGUE'S POND AT LONDON, ONTARIO

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Introduction

During the summer of 1960 a study was undertaken of the population of insects emerging as adults from Spettigue's Pond in London, Ontario. It is one of three "kettle lakes" situated at the northeast corner of Wellington Road and the road separating what were Concessions 1 and 2 of the Township of Westminster before this area was annexed to the City of London in 1961. The three ponds are South Walker, Spettigue's and Saunders Ponds. Accounts of insects emerging from South Walker Pond and Saunders Pond are given by Judd (1960, 1964) and of harvestmen and spiders trapped on Spettigue's Pond by Judd (1961b). Spettigue's Pond is about 1000 feet long in the east-west direction and lies in a small depression ringed by low hills (Fig. 1). It is entirely surrounded by woods and access to it is by footpaths through the woods. In spring, rain and melting ice cause flooding around the pond outward to about the line indicating 900 feet above sea level. An account of the vegetation surrounding the pond is given by Judd (1961b). In 1960 floating vegetation extended from the shore to the line indicated by A - A- A in Figure 1.

Methods

Insects were trapped in a tent-trap set out on the water at each of five collection sites (Fig. 1). Each trap was built to enclose four square feet of water surface (Judd 1957) and was anchored in one position during the course of the investigation.

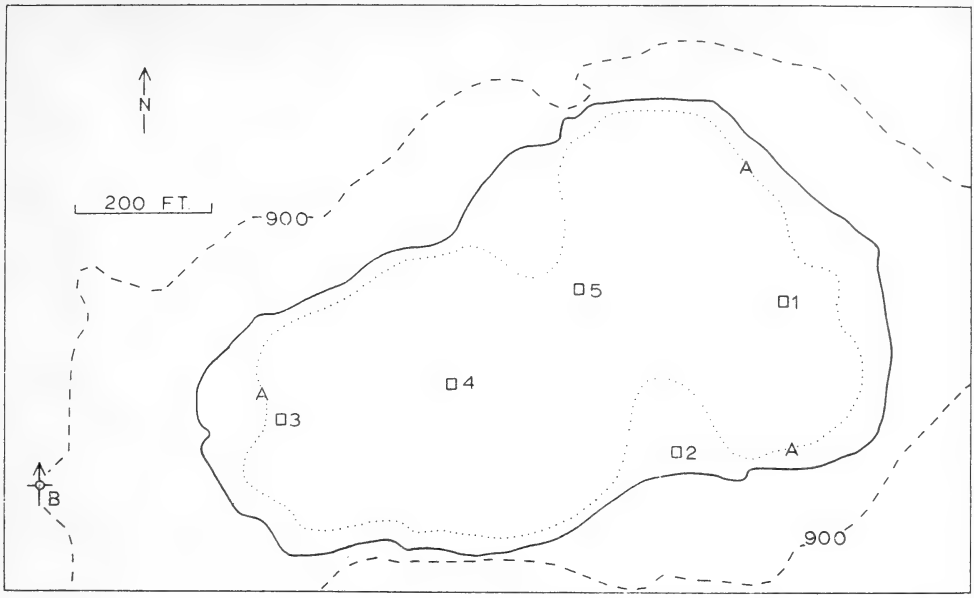

FIG. 1. Map of Spettigue's Pond showing location of the five tent-traps (squares, 1-5). A-A-A, outer limits of floating vegetation; B, location of co-ordinate point 42°57' N 81°13'W; 900-900, contour line 900 feet above sea level.

The pond was covered with ice until April 6. On April 13 the south shore and adjacent water were still covered with ice and snow, the north part of the pond had open water for a distance of ten feet from shore, and floating ice occupied the centre of the pond. On April 20 all remaining ice melted and on April 21 the five traps were anchored in position. Trap 1 was placed on water 17 feet deep and 150 feet from the east shore, Trap 2 on water 3 feet deep and 25 feet from the south shore, Trap 3 on water 4 feet deep and 100 feet from the west shore, Trap 4 on water 22 feet deep and 200 feet from the north shore and Trap 5 on water 7 feet deep and 200 feet from the north shore. There was no vegetation at Traps 1 and 4. Trap 2 had in and around it leaves of *Nymphaea odorata* Ait. and *Potamogeton gramineus* L. and beneath it masses of *Chara* sp. Trap 3 was anchored just off a growth of *N. odorata, Nuphar advena* (Ait.) Ait. f. and *P. gramineus* and had beneath it masses of *Chara* sp. Trap 5 was anchored about 25 feet from a growth of *N. odorata* and *P. gramineus* and had beneath it masses of *Chara* sp. The traps were removed from the water on October 5.

The traps were visited daily by boat and the insects caught in them were collected as described by Judd (1957). The depth of the water at each trap was recorded daily, starting on April 21. The water level fell gradually during the season and by October 5 was 14 inches less than the depth measured on April 21 when the traps were set in position.

The various group of insects were identified by the following taxonomists (ERI—Entomology Research Institute, Canada Department of Agriculture, Ottawa; ROM—Royal Ontario Museum, Toronto; ARS—Agricultural Research Service, Department of Agriculture, Beltsville, Maryland): J. G. Chillcott, ERI (Ephydridae, Muscidae, Sphaeroceridae); R. deRuette, ERI (Coleoptera); F. P. Ide, University of Toronto (Ephemeroptera); L. A. Kelton, ERI (Mesoveliidae); W. R. M. Mason, ERI (Braconidae, Ichneumonidae); C. D. Miller, ERI (Pteromalidae); E. G. Munroe, ERI (Lepidoptera); G. E. Shewell, ERI

(Simuliidae); J. R. Vockeroth, ERI (Dolichopodidae, Phoridae, Sciaridae); E. M. Walker, ROM (Odonata); G. B. Wiggins, ROM (Trichoptera); W. W. Wirth, ARS (Ceratopogonidae, Chironomidae). Culicidae were identified by the writer, using appropriate keys. During the summer of 1960 Mr. M. S. Beverley made collections at the traps, sorted out specimens and recorded data. The Department of Veterans Affairs of the Federal Government, on whose property Spettigue's Pond lies, granted permission for the study to be undertaken. The project was supported by funds from the Ontario Research Foundation. All specimens are retained in the Department of Zoology, University of Western Ontario, except those noted as "kept" in the institutions in which they were identified.

Account of Total Catch

The numbers of the various insects in the eight orders collected are presented in Table 1. During the trapping period, April 21 to October 5, 6,926 were captured. Most of the insects are species whose larvae or nymphs live submerged and whose adults emerge from the water, but a few, e.g. Mesoveliidae and some beetles, are insects that dwell on emergent aquatic vegetation. The great majority (96.56%) were Diptera and among these the Chironomidae predominated (77.24%). Next in point of numbers (18.5%) were Culicidae. The other families of Diptera and other orders were present in much smaller numbers. The area of water surface covered by each trap was 4 square feet, so the total area from which insects were collected was five times this area, 20 square feet. The average yield for the season was 346 insects per square foot. The average catch per square foot for the five traps, respectively, was 386, 332, 547, 160 and 307. The least productive site was at Trap 4 where the water was deepest, the trap was farthest from shore and no vegetation was present. The other four traps were more productive, with Trap 3 being most productive, having a combination of shallow water, closeness to shore and the greatest accumulation of species of aquatic plants nearby.

Account of Species Collected

The five bracketed numbers following the name of each species are the numbers of that species trapped, respectively, in the five traps.

EPHEMEROPTERA

Baetidae

Baetis intercalaris McD. — 22 ♀♀ (1:1:11:2:7); May 5, June 6-22, July 14, August 1-11. This species was previously trapped on Medway Creek at Arva by Judd (1962).

Callibaetis ferrugineus Walsh — 4♂♂, 2 ♀♀ (0:2:3:0:1); May 24-30, June 19, 20, July 14. This species was also trapped on South Walker and Saunders Ponds (Judd 1960, 1964).

Caenis (? *simulans* McD.) — 2 mayflies (1:1:0:0:0:); August 8, 20. *C. simulans* was trapped by Judd (1953) on the Dundas Marsh.

ODONATA

Coenagriidae

Eight damsel-flies (all kept) (0:1:3:1:3); June 2-13, August 18. The insects were in their teneral condition and thus were unidentified, except for two *Enallagma hageni* (Walsh).

TABLE 1. Number of Insects of the Eight Orders Collected in the Traps.

Group	Trap 1		Trap 2		Trap 3		Trap 4		Trap 5		Diptera		Total No.	% of Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	% of Diptera		
Ephemeroptera	2	6	4	12	14	43	2	6	8	33			30	0.45
Odonata	0	0	1	13	3	37	1	13	3	37			8	0.09
Trichoptera	54	42	8	10	26	21	7	7	22	20			117	1.75
Lepidoptera	0	0	1	50	0	0	0	0	1	50			2	0.03
Hemiptera	23	56	0	0	8	24	4	12	3	8			38	0.57
Coleoptera	2	25	6	75	0	0	0	0	0	0			8	0.09
Diptera														
Culicidae	335	33	68	7	163	14	288	26	241	20	1,095	18.50		
Chironomidae	1,035	22	1,123	24	1,852	34	284	5	873	15	5,167	77.24		
Ceratopogonidae	10	5	93	45	33	17	28	16	32	17	196	1.96		
Sciaridae	0	0	0	0	0	0	1	100	0	0	1	0.01		
Dolichopodidae	0	0	1	50	1	50	0	0	0	0	2	0.02		
Phoridae	0	0	0	0	1	100	0	0	0	0	1	0.01		
Simuliidae	0	0	0	0	0	0	1	50	1	50	2	0.02		
Ephydridae	71	33	20	9	77	35	19	9	31	14	218	2.18		
Sphaeroceridae	0	0	1	25	2	50	0	0	1	25	4	0.04		
Muscidae	0	0	0	0	0	0	0	0	2	100	2	0.02		
Total Diptera	1,451	22	1,306	20	2,129	30	621	10	1,181	18	6,688	100.00	6,688	96.56
Hymenoptera	11	28	3	9	6	18	6	18	9	27			35	0.46
Totals	1,543	22	1,329	20	2,186	30	641	10	1,227	18			6,926	100.00

TRICHOPTERA

Hydroptilidae

Orthotrichia cristata Morton — 4 ♂♂, 4 ♀♀ (kept) (0:0:0:2:6); June 6-18, August 12. Ross (1944) records the occurrence of this species in Illinois and Michigan and reports that adults emerge from June to August.

Hydroptila sp. — 2 ♀♀ (kept) (0:0:0:1:1); June 11, August 6.

Hydropsychidae

Nyctiophylax vestitus (Hagen) — 35 ♂♂, 24 ♀♀ (kept) (53:2:0:0:0); June 28-August 12, maximum July 13 (13 insects). This species was also trapped on South Walker Pond (Judd 1960) and Saunders Pond (Judd 1964) though in lesser numbers than on Spettigue's Pond.

Psychomyiidae

Polycentropus interruptus (Banks) — 13 ♂♂, 23 ♀♀ (kept) (0:3:21:4:8); June 4-July 6, maximum June 7 (7 insects). This species was also trapped on South Walker Pond (Judd 1960) and Saunders Pond (Judd 1964).

Leptoceridae

Athripsodes sp. — 1 caddis-fly (kept) (0:0:0:0:1); July 14.

Oecetis inconspicua (Walker) — 1 ♂, 7 ♀♀ (kept) (0:3:4:0:1); June 6-30, August 19, 21. This species was also trapped on South Walker Pond (Judd 1960) and Saunders Pond (Judd 1964).

Phryganeidae

Agrypnia vestita (Walk.) — 1 ♂, 1 ♀ (kept) (0:0:1:0:1); June 5, 9. This species was also trapped on Saunders Pond (Judd 1964).

Agrypnia straminea Hagen — 1 ♀ (kept) (1:0:0:0:0:); September 18. This species was also trapped on Saunders Pond in early fall (Judd 1964).

LEPIDOPTERA

Pyralidae

Paraponyx badiusalis Wlk. — 1 ♀ (0:0:0:0:1); August 26. This species was also collected by Judd (1953) on the Dundas Marsh. The food of the larva is *Potamogeton* (Judd 1953) which grew near Trap 5 in which the moth emerged.

Munroessa serralinealis B. and B. — 1 ♀ (0:1:0:0:0); September 1. Usinger *et al.* (1956) record species of this genus as aquatic insects.

HEMIPTERA

Mesoveliidae

Mesovelia mulsanti White — 38 bugs (23:0:8:4:3); June 14-September 13. This species was also trapped on South Walker Pond and Saunders Pond (Judd 1960, 1964).

COLEOPTERA

Carabidae

Bembidion sp. — 1 beetle (0:1:0:0:0); August 21. Beetles of this genus were also collected at other situations in London along the Thames River by Judd (1957).

Chrysomelidae

Donacia sp. — 1 beetle (0:1:0:0:0); August 29. A beetle of this genus was also trapped on Saunders Pond (Judd 1964). Marx (1957) records that the host plants of beetles of this genus include various species of *Nymphaea* and *Potamogeton,* both of which were present in Trap 2 where the beetle emerged.

Dibolia borealis Chev. — 1 beetle (0:1:0:0:0); May 15. Blatchley (1910) records that this beetle occurs on plantain in the leaves of which the larvae develop. The specimen may have been washed beneath the trap and survived to crawl up inside.

Curculionidae

Calendra minima Hart — 2 beetles (1:1:0:0:0); May 10, 23. A beetle of this genus was trapped on South Walker Pond (Judd 1960).

Bagous americanus Lec. — 2 beetles (0:2:0:0:0); July 3, August 5. This species was also trapped on Saunders Pond (Judd 1964). McGaha (1954) records that the host plant of this species is *Nymphaea odorata,* a plant which grew around Trap 2 where the beetles were trapped.

Eubrychiopsis lecontei Dietz — 1 beetle (1:0:0:0:0). Blatchley and Leng (1916) record that this species occurs in Ontario and that weevils in the tribe to which it belongs occur mostly on herbs in low,wet places.

DIPTERA

Culicidae

Chaoborus punctipennis (Say) — 247 ♂♂, 532 ♀♀ (185: 63:155:164:212); June 3 - September 18, maxima June 21 (33 insects), July 21 (86 insects), August 20 (18 insects), September 15 (13 insects). Four maxima of emergence of this species were also noted on South Walker Pond and Saunders Pond by Judd (1960, 1964).

Chaoborus flavicans (Meigen) — 152 ♂♂, 164 ♀♀ (150:5:8:124:29); June 2-September 16, maxima June 21 (20 insects), July 26 (23 insects), August 26 (10 insects), September 15 (4 insects). Four maxima of emergence of this species were also noted on South Walker Pond and Saunders Pond by Judd (1960, 1964).

Chironomidae

Pentaneura monilis (L.) — 340 ♂♂, 377 ♀♀ (71:208:253:7:178); May 8 - September 17, maxima May 28 (26 insects), July 13 (21 insects), September 3 (15 insects). This species was also collected by Judd (1960, 1964) on South Walker Pond and Saunders Pond.

Pentaneura sp. — 20 ♂♂, 41 ♀♀ (17:14:16:2:12); May 4 - September 17.

Clinotanypus thoracicus (Lw.) — 2 ♂♂, 2 ♀♀ (0:4:0:0:0); June 30, July 7, 9, 18. This species was also collected from South Walker Pond and Saunders Pond by Judd (1960, 1964) in similarly small numbers in June and July.

Pelopia punctipennis (Mg.) — 1 ♂ (1:0:0:0:0); July 4. This species was collected in larger numbers from the Thames River (Judd 1957) and Saunders Pond (Judd 1964).

Pelopia stellata (Coq.) — 2 ♂♂, 3 ♀♀ (3:0:1:0:1); July 31 - August 6. This species was collected also from South Walker Pond and Saunders Pond by Judd (1960, 1964).

Procladius bellus (L.) — 239 ♂♂, 241 ♀♀ (270:26:55:47:82); May 13-September 10, maxima May 25 (48 insects), July 21 (20 insects). This species was also caught in large numbers on the Thames River, South Walker Pond and Saunders Pond by Judd (1957, 1960, 1964).

Procladius culiciformis (L.) — 269 ♂♂, 564 ♀♀ (177:93:256:130:177); May 4 - September 16, maxima May 17 (42 insects), July 16 (33 insects), August 24 (7 insects). This species was also trapped on the Thames River, South Walker Pond and Saunders Pond by Judd (1957, 1960, 1964).

Hydrobaenus sp. — 4 ♂♂, 5 ♀♀ (1:0:2:1:5); April 23 - May 25.

Cricotopus bicinctus (Meigen) — 6 ♂♂, 1 ♀ (0:3:0:3:1); May 23, June 22, 28, August 12, 22, September 8. This species was also collected on the Thames River, South Walker Pond and Saunders Pond by Judd (1957, 1960, 1964).

Polypedilum fallax (Joh.) — 12 ♂♂, 30 ♀♀ (0:40:2:0:0); July 26 - September 14, maximum July 26 (24 insects). This species was also trapped on the Thames River and Saunders Pond by Judd (1957, 1964). Its concentration in Trap 2 is in accord with the report of McGaha (1952) that this species feeds on species of *Nuphar,* for plants of this genus were present in Trap 2.

Polypedilum sp. — 499 ♂♂, 429 ♀♀ (123:314:347:15:129); April 23 - September 16.

Tanytarsus nigricans (Joh.) — 2 ♂♂, 20 ♀♀ (1:2:13:5:1); May 4 - September 16. This species was also trapped on the Thames River and Saunders Pond by Judd (1957, 1964).

Tanytarsus subtendens Townes — 30 ♂♂ (0:3:19:6:2); May 10 - September 17. This species was also trapped on Saunders Pond by Judd (1964).

Tendipes dux (Joh. — 36 ♂♂, 29 ♀♀ (22:2:34:2:5); May 22 - August 27, maxima May 28 (7 insects), August 2 (9 insects). This species was also trapped on the Thames River, South Walker Pond and Saunders Pond by Judd (1957, 1960, 1964).

Tendipes riparius (Meigen) — 1 ♂ (0:0:1:0:0); May 28. This species was trapped in large numbers on South Walker Pond (Judd 1960).

Glyptotendipes brachialis (Coq.) — 1 ♂ (1:0:0:0:0); May 28. This species was trapped in large numbers on the Thames River (Judd 1957) and in small numbers on South Walker Pond and Saunders Pond (Judd 1960, 1964).

Glyptotendipes lobiferus (Say) 3 ♂♂, 1 ♀ (0:4:0:0:0); June 25, July 21. August 20. This species was trapped in large numbers on the Thames River (Judd 1957) and in small numbers on South Walker Pond and Saunders Pond (Judd 1960, 1964).

Microtendipes pedellus (DeGeer) — 35 ♂♂, 11 ♀♀ (20:10:3:2:10); May 8 - September 17, maxima May 22 (3 insects), August 7 (2 insects). This species was trapped on Saunders Pond (Judd 1964).

Calopsectra sp. — 795 ♂♂, 948 ♀♀ (258:388:807:58:232); May 5 - October 5, maxima May 19 (58 insects), July 15 (45 insects), September 14 (38 insects). These midges were also collected in large numbers throughout the season on the Thames River, South Walker Pond and Saunders Pond (Judd 1957, 1960, 1964).

Ceratopogonidae

Atrichopogon sp. — 2 ♀♀ (0:0:0:2:0); August 24, September 18.

Bezzia glabra Coq. — 2 ♀♀ (0:0:1:0:1); June 10, 18. This species was trapped in larger numbers on South Walker Pond and Saunders Pond (Judd 1960, 1964).

Bezzia sp. 1 — 62 ♂♂, 82 ♀♀ (15 kept) (8:80:22:20:14); May 21 - July 28, maximum May 25 (35 insects).

Bezzia sp. 2 — 2 ♂♂, 12 ♀♀ (2 kept) (1:2:10:1:0); May 28 - August 4.

Bezzia sp. 3 — 1 ♂, 4 ♀♀ (2 kept) (0:4:0:1:0); May 25, July 25 - August 2.

Culicoides pseudopiliferus Wirth and Hubert — 2 ♀♀ (1 kept) (0:1:0:1:0); May 27, June 6. This species was also collected on the Thames River (Judd 1957), the specimens being described in the account of Wirth and Hubert (1962) as a new species.

Palpomyia sp. — 8 ♂♂, 19 ♀♀ (5 kept) (1:6:0:3:17); May 7 - June 9, maximum May 24 (4 insects).

Sciaridae

Bradysia sp. — 1 ♀ (0:0:0:1:0); May 24. Flies of this genus were also trapped on the Thames River and Saunders Pond (Judd 1960, 1964).

Dolichopodidae

Hydrophorus aestuum Lw. — 1 ♂ (0:0:1:0:0); July 1. Usinger *et al.* (1956) record that flies of this genus are skaters over ponds and are found near the shores of lakes.

Campsicnemus sp. — 1 ♀ (0:1:0:0:0); July 16. Flies of this genus have also been trapped on the Thames River (Judd 1957).

Phoridae

Megaselia sp. — 1 ♀ (0:0:1:0:0); September 2. Usinger *et al.* (1956) record that a few species of flies in this family are aquatic.

Simuliidae

Simulium vittatum Zett. — 2 ♀♀ (0:0:0:1:1); June 7, July 26. This species was also trapped on Redmond's Pond (Judd 1961a).

Ephydridae

Hydrellia cruralis Coq. — 199 flies (69:13:72:18:27); June 14 - September 18, maximum September 8 (20 insects). This species was also collected in large numbers on Saunders Pond (Judd 1964).

Hydrellia griseola Fall. — 2 ♀♀ (0:0:2:0:0); June 3, August 9. This species was also trapped on the Thames River (Judd 1957).

Hydrellia pulla Cresson — 3 flies (1:1:1:0:0); August 10, 13, September 3. This species was also trapped on Saunders Pond (Judd 1964).

Notiphila loewi Cresson — 14 flies (1:6:2:1:4); June 12 - August 5, maximum July 12 (4 flies). This species was also trapped on Saunders Pond (Judd 1964). Its predominance in Trap 2 is in accord with the presence of *Nymphaea* in this trap for this plant is a food of the larvae (McGaha 1952).

Sphaeroceridae

Leptocera wheeleri Spuler — 4 flies (0:1:2:0:1); July 13, 24, August 4, September 18. This species was also trapped on South Walker Pond and Saunders Pond (Judd 1960, 1964).

Muscidae

Lispe albitarsus Stein — 2 ♀♀ (0:0:0:0:2); July 11, 12. This species was trapped on the Thames River (Judd 1957).

HYMENOPTERA

Braconidae

Chorebidia sp. — 33 wasps (8 kept) (11:1:6:6:9); May 27 - September 17, maximum September 13 (4 insects). Berg (1949) records *Chorebidia* as

parisitic on *Hydrellia cruralis*. The maximum emergence of this wasp occurred on September 13, five days later than the maximum emergence of *H. cruralis* on September 8.

Ichneumonidae

Bathythrix insula (DeGant) — 1 wasp (kept) (0:1:0:0:0); July 16. Muesebeck *et al.* (1951) report no known host of this species but record that other species of *Bathythrix* are parasites of aquatic beetles of the genus *Gyrinus*.

Pteromalidae

Eurydinota lividicorpus Grlt. — 1 wasp (0:1:0:0:0); August 3. Muesebeck *et al.* (1951) record that wasps of this species are parasitic on moths of the genus *Coleophora*.

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SYSTEMIC INSECTICIDES EVALUATED FOR TWO-SPOTTED MITE CONTROL ON GREENHOUSE CUCUMBERS

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The two-spotted mite, *Tetranychus urticae* Koch, remains a problem on greenhouse cucumbers in spite of effective materials available for its control. Foott (1965) discussed the control of mite infestations and noted that the difficulty of treating under-leaf surfaces resulted in poor control early in the season. When the leaf canopy formed above the support wires it became nearly impossible to obtain adequate coverage with spray or dust.

The use of biological control agents against the mites, as an alternative to chemical control, has received increasing attention in the past few years. A predaceous mite, *Phytoseiulus persimilis* Dosse, introduced from Chile, has been shown to be quite effective in controlling mites on greenhouse cucumbers in England (Hussey, Parr and Gould 1965). Another predaceous mite, *Typhlodromus fallacis* (Garman) has been found on greenhouse plants, and might be effective if it were introduced in a planned program.

These two species of predaceous mites will tolerate low doses of the chlorinated hydrocarbon acaricides dicofol and tetradifon. Phosphate acaricides as foliage sprays killed the two species of predaceous mites (Smith, Henneberry and Boswell 1963). The recently registered fungicide-acaricide, Morestan, has been demonstrated to be highly toxic to another *Typhlodromus* species (Downing 1966).

The use of systemic materials applied as root drenches or granules might solve the problem of coverage. This type of treatment also seemed to be the only method of chemical mite control which might be integrated with the use of predaceous mites. Systemic acaricide application to root systems has been limited and most reported studies concern cotton (Ridgeway and Gorzycki 1965). These authors found that phorate, Temik, and dimethoate were among the most promising materials against the carmine spider mite *Tetranychus cinnabarinus* (Boisduval), but phorate was taken up slowly. Baranowski (1966) found that dimethoate and Temik could be added to hydroponic solutions for roses with resultant economic control of the two-spotted mite. Temik was not as phytotoxic as dimethoate which caused defoliation at rates higher than 15 ppm. The known sensitivity of cucumbers to insecticides makes the evaluation of phytotoxicity an important part of the assessment of materials for mite control.

Materials and Methods

Candidate materials were screened by application of four concentrations as root drenches to small cucumber plants grown in sand with nutrient solutions. Six seeds (Burpee Hybrid) were planted in a 6-inch plastic pot in a greenhouse maintained at an average temperature of 68°F. When the first leaves were approximately 2 inches in width, each plant was treated with 5 ml of an aqueous solution applied to the sand at the base of the stem. All the plants in a pot served as replicates for one concentration of drench. The dosages were 0.5, 2.5, 10 and 50 mg active material per plant. When necessary, the chemicals were dissolved in acetone before the water was added, so the most concentrated solution contained 3% acetone.

Twenty-four hours after treatment three uniformly-sized leaves were taken from each pot and placed with the lower surface up, on a wet cotton pad in a

petri dish. Forty adult female mites were transferred to each leaf and mortality counts were made after a 48-hour holding period at 23°C. The remaining plants in each pot were used to evaluate the phytotoxicity a week after treatment.

Materials which were effective against the mites at levels below the minimum phytotoxic level were evaluated in tests designed to define the dosage-mortality relationships. The same methods were used as in the screening tests except that concentrations of applied materials were on a logarithmic scale with intervals of 0.25 log 5. Thus the higher range of doses was 2500, 1672, 1128, 748 and 500 micrograms per plant. Pooled data from at least three runs were analyzed by probit analysis.

Some applications of drenches or granules were made to large cucumbers. These plants were grown in soil with cultural conditions and fertilization schedule similar to those practiced by commercial growers. The drenches were applied at 100 ml per plant to plants about 5 ft high. Granules were placed in a shallow ring trench around the base of the stem and lightly covered with soil. The acaricidal activity in the leaves was assessed by cutting 3-cm discs from leaves at five levels up the plant and determining the mortality of mites held on the discs for 48 hours.

Results

The screening tests served to indicate which materials were systemic acaricides in comparison with those that were ineffective under the experimental conditions. The phytotoxicity was evaluated in terms of the estimated highest safe dosage. In Table I the compounds are listed in order of decreasing effectiveness. Generally the acaricides proved to be phytotoxic at the two higher levels. Symptoms were various degrees of chlorosis of the leaf margins and higher concentrations caused the stem to desiccate and the plants fell over.

TABLE I. Mortality of two-spotted mite in 48 hours on leaves of small cucumbers treated with various root drenches

Material	Active ingredient per plant (mg) 0.5	2.5	10	50	Highest safe dosage (mg)
Zinophos	100	100	—	—	1.0
phorate	96	100	100	100	5.0
Temik	83	100	100	—	2.5
AC 18706	86	89	95	—	1.5
AC 47470	90	96	100	99	0.5
AC 47031	94	96	93	100	1.0
dimethoate	75	100	100	100	1.0
mevinphos	43	83	100	100	2.5
demeton	9	95	99	100	2.5
AC 43064	44	34	65	92	2.5
Bayer 25141	24	91	97	—	0.5
Meta-Systox R	16	23	32	82	5.0
Tranid	2	7	74	—	1.5
diazinon	13	20	14	16	25.0
disulfoton	3	9	6	10	10.0

— Assays could not be made because of severe phytotoxicity.

Other materials tested which were even less effective than disulfoton were Baygon, Dupont 1179, phosphamidon, Bayer 38156, Nemacide and Imidan.

The detailed toxicological studies indicated that there was a certain degree of random heterogeneity with significant x^2 values for some probit mortality lines. There was no doubt that the responses were sigmoidal just as they are with a series of concentrations applied as contact sprays.

TABLE II. Dosage mortality relationships of systemic acaricides applied as root drenches to small cucumbers for two-spotted mite control

Material	Regression line	S.E. of slope	LD_{50} in μ gm per plant
phorate	$Y = 2.64 + 1.20x$	0.37	93.2
Zinophos	$Y = -0.07 + 2.51x$	0.16	105.7
Temik	$Y = 1.68 + 1.52x$	0.24	154.6
dimethoate	$Y = 2.37 + 1.23x$	0.18	137.8
AC 47031	$Y = 2.54 + 1.03x$	0.11	236.8
AC 47470	$Y = 1.72 + 1.22x$	0.11	485.2
mevinphos	$Y = 0.97 + 1.24x$	0.25	1742

The slopes of all regression lines except that of Zinophos were low and did not vary significantly, so the LD_{50} values may be used to compare the potencies of the materials. Zinophos was considered the most effective since the regression line slope was significantly higher than that of phorate.

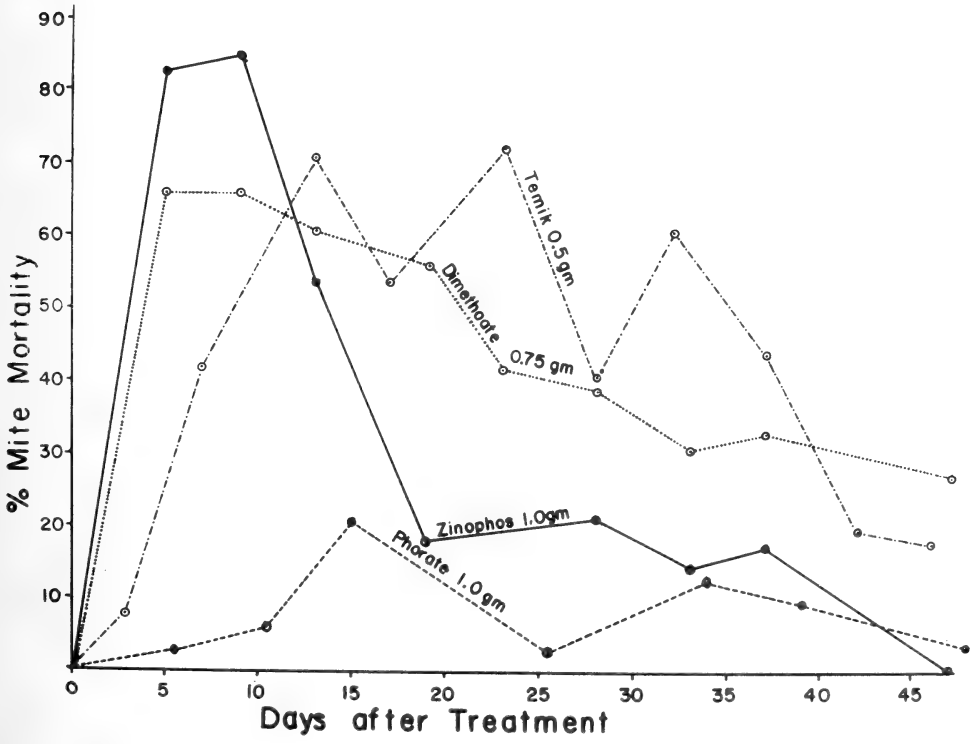

FIG. 1. Mortality of two-spotted mites confined for 48 hours on cucumber leaf discs cut from treated plants at various intervals.

Some of the soil treatments applied to the large cucumber plants were phytotoxic. Both AC 47031 and AC 47470 at 1 gm actual per plant caused severe damage. Phorate at 1 gm was safe, Zinophos at 1 gm was slightly phytotoxic, and dimethoate ot 0.75 gm caused somewhat greater damage than Zinophos. A series of treatments with Temik indicated that the maximum safe dosage was 0.75 gm.

The leaf disc bioassays for four treatments are shown in Figure 1. The only material applied as a granule was Temik, and this method of application might be the cause of the fluctuations in the assay. Mite mortality on leaf discs from the top of the plants was not consistently higher or lower than the mortality on discs from lower leaves.

Discussion

The screening tests gave reliable data on the inherent systemic toxicity of compounds to the two-spotted mite, and a relative measure of their phytotoxicity to cucumbers. The more detailed studies determined comparative toxicity by providing regression line equations. These data should be useful in determining the possible development of resistance in the mites to these systemics. There is no obvious relation between the chemical structures and effectiveness as systemic acaricides. The compound AC 47470 and AC 47031 differ only by the methyl radical of the former, but the latter is twice as toxic.

The leaf disc bioassays gave a measure of the residual effectiveness of the treatments under normal greenhouse conditions. They were an expression of the total effect of plant uptake, metabolic degradation, toxicity of metabolites and plant growth dilution. Phorate is apparently bound by the soil and released slowly, or it is rapidly metabolized in the plant to non-toxic compounds.

The mite mortalities illustrated in Figure 1 are limited in that they are adult 48-hour mortalities. The effect of treatments against a resistant population of mites would be continuous against all stages with a much greater resultant mortality. Residues that gave 30% mite kill in 48 hours would likely eliminate a population over a longer period.

The uptake and persistence of Zinophos, Temik and dimethoate suggest that they could be used on greenhouse cucumbers early in the season, until the plants are about 3 ft high. This would provide protection against early mite infestations.

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PARASITIZATION OF SOCIAL HALICTINE BEES IN SOUTHERN ONTARIO

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Mining bees belonging to the subfamily Halictinae are abundant all over Ontario and their nests are found in a great variety of habitats. Immature stages develop in closed or open cells which are found along burrows or in clusters surrounded by a cavity. The most interesting aspect of halictine biology is the occurrence of both solitary and social species within any one region. Mated and overwintered females of solitary species establish their nests early in spring and provision up to two dozen cells, from which emerges a single generation of males and females in late summer. The majority of species have more than one generation per year and it is the morphological and physiological changes in the first brood which determine the degree of sociality such a species has attained.

The often large and rather permanent nest aggregations of social species offer an ideal habitat for a variety of inquilines and parasitoids who practice their trade above and below the soil surface. For convenience, parasitization of adult bees and that of immature stages is therefore described separately.

Attackers of Adult Bees

Acarina

Female halictines often carry large numbers of mites and their immature stages (hypopi). Small hypopi usually drop off provisioning foragers and the mites develop with the new bees in the brood cells. Unpigmented worker pupae of *Halictus ligatus* Say (nest excavated 19 June 1963) had mites scattered all over their integument whereas their occurrence on adult bees is more confined to inaccessible parts of the insect. How much damage mites do is still unknown but it may be slight, since bee larvae are usually able to complete development in their presence. The level of infestation varies among individuals and populations but we have found that *Halictus confusus* Smith was often so severely infested that the basal tergum, together with the postgenae and other sheltered parts of the bee's integument were obscured by mature mites. *H. ligatus* seemed less affected whereas *Evylaeus cinctipes* (Prov.) and *Augochlorella striata* (Prov.) were comparatively free from the ectoparasite.

Conopidae

This family of flies exhibits a rather specialized mode of life. Adult females oviposit in flight by inserting a muscular ovipositor between two tergites of the host (Bohart, 1941). The larva hatches in the abdominal cavity and feeds on the surrounding tissues. Pupation takes place within the abdomen of the dead bee and the young fly emerges from its puparium a few weeks later.

Immature stages of conopid flies have rarely been associated with the corresponding adults and identification of dissected material is therefore difficult. Mr. K. G. V. Smith of the British Museum (Natural History) has kindly identified our material and summarized the present knowledge of this successful group (Smith, 1966). He concluded that the majority of species are not host specific but will strike a variety of aculeate pollinators. This agrees with our observations since we found larvae of *Thecophora occidensis* (Wlk.) in a wide range of

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halictine bees. The hosts belonged to different genera and included the tiny *Dialictus imitatus* (Sm.) as well as the much larger *Lasioglossum forbesii* (Robertson), thus explaining the wide size range in the adult parasitoids.

Bees and their parasitoids were especially numerous in a location near the Forks of Credit about 50 miles west of Toronto. The main halictine species were *H. ligatus, H. rubricundus* (Christ.), *L. forbesii* (Roberts.), *E. cinctipes* (Prov., *D. imitatus* (Sm.), *D. lineatulus* (Crawford) and *D. laevissimus* (Smith). *Thecophora occidensis* larvae were found in all these species and the parasitoid was so abundant during the summer that sweeping the vegetation often yielded several hundred flies in less than five minutes. These large populations were maintained throughout the period of our study (1960-1965) and there was no evidence that either the bee or the fly population was subject to drastic fluctuations. This rather unusual equilibrium between the hosts and parasitoid (really a slow motion predator) found an explanation when the bionomics of the main host, *E. cinctipes,* became more fully known.

This bee is social and possessses a female caste system which separates the large, long lived queens from the smaller, short lived and nonreproductive workers. Overwintered queens appear early in spring and about 10% of the samples taken in late April have small conopid larvae in their abdomina. This percentage decreases over the next 2-3 weeks (the duration of the spring provisioning phase) because the growing parasitoids force the females to abandon all brood rearing activities and to retire to their newly constructed nests where they die soon afterwards. The young flies emerge around the middle of June, about 2 weeks before the summer brood of *E. cinctipes* appears, which is immediately attacked by the mated females of *Thecophora.* The density of the parasitoid is such that workers often receive an egg on their first foraging trip! In 1965, when nest provisioning started on 24 June, 5% of the workers had been parasitized three days later, but the proportion of infested bees quickly rose to 13% (3 July), then 33% (10 July) and finally to 70% (26 July) of the samples dissected. The summer provisioning phase in *E. cinctipes* lasts from 14-17 days and coincides with the blooming of *Rhus typhina.* All nests are closed at the end of this period, but the surviving females remain in the nest. Previously marked nests were excavated after closure and the total nest populations were dissected and checked for conopids; four interesting points were found:

1. In a few nests, all workers had been parasitized.
2. In many nests, a majority of workers contained parasitoids (Figs. 1H-N).
3. Some workers showed multiple parasitization, i.e. an abdomen contained from 2-6 larvae (Figs. 10-T).
4. A few bees were found dead at the bottom of the shaft; the third instar of the fly had filled the abdominal cavity and was feeding on thoracic tissue (Fig. 1D).

Smith (1966) suggested that the unique morphological adaptation of this larva permits a better utilization of the available food than is possible with the less specialized abdominal feeders of other conopid genera.

Two reasons may account for the abundance of *E. cinctipes* under intense conopid parasitization:

1. Reproductive females can only be parasitized during the short period between emergence and the beginning of diapause; the percentage of infected overwintered females was found to be low.
2. Parasitized workers, normally nonreproductive, live long enough to forage throughout the short summer phase and, in this respect hardly differ from healthy workers.

3. Immature stages of the developing fall generation are unaffected and there is no apparent difference in the clutch size between parasitized and healthy nest populations.

The solitary *L. forbesii* appears more susceptible to conopid parasitization; this species is never very abundant in the Forks of Credit locality but the percentage of infected females was often high: 7 out of 9 overwintered bees collected on 30 April 1965 and introduced into breeding cages must have contained young larvae since seven flies emerged between 15 and 26 May, 1965. It appears that the females of *L. forbesii* spend a long time on flowers before they enter diapause, thus inviting more attacks by *T. occidensis*. This species uses *L. forbesii* as a host reservoir to survive the winter, undoubtedly the most vulnerable stage in the parasitoid's life cycle.

H. ligatus, whose social organization is somewhat different from that of *E. cinctipes,* was studied at several localities. Conopid parasitization in the many samples dissected was never above 5% but for one notable exception: Several hundred auxiliaries (nonreproductive overwintered females in pleometrotic nests) collected on 21 June 1964 near Toronto showed an unusually high proportion of infected individuals. Over 33% of the bees appeared to have been parasitized recently; only eggs and quite small larvae were found in the dissections. Two genera of Conopidae were involved. Many larvae had the horn-like posterior projections characteristic of the genus *Zodion,* the rest were similar to *Thecophora.* The infestation of so many auxiliaries late in spring was probably made possible by local phenological conditions that favored the parasitoids. But the damage to the *H. ligatus* population must have been small, because all the parasitized auxiliaries were approaching the end of their foraging period and would have died or been replaced by the first brood of workers. The continuous production of workers means that the *ligatus* nests are not closed periodically as they are in *E. cinctipes* and that all all bees that die are promptly removed from the nest and eaten up by ants. This fact may prevent a conopid population build-up in pure aggregations of *H. ligatus.*

Parasitization of Immature Bees

Meloidae and Rhipiphoridae

The two families have similar life histories: Females lay eggs on or near flowers and the hatched larvae take up station in them. The often specialized first instar clings to the pollinator and is carried to a newly provisioned cell. The parasitoid develops by devouring the contents of one or several cells (MacSwain, 1956). First instars of an unidentified species of *Meloe* were taken from a provisioned cell (without egg) of *E. cinctipes* on 3 July 1965 (Forks of Credit). Similar larvae have been noted on several *cinctipes* females in the permanent collection. *Rhipiphorus walshi* Lec.[2] was fairly common around the nests of *D. lineatulus* at the Forks of Credit but no immature parasitoids were found during excavations.

Anthomyiidae

Leucophora unistriata (Zetterstedt) and *L. johnsoni* Stein[3] are univoltine and were present in large numbers around the nesting sites at the Forks of Credit. They appeared at the beginning of May but were gone by the end of the same month. These flies usually rest on the ground or vegetation and make short excursion flights at times. Approaching bees stimulate pursuit and pollen laden females especially are followed closely. Bees often attempt to shake off their pursuers and delay their return to the nest, but it was obvious that the flies located many nest

[2]Det. T. J. Spilman; [3]Det. A. C. Pont

entrances. When a fly finds a nest it enters it backwards and spends from 20-80 seconds inside. Many nests excavated at the end of May contained the large larvae of these parasitoids. A closed nest of *E. cinctipes,* excavated 23 May 1965, had four cells of which three were completely empty and one contained the remains of a pollen ball on which four large maggots were feeding gregariously. About 20% of all the nests excavated in early June were found to have been destroyed by *Leucophora* and were empty. The fly larvae pupate in the surrounding soil and require a cold shock to break the diapause. *Halictus rubicundus* and *Dialictus lineatulus* were especially hard hit by the parasitoids because of their early provisioning period which coincides with the flight period of the flies. *H. ligatus,* whose foraging phase begins at the end of May, was not attacked at all in this locality.

Mutillidae

Pseudomethoca frigida (Smith)[4] is another univoltine parasitoid but does not appear before the beginning of June and vanishes before the beginning of August. Four nests of *E. cinctipes* contained one female mutillid each when we excavated them in early July, 1965, although the nests had been guarded when we observed them. The parasitoid overpowers the guards at the entrance and closes the nest from the inside. A nest excavated on 8 July had been closed and a dead *cinctipes* worker was found in the upper portion of the shaft. A living worker was at the bottom of the burrow and seemed to have no interest in the mutillid, which was found near the brood cells. Another *cinctipes* nest was taken intact to the laboratory on 29 July 1964. In due course, four females and one male of *P. frigida* emerged from the nest, although no further bees were reared from it. Mutillids are characteristic representatives of southern faunae and their scarcity in Ontario is probably accounted for by the adverse conditions met with at the northern edge of their range.

Halictidae

The best known and most species-specific parasitoids of Halictinae are the cuckoo bees belonging to the genus *Sphecodes*. The brightly colored females are often conspicuous by their characteristic searching flight. *Sphecodes* spp. have similar life cycles to their hosts and there is great morphological resemblance in wing venation and male genitalia. The parasitic modifications, i.e. lack of pollen collecting apparatus, heavily sculptured integument and the cherry red abdomen in the females do not obscure the common origin. The evolution of parasitic forms from certain *"Protohalictus"* types could have paralleled that of *Psithyrus* from *Bombus*. Richards (1927) indicated for the latter that the southern races of industrious species often become parasitic at the northern edge of their range apparently because the adverse conditions have made permanent a temporary or local parasitization such as can still be observed when *Bombus terrestris* queens usurp the nests of *Bombus lucorum* (Sladen, 1912). Perhaps it is no coincidence that southern races of certain industrious halictines, e.g. *Evylaeus calceatus* (Scop.) and *E. nigripes* (Lep.) exhibit a bright red abdomen and that the mediterranean *E. elegans* (Illiger) and *E. sphecodimorphus!* (Vach.) are only known in the red phase. Intra- and interspecific nest usurpation and facultative parasitization are still routine around halictine nest sites (Plateaux-Quenu, 1960; Knerer and Plateaux-Quenu, 1966) and their successful practice in the past must have encouraged the evolution of *Sphecodes* and *Paralictus* from a common halictine pool.

Sphecodes minor Robertson is the cuckoo of *E. cinctipes* in southern Ontario. Both host and parasitoid have two annual broods and the mated overwintered females of both species appear very early in spring. They visit the flowers of *Tussilago* and *Salix* and spend the first few nights in shallow burrows. The spring

[4]Det. K. V. Krombein

provisioning phase of the host starts with the beginning of May and *Sphecodes* females about that time commence their exploratory flights. The haplometrotic nests of *E. cinctipes* are unguarded during spring and the parasitoids usually enter them when the queen is away foraging. The cuckoo oviposits in suitable cells, leaves the nest and carefully closes the nest entrance before flying off. The rightful owner is unable to locate her parasitized nest again and the new generation of *S. minor* can develop undisturbed. *Sphecodes* females disappeared gradually from the scene until none were seen at the end of May, 1965, about 1-2 weeks after all *cinctipes* nests were closed. The summer generation of males and females of *S. minor* appeared around the middle of June 1965, two weeks before the summer provisioning phase of its host began. The nests at that period contain a matrifilial society consisting of a queen and 4-5 workers. The queen never leaves the nest during the active phase and lays all the eggs; the workers forage and guard the nest entrance. Summer females of *Sphecodes* appear to be more aggressive than their mothers and thereby resemble the European *S. monilicornis* whose fights with the social *E. malachurus* (K.) have been described by Legewie (1925). We observed a fight at the Forks of Credit on 29 June, 1965. A searching *S. minor* female located a nest of *cinctipes* and attacked immediately. The guard blocked the nest entrance with its abdomen but the parasitoid dug a new tunnel next to the entrance to cut off the guard. Then it squeezed the latter against the burrow wall and stung it several times before pushing it out of the nest entrance. The cukoo then closed the nest from inside; the whole operation took less than five minutes and the outcome of the battle was never in doubt. Another closed nest of *E. cinctipes* contained 21 cells when we excavated it 5 July, 1965. It harbored a single *S.minor* female. The number of searching parasitoids had already declined by that time because most of them had entered a nest of its host. Perhaps a *Sphecodes* needs to gain control of only one nest in the summer phase to be able to oviposit the full complement of eggs. Often there are up to 30 suitable cells in any one nest and the production of that many oöcytes may take longer than the two weeks during which the nests can be found open.

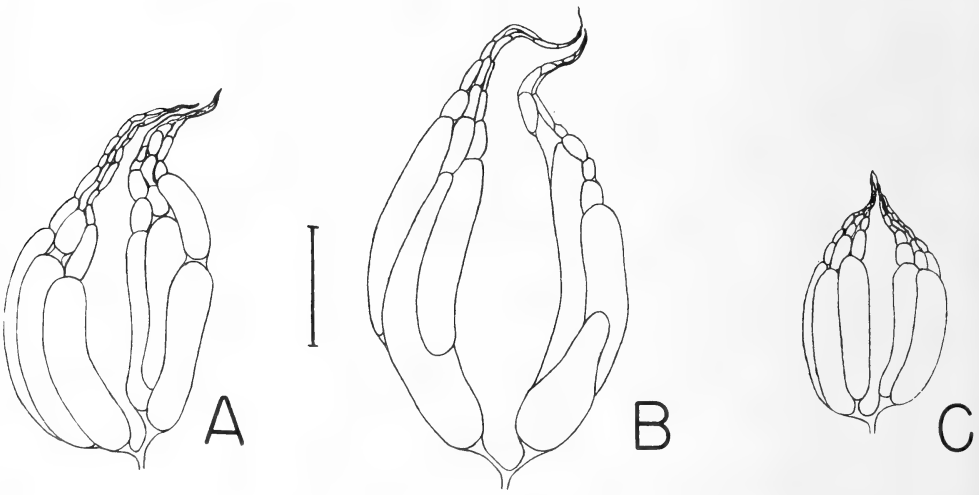
A closer study of the parasitoid was possible in the rearing cages which had been in use for two years in our Toronto laboratory. A single *S. minor* female was introduced into such a cage on 3 May, 1965. A nesting site and cut flowers had been provided for the females of several halictine species, among them 12 *cinctipes* queens. The newly introduced parasitoid took up searching flights immediately and had located the majority, if not all the twelve nests, by the next day. From 4 May until her removal on 8 May the cuckoo hardly varied her behaviour pattern:

1. Searching flights in the morning during which many nests were investigated;
2. Occupation of a suitable nest in the late afternoon;
3. Reappearance next morning;
4. Minute closing and camouflaging of the nest entrance.

Thus, she parasitized four spring nests in as many days and the other nests in the cage could only be saved from destruction by the cuckoo's removal. It seems that the behavior pattern differs in two main respects from that exhibited in summer: there is little violence during the occupation of the host's nests, since they are not defended at that stage; and the small number of provisoned cells (3-5) in spring nests forces the cuckoo to attack a succession of burrows during the spring provisioning phase. Intimidation of returning *cinctipes* queens seemed to cause akinesis in the latter, i.e. they can be handled as if they were under the influence of CO_2 or low temperatures. This state seemed to wear off after minutes or hours and the queens later searched for their nests. None of the four queens found their original nest or constructed a new one but usurped an active nest of *L. forbesii* and provisioned at least two cells in it.

Discussion

Parasitization undoubtedly constitutes a primary factor in the regulation of bee populations. Future generations may be limited by "niche parasitoids" like *Leucophora* spp. which seem to attack all ground nesting Apoidea, but are more often affected by host specific cuckoos like *Sphecodes* and *Nomada*. Solitary halictine species are obviously subject to some parasitic pressure but the often large and permanent nest aggregations of gregarious species may favour the parasites by their greater availability. Fluctuations of physical factors could be advantageous to the host in one year and to the parasite in another, but the equilibrium may easily be upset by climatic caprice and the parasite could "outnumber its host considerably, though such a success is not often likely to last more than one or two seasons" (Perkins, 1919). This is especially true in view of the tremendous fecundity of nearly all parasitic species which allows such rapid increase under suitable conditions, and seems to hold in our situation, when the ovaries of a *cinctipes* queen at the peak of the summer phase are compared with those of her main enemies, *Pseudomethoca* and *Sphecodes* (Figs. 1A-C). Such must have been the fate of the famous *Evylaeus malachurus* "colony" near Riedenburg in Franconia (E. Stoeckhert, 1923) where thousands of nests were under periodic observation from 1916 till 1953 but which had died out completely by 1964 (pers. comm. F. K. Stoeckhert, 1965).



Figs. 1 A-T. Parasitization of *Evylaeus cinctipes* (scales represent 1mm).

Figs. 1 A-C. Ovaries during summer phase of: A. *Sphecodes minor;* B. *Evylaeus cinctipes* and C. *Pseudomethoca frigida.*

There are obvious adaptations in the host-parasite relationship which can lead to a better survival of the industrious species. *H. ligatus,* for example, does not seem to be parasitized by *Sphecodes* in southern Ontario. Possibly the parasitoid is only missiing in the northern regions of the host's distribution; it is very unlikely that such a widely distributed species is without a cuckoo all over its range. The early spring period of the social *E. cinctipes* saves the queens from conopid attacks but exposes the nests to the devastations of *Leucophora* spp. *H. ligatus* avoids the latter by its later spring period but has to sacrifice many foraging auxiliaries to conopids under certain conditions.

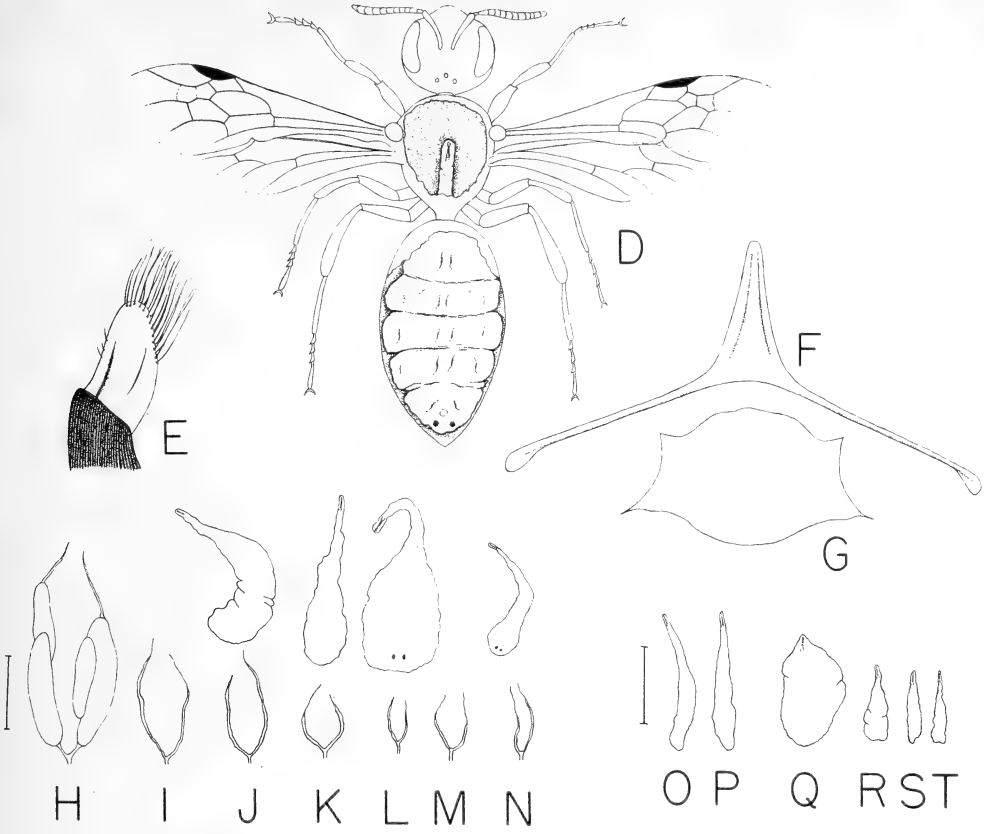


FIG. 1 D. Dead worker of *E. cinctipes* with tergites removed to reveal a third instar of *Thecophora occidensis*. The bee's abdomen is completely filled and the larva has gained access to the thorax via the petiole.

FIGS. 1 E-G. Genital armature of *Sphecodes minor* ♂. E. Gonostylus; F. Abdominal sternite 8; G. Abdominal sternite 7.

FIGS. 1 H-N. Abdominal contents of all the females found in a closed nest of *E. cinctipes* (Forks of Credit, 8 July, 1965). H. Ovaries of queen, showing resorption; I-N. Ovaries of the six workers, four of them with larvae of *T. occidensis*.

FIGS. 1 O-T. Six larvae of *T. occidensis* found in the abdomen of a live worker of *E. cinctipes* (Forks of Credit, 15 July, 1965).

Published reports and observations indicate that nest guarding provides only limited protection against mutillids and *Sphecodes*[5], so Lin's (1964) emphasis on nest guarding as a reason for the evolution of halictine social behaviour is surprising, unless his theory works even when nest defense is not completely successful. Observations not mentioned by Lin do not fit into the theory; certain non-social halictines (e.g. *Lasioglossum leucozonium* (Schrank)) will fiercely defend their nests at the slightest provocation whereas pleometrotic spring nests of the social *H. ligatus* are never guarded although they often contain up to six overwintered females. Finally, the theory does not explain the success of *Evylaeus marginatus* (Br.), whose perennial and populous colonies have achieved the highest social organization of any halictine bee without guarding their nests.

[5]Legewie (1925) observed fights between *Sphecodes monilicornis* and *Evylaeus malachurus*: 75 out of 76 were won by the parasitoid with the loss of 283 *malachurus* lives!

Appendix

Mitchell (1960) omits a description of the male of *Sphecodes minor* Robertson and it appears that it was previously unknown or has not been associated with the female. The description below, based on our reared males, is given to fill this gap in the species systematics.

Sphecodes minor Robertson

Male—Length 6-7mm; head and thorax black, abdomen entirely black; head broader than long; eyes slightly convergent below; clypeus convex; mandibles dark reddish apically; antennae entirely black, basal segment of flagellum slightly broader than long, the second and following segments nearly twice this length, entirely simple; lateral ocelli subequally distant from eyes and each other; face thinly pubescent, punctures coarse and close in general, somewhat finer around antennae; those on clypeus coarse and evenly close; punctures on vertex finer and more distinctly separated; cheeks reticulate, postgenae striate; wings infuscated, veins piceous; tegulae brownish testaceous, becoming yellowish-hyaline anteriorly; legs dark; scutum and scutellum shining between deep and distinct punctures, these well separated over most of scutum, becoming somewhat finer and closer between notaulices and tegulae; scutellum very slightly impressed medially, punctures quite sparse; pleura coarsely reticulate; dorsal area of propodeum coarsely reticulate, crescent sloped, lateral sides coarsely striate; abdominal terga smooth and shining, punctures distinct, scattered over disc of first tergum, somewhat closer and more regular on second and third, apical margins narrowly impunctuate, concolorous with remainder of discs; gonostylus and abdominal sternites 7 and 8 as illustrated (Figs. 1E-G).

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EGG PRODUCTION OF HOUSE-FLY ADULTS FED HUMAN BLOOD CONTAINING VARIOUS SUPPLEMENTS

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The adult house-fly, *Musca domestica* L., is polyphagous. This species and *M. vicina* (Macq.) may even utilize blood when the opportunity arises (Aders 1916 and Lever 1934 respectively in West 1951), although they are not usually classed with the facultative haematophagous Diptera (West 1951).

Early in our research on nutrition and reproduction of the house-fly (Morrison and Davies 1964), experiments were performed in which blood was fed to the adult females, to determine its adequacy for egg production.

Materials and Methods

Larvae of an inbred strain of house-flies from the Entomology Research Institute for Biological Control, Belleville, Ontario were reared on a standard CSMA medium (Moreland and McLeod, 1957; Morrison, 1963), and stock cultures of adults were fed fresh skim milk.

During the first 24 hr after emergence, experimental house-fly adults were withdrawn from the stock culture and placed in glass cylinders 15 cm wide by 18 cm high) topped with clean nylon netting. Cylinders rested on trays covered with two layers of Whatman No. 1 filter paper. In the center of each section of the tray holding a cylinder was a hole (2.8 cm diam.) into which would fit, from below, a No. 6 rubber stopper. Through a central hole in each stopper a glass vial (12 mm by 35 mm), holding the liquid diet soaked in an absorbent cotton wick, was inserted. In order to have maximum oviposition, each cylinder contained initially 12 females and 3 males (Morrison, 1963). The liquid test diets were modified human whole blood, or modified plasma derived from it (Table I). The blood, obtained from the Canadian Red Cross, had been stored for about a month with added ACD solution (d-glucose 1.47 g, sodium citrate 1.32 g and acid citric anhyd. 0.44 g per 100 ml whole blood). Fecundity of house-flies fed these diets was compared to that of milk-fed flies. In each experiment three test cylinders and one milk control cylinder was used.

Results

Human whole blood and blood plasma, with or without added sucrose (3.42 g/100 ml), when fed to adult female house-flies did allow the laying of some eggs but many fewer than the number laid by milk-fed females. The eggs laid by flies fed blood or plasma were normal in appearance and most were viable.

To bring the nitrogen concentration of these diets to that of chemically defined diets used in other experiments (Morrison and Davies, 1964), i.e., 0.76%, the whole blood and plasma were diluted with distilled water (Table I).

Diluting the blood or plasma (diets 5 and 9 respectively in Table II) produced no improvement in egg production per experimental female over that with the undiluted diets, being still less than half that of milk-fed females. By adding isoleucine to the diluted diets (diets 6, 7 and 10) and keeping the nitrogen level the same, only a slight improvement in fecundity occurred. However, a marked increase in fecundity was shown when the diets were further supplemented with the Wesson salt mixture (diets 8 and 11). The fecundity over four or even eight

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days of oviposition with the supplemented blood was greater, especially at first (Table II). Also there was an improvement in the survival of the adults and viability of the eggs in comparison with the previous test diets. In fact, these features were equivalent to those found with milk-fed flies.

TABLE I. Composition of diets containing human blood which were fed to adult house flies (nitrogen level maintained at 0.76%).

Diet	5	6	7	8	9	10	11
Whole blood (ml)[a]	28	22	22	22	—	—	—
Blood plasma (ml)	—	—	—	—	62.5	60.2	60.2
Sucrose (g)	3.42	3.42	3.42	3.42	3.42	3.42	3.42
L-isoleucine (g)	—	0.25	0.25	0.25	—	0.25	0.25
Wesson salts (g)[b]	—	—	—	0.15	—	—	0.15
Distilled water (ml)	100	100	100	100	100	100	100

[a] one-month old blood in ACD which contained an average of 1.47 g glucose per 100 ml

[b] Mixture of Wesson (1932) containing, in mg/g, calcium carbonate 210.0, copper sulphate 0.39, ferric phosphate 14.7, magnesium sulphate 90.0, manganese sulphate 0.20, potassium aluminum sulphate 0.09, potassium chloride 120.0, potassium dihydrogen phosphate 310.0, potassium iodide 0.05, sodium chloride 105.0, sodium fluoride 0.57, tricalcium phosphate 149.0.

TABLE II. Fecundity of house-fly females fed diets containing human blood compared with that of milk-fed females.

Test diet[a]	Number of eggs per experimental female					
	Four days of egg laying			Eight days of egg laying		
	Test diet[b] (T)	Milk Diet (M)	Ratio T/M	Test diet[b] (T)	Milk Diet (M)	Ratio T/M
5[c]	75.1	192.2	0.41	—	—	—
6	91.1	152.4	0.60	—	—	—
7	105.1	168.5	0.62	115.2	268.2	0.43
8	171.7	101.3	1.7	311.0	238.6	1.3
9	67.7	199.0	0.34	79.4	286.6	0.28
10	48.8	130.1	0.38	86.1	258.7	0.33
11	110.3	130.5	0.85	192.3	164.1	1.2

[a] for composition of diets see Table I

[b] average of three cylinders

[c] Three days of egg laying only

Discussion

The house-fly must have a dietary source of both carbohydrate and protein if it is to survive and reproduce (Glaser, 1923; Kobayashi, 1934; Derbeneva-Ukhova, 1935). In our experiments, by using human whole blood or plasma as the combined protein and carbohydrate source, viable eggs were laid by house-fly females, but egg production was much below that of milk-fed flies. This was also found by R. Bodnaryk and Morrison (unpublished notes). Neither the dilution of these diets with water, bringing the total nitrogen level to 0.76%, nor the addition of sucrose, improved fecundity, which still remained less than half that with milk. In *Aedes aegypti* (L.) eggs also developed whether females were fed whole blood, plasma or washed erythrocytes of rabbits (Woke, 1937a) but 16 times as many eggs were laid by females fed de-fibrinated sheep blood instead of washed erythrocytes (Greenberg, 1951). Also, Glaser (1923) showed that the

blood-feeding stable-fly, *Stomoxys calcitrans* (L.), only laid eggs when on a diet of whole or defibrinated blood and not when on a diet of plasma or washed erythrocytes.

Differences have been found in the nutritional value of the blood of various vertebrate animals. When adult female mosquitoes were fed on man, fecundity was lower than when fed on rat, guinea pig or rabbit (Roy, 1931 for *Anopheles stephensi* Liston; Tate and Vincent, 1936 for *Culex pipiens* L.), or on canary (Roubaud and Mezger, 1934; Woke, 1937b for *C. pipiens*). *Aedes aegypti* laid fewer eggs when fed on a human or monkey than when fed on guinea pig, rabbit, canary, turtle or frog (Woke, 1937c). Human blood contains much less isoleucine (less than 1/10) than rabbit or pig blood, and beef and sheep bloods are also low in isoleucine (Block and Bolling, 1951). This was the only 'essential' amino acid showing such variation among the bloods of these animals. The influence of isoleucine was reflected in the fecundity of *A. aegypti* feeding on these different bloods (Lea *et al.,* 1958). Fecundity in this mosquito could be improved by increasing the isoleucine content of human, beef and sheep bloods. Greenberg (1951) also found that isoleucine alone among the 'essential' amino acids, when added to washed sheep's erythrocytes, improved egg production in *A. aegypti.* Therefore, it was possible that the low level of isoleucine in human blood and plasma was depressing fecundity of house-flies in the present experiments. However, when the diets of blood and plasma were further supplemented with isoleucine, little improvement in egg production was evident. This agrees with the experiments of Morrison and Davies (1964) in which a chemically defined diet containing an amount of isoleucine almost the same as that for human blood, when fed to female house-flies, gave a fecundity equal to that of milk-fed flies. Thus this level of isoleucine does not appear to be limiting for house-fly reproduction as it was for that of *A. aegypti.*

Some other factor(s) seemed to be lacking in the blood and plasma diets. The further addition of the Wesson mixture of inorganic salts to the whole blood or plasma greatly improved house-fly fecundity. Females fed on the salt-supplemented plasma had a survival and fecundity almost as high as that of milk-fed females, whereas on the supplemented whole blood females had a considerably higher fecundity than those fed milk, even though survival was still inferior after the first five days of egg laying. This doubling of the fecundity with the addition of salts was similar to that found by Lea et al. (1958) for *A. aegypti;* females produced only half as many eggs when the salt mixture was omitted from the diet.

Total phosphorus in mature cows' milk averages 96-100 mg/100 ml, and 70-80 mg of this is inorganic phosphorus (Hawk et al. 1954; Spector, 1956). In human whole blood or plasma, on the other hand, total phosphorus averages about 26 mg/100 ml of which only about 2.9 and 3.2 respectively is inorganic phosphorus (Albritton, 1952). Therefore, it may well be phosphate that was the important constituent of the Wesson salt mixture which improved the fecundity of house-fly females fed salt-supplemented human whole blood or plasma. Moreover, for the blow-fly, *Phormia regina* (Mg.), Rasso and Fraenkel (1954) concluded that potassium phosphate by itself had the same effect on the rate of oögenesis as a complete Wesson salt mixture in the diet. They found ovarian development was unaffected by other individual salts, such as sodium and potassium chlorides, potassium carbonate, magnesium sulphate and tricalcium phosphate. Chippendale (1963) noted that the viability of house-fly eggs was as improved with potassium phosphate in the supplemented casein adult diet as with the Wesson salt mixture. Yolk synthesis was inhibited in *Drosophila melanogaster* Mg., when females were fed supplemented casein diets lacking potassium, magnesium or phosphorus (Sang and King, 1959), and fecundity and egg viability decreased when less of these ions was present in the diet (Sang and King, 1961).

Acknowledgements

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A CHANGE OF FEEDING HABIT IN *ARCHIPS CERASIVORANA* (FITCH) (LEPIDOPTERA, TORTRICIDAE)

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The cherry ugly-nest caterpillar is a well known defoliator of chokecherry *Prunus virginiana* (Craighead *et al* 1950); (Anderson 1960) and occasionally feeds on other Rosaceae. Unlike the eastern and western tent caterpillars *(Malacosoma americanum* (F.) and *M. pluviale* Dyar) it feeds *inside* the web or tent and hence the shrubs attacked may become practically enclosed by a dense covering of silk. In some instances these huge "tents" may extend for hundreds of feet along hedgegrows, etc.

A dramatic change in the food habits of this species was recently observed when W. R. Hutcheson of Huntsville, Ontario, consulted me regarding a web-making insect attacking Scots pine, *(Pinus sylvestris)* Christmas trees in Oro Township, Simcoe Co., Ontario. Inspection showed that the insect in question was *Archips cerasivorana* (Fitch).

The area involved comprised some 25 acres of plantation which had been established in a wornout field or pasture. At the time of planting, presumably about seven years previously, this area had been occupied by a sparse but fairly uniform growth of slow-growing scrubby chokecherry bushes. These had been cut and the pines planted in rows. Eventually suckers were produced from the chokecherry stumps; these were numerous but, because of the poor sandy soil, were slow growing. Apparently in the previous summer, *Archips cerasivorana* females, which lay their eggs very close to the ground on chokecherry stems, had invaded the plantation and had laid large numbers of eggs on the suckers. When the larvae emerged and began to feed they soon exhausted the supply of chokecherry leaves. They then moved over to the Scots pine, some of which were approaching commercial size, sheathed the new growth in silk and began to feed on it (Fig. 1). Although the new needles were destroyed to some extent the new shoots seemed to be preferred and some of these were eaten back to the point where they were one-half inch in diameter (Fig. 2).

The commercial importance of this incident was not great, as most of the trees were still too small for sale and the cherry ugly-nest does not usually persist long in one area. If it had occurred in a year when a big sale was anticipated the effect could have been more serious since the trees, covered with webbing, excrement and pieces of dead needles, were not very attractive and much of this debris might well have persisted until fall; also the remedial pruning required to restore the shape of the trees would postpone sale for a year.

The best remedy for this situation is prevention. Chokecherry bushes in areas designated for Scots pine Christmas tree planting should not only be cut, the stumps should be treated with a brush killer such as 2-4-5-T and suckers re-sprayed if many appear.

It was not possible to follow the progress of the *Archips* population throughout the season but this drastic food change raises problems of growth, survival and fecundity in the pine-feeding population. Experiments along these lines might be very worth while.

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FIGURE 1. New shoots of Scots pine webbed together by *Archips cerasivorana*.

FIGURE 2. New shoot of Scots pine destroyed by *Archips cerasivorana.*

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WARBLE FLY LARVAE CONTROL STUDY

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The recent development of controlling warble grubs by means of a systemic insecticide poured along the back-line of the animal in the fall has given good results. Instructions usually state that treatment should be applied by the end of November. In Ontario many cattle are brought in from the West later than

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November. This raises the question as to the advisability of applying pour-ons at the later date. Two considerations are involved. Will the insecticide be as effective in controlling the grubs if applied after the suggested optimum time? Is there likely to be any increased incidence of toxicity due to the later treatment date?

During the winter of 1966 with the cooperation of Mr. K. Hammond, Orton, Ontario and the Chemagro Corporation, cattle which had originated in Western Canada were treated with Co-Ral 4% and Neguvon 8% as pour-ons in November, January and February.

Steers were randomly allotted to treatment groups. One group was not treated and served as a control. One group was allotted to Co-Ral and Neguvon treatment on each of the following dates: November 30, 1965, January 5, 1966 and February 1, 1966. The material was applied at the rate of ½ oz. per 100 lb. liveweight, maximum 4 oz. per animal. Animals were observed for any toxic reaction for at least 48 hours after treatment. Counts were made of the grubs in the backs of the animals on April 15, 1966.

Warble Control With Pour-Ons 1965-66

Compound	Dosage	Date of Treatment	No. Cattle	Av. No. Grubs	Side Reaction
Control			28	7.0	
Co-Ral 4%	½ oz./100 lb. liveweight	30 Nov. 1965	29	0.14	None
Co-Ral 4%	" "	5 Jan. 1966	20	2.7	None
Co-Ral 4%	" "	1 Feb. 1966	19	0.42	None
Neguvon	" "	30 Nov. 1965	28	0.25	None
Neguvon	" "	5 Jan. 1966	19	0.11	Transient* 3 Animals
Neguvon	" "	1 Feb. 1966	19	0.21	Transient** 1 Animal

*Two animals exhibited excessive salivation 24 hours post treatment. Cleared by 30 hours post treatment. One animal exhibited allergic symptoms 24-30 hours post treatment. Normal by 48 hours post treatment.

**Slight bloat 24 hours post treatment, normal 48 hours post treatment.

The number of grubs present in the control group would indicate that this particular group of cattle was not heavily infested. However, both treatments appear to have reduced the number of grubs present irrespective of the time of their application. The side effects noted were fairly mild in nature.

Preliminary assessment of these data indicate that cattle may be treated with these insecticides as late as February and still achieve reasonable control. The danger of side reactions does not appear to be increased to any marked degree by treatment at the later date. Further studies are necessary.

A second trial was conducted at the New Liskeard Demonstration Farm in which the insecticide was administered either in the feed or in the water. The insecticide used in this case was Tiguvon and the treatment groups were as follows:

Control — no treatment

Tiguvon — 1 mg./kg. body weight for 6 days in the grain ration

Tiguvon — 1.5 mg./kg. body weight for 6 days in the grain ration

Tiguvon —10 ppm. in water for 6 days

Tiguvon —15ppm. in water for 6 days

TABLE I. Summary of Cattle Grub Treatment at Demonstration Farm, New Liskeard, Ontario

Compound	Formulation	Method of Appl.	Dosage Rate	Actual Dosage Mg./Kg./ Day	No. of Animals	Avg. Wt. (Lbs.)	Av. No. Grubs/ Animal	Per cent Control
TIGUVON	1% Feed Premix[a]	Feed	1 mg./kg. body wgt. for 6 days	1.0	19	405	.26	98%
TIGUVON	1% Feed Premix[a]	Feed	1. g mg./kg. body wgt. for 6 days	1.5	20	405	.15	99%
TIGUVON	10% Water Miscible[b]	Water	10 ppm. for 6 days	.76	16	363	1.25	91%
TIGUVON	10% Water Miscible[b]	Water	15 ppm. for 6 days	1.2	14	336	.14	99%
CONTROL		—		—	32	369	12.9	—

[a] Control No. M-10271-A

[b] Control No. 64-205-112

In the groups being fed the insecticide all calves were red about the eyes after the first day of treatment and 3 were off feed but were back on feed by the third day. On the third day three other calves showed marked side effects being sick, staggering and somewhat bloated. By the fifth day all were on feed and eating normally. By the eighth day all signs of redness about the eyes or dullness had disappeared.

When the insecticide was administered in the drinking water one calf on the higher level was off feed and paunchy on the second day.

The results of these treatments are summarized in Table I.

The administration of these materials in either feed or water appears to be an effective method of controlling grubs. However, the side reactions observed when administered in the feed require consideration.

Co-Ral: 0,0-Diethyl 0-3-chloro-4-methyl-2-oxo-2H-benzopyran-7-yl phosphorothioate

Neguvon: 0,0-Dimethyl 2,2,2-trichloro-1-hydroxyethyl phosphonate

Tiguvon: 0,0-Dimethyl 0-[4-(methylthio)-m-toly 1] phosphorothioate

(Accepted for publication: April 29, 1967)

III. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND THIRD ANNUAL MEETING — ENTOMOLOGICAL SOCIETY OF ONTARIO

TORONTO, ONTARIO

NOVEMBER 2-4, 1966

MEETING OF OUTGOING DIRECTORS

The 1965-1966 Board of Directors met on November 1, 1966 at 8 p.m. in the lounge of the Faculty Club on Wilcox Street, Toronto. Those present were President H. A. U. Monro, C. E. Atwood, P. Belton, G. W. Green, Anne Hudson, W. Y. Watson, W. H. A. Wilde and D. H. Pengelly Secretary-Treasurer.

It was moved by W. Y. Watson, seconded by Anne Hudson that the minutes of the last Directors Meeting be accepted as circulated to the membership. Carried.

The Secretary-Treasurer's Report on Finances was the audited statement for the year ending January 1, 1966 and an interim statement to October 31, 1966.

The results of the mail ballot were made known to the Directors.

The Secretary raised the question whether the constitution permitted the announcing of the results of the ballot before the Annual Meeting. After a consideration of the constitution it was agreed that the by-laws were sufficiently flexible.

A letter from G. C. MacNay was read. Mr. MacNay's retirement left vacant the chairmanship of the Committee on the Common Names of Insects. A letter from the newly appointed chairman of the Canadian committee, D. C. Eidt, asked that the Ontario Society's chairman continue as member of the national committee.

Discussion on the usefulness of the common names of insects brought forth a suggestion from W. Y. Watson that the present list be reviewed before any new names were considered. It was agreed that the list should be maintained and also that letters be sent to the past members expressing the thanks of the Society for their contributions.

A discussion on the President's Prize outlined the possible problems that could arise from an increase in the numbers of graduate students. Pres. Monro agreed to form a committee to consider the rulings on this part of the Society's programme.

In a letter, D. M. Davies tendered his resignation as Editor of the Proceedings. This was accepted by the Directors with regret.

At the previous meeting of the Directors the Secretary-Treasurer was asked to consider ways of investing a portion of the Society's funds Canada Savings Bonds were suggested and a motion by P. Belton, seconded by W. Y. Watson that the Secretary-Treasurer increase the total investment to $1000.00 was carried.

Meeting adjourned at 10:30 p.m.

D. H. Pengelly, Secretary-Treasurer

ANNUAL MEETING

The 103rd Annual Meeting of the Society was held in the Ramsay Wright Zoological Laboratories of the University of Toronto. The opening session began at 9:30 a.m. on November 2 with the President, Dr. H. A. U. Monro, as chairman. Members were welcomed by Professor G. deB. Robinson, Vice-President of Research Administration, University of Toronto. After an address and announcements by the President of the Society, the meeting proceeded for the next three days according to the printed programme, beginning with an invitation paper by Dr. G. W. Green, Department of Forestry, Sault Ste. Marie, Ontario.

On the afternoon of November 2, a Symposium on Hibernation and Diapause was presented, with Dr. W. E. Beckel as chairman and with Dr. K. C. Fisher, Dr. D. G. R. McLeod and Dr. Ian Campbell contributing. At 8:00 p.m. a visit and smoker at Scarborough College was attended, courtesy of the Shell Oil Company and the Dean of Scarborough College. On the evening of November 3 a banquet was held at the Westbury Hotel, after which the President's prize was awarded, and Professor Carl Williams, Principal of Erindale College, addressed the gathering.

The following 30 papers were presented during the meeting (some of these appear in the preceding sections of this volume). Those marked * were read by university students for the President's Prize (for result of award see Appendix II).

Monro, H. A. U. (London). Presidential Address — Entomology and Entomologists.

Green, G. W. (Sault Ste. Marie, Ont.). Biometeorological research in Canadian forest entomology. The material presented in this paper has since appeared in : Wellington, W. G., Sullivan, C. R. and G. W. Green 1966. Biometeorological research in Canadian forest entomology. International Journal of Biometeorology, 10 (1) : 3 - 15.

Fisher, K. C. (Univ. Toronto). Comparative aspects of hibernation.

McLeod, D. G. R. (Research Inst. London, Ont.). Photoperiodism and insect diapause as exemplified by the European corn borer, *Ostrinia nubilalis.*

The European corn borer has a facultative diapause in the fifth larval instar induced by a photoperiodic cycle. Diapause can also be terminated by the appropriate regimen. Experiments by Beck *et al* (1965) have shown that there is a physiological rhythm in the epithelial cells of the proctodeum and that this rhythm is in some way responsible for the reactivation of the secretory cells of the brain. A hormone called proctodone is presumed to be released by these proctodeal cells.

The lateral secretory cells have been shown to change in size in a cyclical fashion associated with a photoperiodic regime. It has also been shown that there is a cycle of incorporation of radio labelled leucine associated with the change in cell size. The problems of connecting a physiological rhythm with the external photoperiodic cycle were discussed.

Beck, S. D. I. B. Calvin and D. E. Sumton 1965 Photoperiodic control of a physiological rhythm. Biol. Bull. *128,* 177-188.

Campbell, Ian (Iowa State U.). A critique of current diapause theories.

*Edwards, Carol J. (U. Guelph). The use of palynology in the ecology of the genus *Bombus* Latr. (Hymenoptera, Apidae).

*Grant, G. G. (U. Western Ontario). A method for chemosterilization of mosquitoes in the field.

A modification of the C.D.C. battery light trap was developed which would attract male mosquitoes, chemosterilize them, and allow them to escape back to the field. The plastic sterilizing chamber was provided with slits to allow entry and subsequent exit such that two thirds of the mosquitoes which entered at night escaped to the field by morning. Treated with the chemosterilant tepa, this chamber ensured that at least 90% of the males were sterilized. Of the modifications tested to increase the attraction of males, black light was the most decisive.

*Kobylnyk, R. W. (U. Guelph). Some laser effects on the development of the European pine sawfly pronymphal larvae, *Neodiprion sertifer* Geoff. in the cocoon.

Pronymphal larvae in cocoons were exposed to one of three levels of ruby laser radiation or to mechanical puncture of the cocoons by means of a heated pin or scissors. Larvae in the mechanically-treated groups usually repaired the damaged cocoons, however, larvae in the focused laser groups exhibited no signs of repair. High larval mortality occurred in specimens exposed to one and two focused pulses (each 37.5 kw/cm^2) while larvae exposed to six successively-fired unfocused pulses (each 1 kw/cm^2) exhibited subsequent rates of adult emergence comparable to that of control larvae. Focused laser pulses produced three types of "burns": swelling, depigmentation and disruption of the cuticle. The cause of death has been tentatively attributed to a thermal effect. In contrast, development in the mechanically-treated groups was arrested almost uniformly in larval, pupal, adult and two intermediate stages due to unnatural exposure to atmospheric conditions.

A simple method for sighting material to be lased and a qualitative technique for assessing cocoon contents was described.

*Lall, S. B. (McMaster U.). Sensitivity of labellar contact chemoreceptors of females of the deer fly, *Chrysops vittatus*, to sugars, amino acids and salts (Diptera : Tabanidae).

The paired labellum of female *Chrysops vittatus* Wied., bears on its aboral margins a mixed group of gustatory and tactile hairs; of the four main types, only two were shown by behavioral studies to be gustatory and their structure is being studied with light and electron microscopy.

The sensitivity of the labeller contact chemoreceptors was determined with respect to various sugars, amino-acids and sodium chloride. In all tests, extension of proboscis and the spreading of labellar lobes was used as the index of labellar stimulation. The acceptance threshold for sucrose solution was between 0.005M - 0.0025M, but the other sugar solutions had higher thresholds, although the limits were less precisely determined, i.e., maltose, fucose and melezitose between 0.005M - 0.05M, frustose and glucose between 0.05M - 0.1M and raffinose between 0.1M - 1.0M.
No response was found with 15 amino-acids in 0.05M and 0.005M concentration. Tests with seven amino acids in 0.133M phosphate buffer (pH 7.4) produced a positive response; whether part or all of this was a response to the phosphate buffer is under investigation.

By offering graded concentration of NaCl in 0.5M sucrose solution, the rejection threshold of NaCl was determined as 0.50M.

*Liu, S. T. (U. Waterloo). Blood sugar changes in the hemolymph of the housefly during oogenesis.

In the hemolymph of female house flies 5 sugars were detected by the silver nitrate method. These sugars were chromatographically separated and were identified as trehalose, glucose, fructose, ribose and glycerol. In milk fed flies trehalose, glucose and fructose persisted throughout oogenesis, showing wide fluctuations in concentration, whereas glycerol and ribose were present only in the blood of newly emerged flies. The hemolymph levels of trehalose (in $\mu g/\mu l$) were recorded daily:— at emergence: 12.73; day 1: 18.57; day 2: 15.45; day 3: 8.24; day 4: 28.68. Trehalose to glucose and trehalose to fructose ratios over the same period were, respectively:—at emergence: 3.29; 55.35; day 1: 6.38, 10.20; day 2: 4.65, 3.36; day 3: 2.31, 9.69; day 4: 3.96, 5.14. There was a close correlation between trehalose levels in the blood and glycogen levels in the ovary. From these observations it was considered that the hemolymph sugars trehalose, glucose and fructose reflect certain dynamic metabolic processes taking place within the hemolymph and other tissues during ovarian development in the housefly.

*Lue, P. F. (U. Ottawa). Changes in the free amino acids in the hemolymph of the honeybee, *Apis mellifera* L., during caste development.

At eight stages of larval development the haemolymph of the two female castes of the honeybee, *Apis mellifera* L. was examined for free amino acids. Twenty-seven identified free amino acids and three unidentified ninhydrin-positive compounds were detected by thin-layer chromatography. In addition to the amino acids identified by earlier workers, ornithinine, methionine sulphone and/or sulphoxide, y-amino-n-butyric acid were identified in this investigation.

The total amino acid concentration was greater in the queen than in the worker. A fluctuation in amino acid content was usually observed. However, the general trend in both castes was for the amino acid concentration to decrease with age.
Aspartic acid concentration varied so greatly between the two castes that it is suggested as a criterion of dimorphism.

Non-essential amino acids were identified by an indirect method involving radiological procedure.

The significance of these results was discussed in relation to female dimorphism.

*Yang, Y. (McMaster U.). Activity of trypsin from several black-fly species (Diptera : Simuliidae).

The "*in vitro*" trypsin activity was demonstrated from 6 simuliid species in 3 genera. Different levels of trypsin activity were found in sugar - fed *Simulium venustum, Cnephia dacotensis* and *Prosimulium decemarticulatum*. Most of the trypsin activity in *S. venustum* was derived from the mid-gut. No trypsin activity was found in the salivary glands or carcass. The phenomenon of an increased trypsin activity after feeding on bird blood was determined. The blood and sucrose mixture in the crop of *S. venustum* stimulated a steady enzyme activity, as the mixture was dispatched slowly to the mid-gut. A low environmental temperature depressed mid-gut secretion, and thus blood digestion. Certain observations were further substantiated histologically. The peaks of trypsin activity in both *S. venustum* and *S. rugglesi* were identical at pH 8.4 and the

substrate concentration to reach half of the maximal velocity was similar. A very specific, sensitive and convenient colorimetric micromethod, utilizing TAME, was adopted as the standard method for the trypsin estimation on the bloodsucking insects.

*Fisher, K. R. S. (U. Toronto). Diapause in northern and southern populations of *Neodiprion pratti*.

In the northern population, from Ontario, there appears to be an obligatory diapause lasting about 30 days at 20°C. The diapause may be broken by exposure of the eggs to 15°C or lower. Once diapause-development has been completed it was postulated that the development remains arrested because the thermal threshold of morphogenesis is relatively high, lying between 15°C and 20°C.

In the southern population, from the Virginia region of the United States, there seems to be a facultative egg diapause which is induced by exposure of the eggs to low temperatures.

The differences found in the egg diapause of the two populations may be an indication of the establishment of two geographical races within the *N. pratti* complex by adaptation to climate.

Bond, E. D. and Monro, H. A. U. (Research Inst., London). The role of oxygen in the toxicity of fumigants to insects.

The response of insects to the toxic effects of many fumigants is determined to a large degree by the amount of oxygen available to them. Spiracular movement and metabolic rate, both of which are controlled by oxygen tension, are important factors in toxicity. When the oxygen supply is reduced fumigant uptake is increased because the spiracles remain open for longer periods of time. However, in some insects, tolerance is greatly increased when air pressure and oxygen tension fall below a certain critical level. This level varies with different species but it may be related to the ability to absorb oxygen from an hypoxic atmosphere. At high oxygen tensions fumigant uptake is apparently reduced during the exposure period but toxicity is enhanced when insects are retained in pure oxygen after the treatment. Aerobic metabolism, which is goverend by oxygen tension, appears to be directly involved in the toxication process.

Boyce, H. R. and McKeen, C. D. (Research Stn., Harrow). Some observations on vectors and transmission of tobacco etch virus.

George, J. A. and Brown, A. W. A. (U. Western Ontario). Effect of the chemosterilant Hempa on *Aedes aegypti* and its liability to induce resistance.

Treatment of larvae of the yellow-fever mosquito *Aedes aegypti* L. with 1280 ppm hempa induced small intrachomosomal deletions after 36 hours, with broken chromosomes appearing after 48 hours. Larval selection with hempa resulted in an increase in tolerance to the chemosterilant by the F_5 which was more than lost in the F_6 generation. Since the sterility shown by the selected strain, whether after treatment or not, was greatly increased by inbreeding, it is concluded that the reversal of the trend towards increased tolerance was due to the acquisition of inheritable recessive genetic defects similar to those intrachromosomal deletions observed cytologically.

Griffiths, K. J. (Sault Ste. Marie, Ont.). The establishment of *Lophyroplectus luteator* (Thunberg) on *Neodiprion sertifer* (Geoff.) in Ontario.

Lophyroplectus luteator (Thunb.), a European ichneumonid, has been liberated in three *N. sertifer* infested plantations in southern Ontario. In one plantation, where an introduction was made in 1962, the parasite has survived three years and has spread at least 7/10 mile. No recoveries have been made from another, smaller introduction in that year. In the third introduction, made in 1964, the parasite has survived one year, but the small numbers of parasites obtained and the absence of females in collections suggest that establishment may not have occurred.

Lyons, L. A. (Sault Ste. Marie, Ont.). Some recent population trends of *Neodiprion sertifer* in Ontario.

Annual records of population density in eight pine plantations in southern Ontario are examined and discussed. In most young plantations, density increases rapidly for two to four years following the first appearance of the sawfly, but is therafter gradually suppressed. Observed differences between host species in population trends are attributed to differences in the time at which the stands became infested, rather than to the superiority of certain host species. In a stand of 40-year-old jack pines, intense prolonged eonymphal diapause led to a sharp decline in sawfly density, but also protected the population from the near-elimination it would otherwise have experienced due to nuclear polyhedrosis.

NIGAM, P. C. (Chemical Control Res. Inst., Ottawa). Effect of emulsifiers and solvents concentrations on the toxicity of lindane emulsions.

Some factors which determine the effectiveness of insecticidal emulsions have been investigated using the second instar hoppers of the Desert Locust *(Schistocerca gregaria* Forsk) as test insect. After preliminary selection from the available chemicals three solvents viz., solvent "A", xylene, turpentine oil and five emulsifiers viz., Emulsifier "L" Tween-80, Triton X-100, Teepol-L and Sandovit, were investigated in detail. This investigation had provided information regarding the relative efficiencies of different solvents and emulsifiers, and their optimum concentrations for lindane emulsion. It was found that the efficiency of different emulsifiers and solvents should be compared at the values of their optimum concentrations instead of comparing them at any arbitrary concentration. Statistical analysis showed that the LC_{50} values of the insecticide formulated with different emulsifiers or solvents at their optimum concentration were not significantly different. The concentrations of the emulsifiers were determined at which just stable emulsions were obtained and these were designated as minimum concentrations. Similarly the concentrations of emulsifiers at which maximum toxicity was obtained were designated as optimum concentrations. In every case the optimum concentration was always found to be higher than the minimum concentration showing that for biological efficiency more emulsifier is needed than what was required for just stable emulsion i.e., for physical stability.

RIOTTE, J. C. E. (Royal Ont. Mus., Toronto). Unusual pierids in Ontario.

Pieris virginiensis H. Edw. was re-found in Ontario after many decades. The question "what is *Pieris virginiensis*" which seemed to be quite remote to us is now of some interest to Ontario Entomologists. The question is decided in the sense of Warren's work on the androconial scales in species of *Pieris.*

Euchloe ausonides mayi Chermock & Cherm. was first found to be moving into Ontario from Manitoba in 1947 by a summer field-party of the R.O.M. Later it was found by Syme in 1958 near Beardmore (Thunder Bay District) and this year the summer field-party of the R.O.M. found it 22½ miles more to the east on Highway 11 than Syme did and even in the forest near Geraldton, approximately still 15 miles more to the east. The butterfly is connected with *Arabis drummondi* which is found on more arid places in the bush and along the Highway. The range extention can be considered impressive. *Pieris protodice* Boisd. & LeC. was in old times not uncommon in southern Ontario. It is now one of the rarest butterflies. The slide shown represents a specimen of approximately 100 years of age from the historic Bethune collection (in the R.O.M.). It was caught this year by a schoolboy in the midst of Toronto in the little park near Christie and Shaw Streets — A colony of the other, so called "western", checkered white is in Northern Ontario at Lansdown House on Lake Attawapiskat. *Pieris occidentalis* Reakirt, which is taxonomically distinct from the aforementioned *protodice,* was found there in 1939 by the summer field-party of the R.O.M. This colony is the most eastern known.

THOMAS, J. B. (Sault Ste. Marie, Ont.). Gastric caeca as an aid in the taxonomy of Scotltidae.

WIGGINS, G. B. (Royal Ontario Mus., Toronto). Temporary ponds and caddis-flies.

YAMAMOTO, T. (Royal Ont. Mus., Toronto). Variations in the winter stonefly, *Allocapnia granulata* (Classen), as indicators of Pleistocene faunal movements.

A study of the variations in the genitalic structures and wings of the males of the winter stonefly *Allocapnia granulata* (Claassen) demonstrates the possibility of employing intra-specific differences in deducing the past dispersals of the species. *A. granulata* exhibits variations which, when plotted against several transects taken across its geographic range, indicate that the species contains an eastern population from the Atlantic Coast to central Illinois and a western population occurring from central Missouri to central Oklahoma. The eastern population contains two, the western three subpopulations. All are definable only on a modal basis.

The following sequence of events is indicated by a phylogenetic analysis of the variants and their present geographic distribution. From the Cumberland plateau-Appalachian region in which the progenitor of *A. granulata* originated, the species dispersed northward and subsequently divided into a northern and southern segregate, the northern one evolving shorter wings. Probably at the onset of the last glacial epoch, the more northern population moved south and westward as far as Oklahoma. The main eastern and western populations arose with the separation of the displaced modern segregate at about the mid-Illinois line. The western population subsequently broke up into subpopulations which moved northward only slightly. The eastern population moved northward as the glaciers dissipated, colonizing the deglaciated country from Minnesota to the East Coast.

McClanahan, R. T. (Research Stn., Harrow). Systemic insecticides used against the two-spotted spider mite on greenhouse cucumbers.

Watson, W. Y. (Laurentian U.). Some ecological and anatomical considerations of the larvae of certain Tendipedidae.

Anatomical characters and tube-building habits of species of *Glyptotendipes* and *Tendipes* are compared. Suggestions are made concerning the value of the chaetotaxy of the larval head capsule and of tube construction in taxonomy. The practical value outside of entomology of the tube-building habits of Tendipedid larvae are briefly considered.

Friend, W. G. (U. Toronto). The use of ionizing radiation for the control of insects. Report of a work conference held at Tel Aviv, Israel, Oct. 17 to 21, 1966.

Fieldmeth, C. R. (U. Toronto). Effect of water current on the respiratory responses of a stream caddis-fly larva.

The study was undertaken to determine the role of water current on the respiratory responses (oxygen consumption, abdominal undulations) of the stream caddisfly larva, *Pyconopysche guttifer*. As water current increased, respiration of normal larvae first increased, then decreased. Abdominal undulations remained constant until current exceeded 4-6 cm/sec, then decreased. Decrease in ventilation corresponds to a drop in respiration over the same velocity range. Respiration of anaesthetized larvae increased rapidly to 1 cm/sec, only gradually rising is faster velocities. Field occurrence correlated with maximal oxygen consumption and respiratory activity suggesting the importance of low flow rates to maintenance of a sufficient metabolic level. Restriction to these low velocities is behavioural as animals pull into their cases, being unable to navigate in higher velocities.

Baker, W. V. (U. Toronto). Stridulation and behaviour in three species of Passalidae.

The Passalidae are mainly tropical beetles which live aggregated under the bark of decaying trees. The adults stridulate and the larvae are also said to do so. These features allow the Passalidae to be regarded as social beetles, in spite of the fact that observations have been almost entirely restricted to *Passalus cornutus (Popilius disjunctus)* which is found in North America.

Observations on three species of *Pentalobus* found in Ghana suggest that these beetles can hardly be regarded as social since they do not exhibit any of the features of cooperation and interdependence characteristic of social insects. Furthermore, the larvae do not stridulate and stridulation does not appear to play any part in the lives of these insects while they are in the shelter of logs. It is further suggested that these beetles do not bore into wood but are secondary invaders and may not even be entirely lignivorous.

Further observations on aggregation, feeding and pupal-case building suggests that the larvae are not dependent on the adults.

Angus, T. A. (Sault Ste. Marie, Ont.). Comparative toxicity of some *Bacillus thuringiensis* varieties.

Rahalkar, G. W. and Nair, K. K. (Research Inst., Belleville, Ont.). Influence of diapause on the radiosensitivity of Khapra beetle larvae.

Studies were conducted to determine the effects of varying periods of diapause on the radiosensitivity of the Khapra beetle larvae (*Trogoderma granarium* Everts). There was practically no mortality in the irradiated larvae during diapause but it manifested itself only after the diapause was broken at 38° C. Since the calculated LD_{50}'s for 10, 20 and 30 days of post irradiation diapause were not significantly different from one another it was also evident that increases in the length of diapause had no significant effect on post diapause survival time. On the other hand pupation seemed to be influenced by the duration of diapause in the irradiated larvae. This effect was best discernable at low doses. The significance of these findings is discussed.

Annual Business Meeting

The annual meeting was held in Room 432, Ramsay Wright Laboratories, University of Toronto, on November 4, 1966.

The business meeting was opened by President Monro. The minutes of the previous meeting were circulated to the membership (September 25) and, on a motion by S. E. Dixon, seconded by H. R. Boyce, these were accepted as circulated.

The President in his Report thanked all those who through their attendance, participation in the programme and in the organization, made this meeting a real success. The unavoidable postponement from the original dates had resulted in some anxiety. He thanked D. M. Davies for his fine work as Editor of the Proceedings and announced that W. W. Judd had been approached as his successor as Editor.

A new Committee on the Common Names of Insects was presented, subject to final acceptance by those concerned:

G. B. Wiggins (Chairman)

H. W. Goble

O.H. Lindquist

W. Y. Watson

The President drew attention to the increase in numbers of papers presented for the President's Prize. In anticipation of a continuing increase, a committee was established to consider ways and means of handling this part of the programme in the future. The committee members are D. M. Davies, F. Fletcher, P. E. Morrison and H. A. U. Monro.

It was moved by P. Belton, seconded by W. G. Friend that this report be accepted. Carried.

The Secretary-Treasurer presented the Financial Statement for the year ending December 31, 1965 (Appendix I). It was moved by C. E. Atwood, seconded by W. G. Friend that this be accepted. Carried.

The interim statement of finances to October 31 was presented. Questions on the differences in the sales of reprints, and costs of printing as compared to other years were answered by the Secretary-Treasurer.

The acceptance of this report was moved by H. R. Boyce, seconded by G. W. Green. Carried.

The results of the mail ballot were presented. The newly elected members of the Board of Directors are — C. E. Atwood, P. Belton, H. R. Boyce, G. W. Green, P. E. Morrison, Helen Salkeld, W. H. A. Wilde.

Editor's Report

Volume 96 of the Proceedings has been mailed to members. It included 19 papers and 17 abstracts.

Two types of reviews have been encouraged. One is a review of an insect or group of special interest or economic importance in Ontario, indicating its past history and present status. The other is a review of insects, arthropods and nematodes of economic importance affecting man and his produce during the past year.

Professor W. W. Judd has agreed to act as editor in the coming year and I shall give him all the assistance that I can.

We should begin thinking now of making Volume 100 a special publication.

Moved by D. M. Davies, and seconded by W. Y. Watson that this report be accepted. Carried.

Douglas M. Davies

Report of Library Committee

During the past year the facilities of the library have been used by Library Loan Services, members of the staff of the Zoology Department of the University of Guelph and graduate and undergraduate students at Guelph.

Approximately 70 exchanges have been received regularly and cataloging and boxing is well in hand.

Library Loan requests made up the bulk of lending material and 44 requests have been dealt with this year to date. In most instances the publication containing the desired article was shipped to the borrower on a one-month-loan-period but where the article appeared in a large volume or was only a few pages, photocopy pages were made and sent to the borrower. This procedure was also followed if the article was in what was considered to be a very valuable volume.

With the expansion of the University, the increasing demand for space in the Department of Zoology and the new concept of library administration of the University's chief librarian, it is felt that the Society should give some thought to the future of the library. For some years now the library has occupied a room in the basement of the Zoology Department. This room is 24' x 40' and is set up with 1900 lineal feet of shelving space. The size and location of this room make it a very valuable piece of property and while it has not been suggested, there is every reason to believe that we will be asked to vacate in the near future.

W. C. Allan, Chairman.

The librarian, questioned on the publication of a list of library acquisitions, reported that a list was published in 1952 and a second list mailed to members in 1959. The size of this undertaking is too great to warrant a repetition at the present time. The holdings are available from the Union List of Periodicals.

The acceptance of the report was moved by W. C. Allan, seconded by H. Wressell. Carried.

Report of the Resolutions Committee

1. WHEREAS the University of Toronto, by making available excellent facilities has greatly contributed to the success of the 103rd Annual Meeting,

BE IT RESOLVED that our Society through the Secretary extend to the President of the University, Dr. Bissell, our sincere thanks.

2. WHEREAS the Programme and Social Committees under the Chairman Dr. C. E. Atwood, have done an excellent job in preparing for the meeting,

BE IT RESOLVED that our Society, through the Secretary express our appreciation for their efforts.

3. WHEREAS the annual competition for the President's Prize is an important part of our meeting, and since the judges have once again been given a difficult responsibility in deciding the winner,

BE IT RESOLVED that the Society extend our appreciation to Dr. F. W. Fletcher, Dr. E. Becker, and Dr. R. L. Edwards, and further that the contestants themselves be extended the appreciation of the Society for their contributions.

4. WHEREAS the visit to Scarborough College and the hospitality extended while there proved to be a highlight of the non-scientific aspects of the meeting,

BE IT RESOLVED that this Society express its appreciation to the Dean, Dr. W. E. Beckel, and to the Shell Oil Company.

5. WHEREAS the efforts of Dr. K. C. Fisher and his staff have greatly assisted the physical operation of the meeting,

BE IT RESOLVED that the special thanks of the Society be expressed to him.

6. WHEREAS the current executive has overcome great difficulties this year in organizing the Annual Meeting,

BE IT RESOLVED that the membership extend to them their appreciation.

J. B. Thomas, Chairman; H. B. Wressell, S. E. Dixon.

Moved by J. B. Thomas, seconded by H. B. Wressell that this report be accepted. Carried.

Grant to Zoological Society of London

A letter from the Zoological Society of London was read. In the past the Society has given $100.00 to help in the publication of the Zoological Record. Considerable discussion arose concerning the continuing need for these monies. The Secretary, questioned on a financial statement of the Zoological Society of London, reported that he did not have one. Because of our own Society's limited resources it was suggested that the monies be used to the best interest of the Society. Several motions were proposed, amended and withdrawn in favour of the following: J. Mc B. Cameron moved that the Grant be sent this year, and that the Secretary obtain a price list of back issues so that in the future our money will be a subscription for the current issue of the Insects Section of the Record and the balance be applied to the purchase of back issues. The motion was seconded by C. Sullivan. Carried.

A letter from Dr. B. N. Smallman inviting the Society to meet at Queen's University, Kingston in 1967 was read.

A motion to accept Dr. Smallman's invitation, the meetings to be held in October or November, was made by J. McB. Cameron, seconded by G. W. Green. A Saturday session was suggested so that the new Biology Building could be used. Members voiced approval of the opportunity to see and use these new facilities but the idea of a Saturday session did not get general approval. A letter of acceptance is to be sent to Dr. Smallman. The opinions on the Saturday sessions are to be outlined in this letter also.

Motion carried.

It was moved by D. H. Pengelly, seconded by W. C. Allan that Payton and associates be appointed auditors for 1967. Carried.

Meeting adjourned on a motion from H. B. Wressell.

D. H. Pengelly, Secretary-Treasurer.

Meeting of Incoming Directors

The newly elected Directors met in Room 432 of the Ramsay Wright Zoological Laboratories, November 4, 1966 at 12:15 p.m. Those present were President Monro, C. E. Atwood, P. Belton, H. R. Boyce, G. W. Green, P. E. Morrison, and D. H. Pengelly Secretary-Treasurer. C. E. Atwood was nominated by G. W. Green for the Presidency. Nominations were closed on a motion by P. E. Morrison. Carried.

President Atwood took the chair. H. A. U. Monro nominated H. R. Boyce as Vice President. P. Belton moved the closing of nominations. Carried.

W. C. Allan was re-appointed Librarian for the Society. The Directors were unanimous in their appreciation of Mr. Allan's work and approved the continuing maintenance of the library. He begins his sixteenth year in this capacity.

D. H. Pengelly was re-appointed Secretary-Treasurer.

W. W. Judd had been asked to consider the Editorship of the Proceedings. This was approved by the Directors.

A nominating committee was appointed to prepare the slate of Officers for the next election of Directors.

It was moved by H. R. Boyce that G. Dustan be named chairman of this committee and that the other members be the Past President H. A. U. Monro and the Secretary Treasurer. Seconded by G. W. Green. Carried.

On a motion by H. A. U. Monro, seconded by H. R. Boyce, W. E. Heming and A. J. Musgrave were appointed scrutineers of the mail ballot.

It was requested that copies of the constitution be given to the Directors.

Meeting adjourned 1:00 p.m.

D. H. Pengelly, Secretary-Treasurer

APPENDIX I

ANNUAL FINANCIAL STATEMENT FOR 1966

RECEIPTS		DISBURSEMENTS	
Dues Received	$ 2,064.51	Dues sent to Ottawa	$ 1,616.00
Exchange on cheques	10.67	Exchange on cheques	21.59
Premium on U.S. Funds	26.79	Library Maintenance	200.00
Sale of Reprints	830.00	Insurance	25.00
Sale of Proceedings	85.31	Printing	622.02
Sale of Insect Cabinets	349.00	Stationery	75.88
Bank Interest	58.43	Supplies	5.30
Bond Interest	18.00	Postage	286.35
Grant from Prov. Govt.	300.00	Auditors (1965, 1966)	10.00
Cash Advanced Annual Meeting	100.00	Honorarium to Sec. Treas.	50.00
Receipts from Annual Meeting	603.00	Grant to Zoological Soc.	100.00
Gov't. Bonds	400.00	Annual Meeting	
Bank Balance Jan. 1/66	1,603.91	Cash advanced	100.00
		Travel by Pres.	28.10
	$ 6,449.62	Telephone	10.65
		Name Tags etc.	18.48
		Programmes and Tickets	51.01
		President's Prize	50.00
		Banquet Speaker	50.00
		Banquet	514.65
		Symposium	150.00
		Caterers, Coffee	134.40
		Government Bonds	400.00
		Bank Balance Dec. 31/66	2,228.99
			6,748.42
		Less Outstanding Cheques	298.80
			$ 6,449.62

Signed—C. J. Payton
B. E. Saunders, Auditors

APPENDIX II

PRESIDENT'S PRIZE

Eight papers were presented by university students at the 103rd annual meeting in the sixth annual competition for the President's Prize (see list of students, titles and abstracts above).

The judges, F. W. Fletcher, Edward Becker and R. L. Edwards, awarded the fifty dollar prize and Certificate of Merit to K. R. S. Fisher, the presentation being made at the banquet by Dr. H. A. U. Monro.

K. R. S. Fisher was born in Toronto, Ontario in 1942. He received the Bachelor of Science degree from the University of Toronto in 1963 and proceeded directly to Graduate School. His graduate training at Toronto was interrupted by a year at the University of Paris in Professor Th. Lender's laboratory where he investigated the *in vitro* culture of *Periplaneta americana* embryos.

In February 1967 he received the Master of Science degree from the University of Toronto. Mr. Fisher is at present working toward his Ph.D. at the same institution.

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ENTOMOLOGICAL SOCIETY OF ONTARIO

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1966 - 1967

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INSECTS OF THE SEASON 1967 RELATED TO FRUIT, VEGETABLES AND ORNAMENTALS

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Fruit

The amount of injury to fruit by insects was again small in 1967. There were, however, some exceptions. The European red mite, *Panonychus ulmi* (Koch), was well controlled in most orchards early in the season but some large, persistent infestations occurred in Southwestern Ontario and in some other areas in August and September. This was probably the most serious problem on tree fruits. The codling moth, *Carpocapsa pomonella* (Linnaeus) and the red-banded leaf roller, *Argyrotaenia velutinana* (Walker), two of the major pests of apples, were not serious. The eye-spotted bud moth, *Spilonota ocellana* (Denis & Schiffermüller), has been present in very small numbers for several years including the 1967 season. Larger numbers than usual of the oriental fruit moth, *Grapholitha molesta* (Busch), survived the winter of 1966-67 in the Niagara Peninsula but succeeding broods decreased with little infestation at harvest. This insect was not a problem in Southwestern Ontario except in a few orchards east of Leamington. The apple maggot, *Rhagoletis pomonella* (Walsh) and the cherry fruit flies, *Rhagoletis* spp. were controlled satisfactorily.

Damage from the plum curculio, *Conotrachelus nenuphar* (Herbst), aphids and leafhoppers, mostly *Empoasca fabae* (Harris), was greater than average. Pear psylla, *Psylla pyricola* Foerster, infestations were light early in the season but caused some damage in Southwestern Ontario in September.

A leaf miner, *Fenella nigrita* WestW., was reported by G. G. Dustan, Vineland Station and identified by H. E. Milliron, Ottawa on strawberries in June 1967 at Virgil. This appears to be the first record for Ontario.

Vegetables

Some insects and the garden slug were important on vegetables. As in 1966, the sap beetle, *Glischrochilus quadrisignatus* Say, was probably the most important. Infestations in tomatoes were of such proportions in some fields that a number of loads were rejected by the processor. They continued to infest raspberries in a wide area of Southwestern Ontario. Infestations in corn were less severe. The Colorado potato beetle, *Leptinotarsa decemlineata* (Say) was more plentiful on potatoes and tomatoes than for a number of years. Several species of flea beetles were plentiful, especially the more recently introduced species, *Phyllotreta cruciferae,* on cole crops. Root maggots, *Hylemya* spp. injury varied

in the truck crop areas of the Province. Early rutabagas were seriously damaged in Bruce County but damage was light on the late crop in most of Ontario.

Field Crops

Slugs continued to be an important problem, the principal species being *Deroceras reticulatum* (Müll). Some fields of corn were severely damaged in May and June, delaying satisfactory establishment of the crop. In a few fields damage occurred again in September when they fed on the leaves from the ground up to three feet. Slugs also caused extensive damage on some fields of commercial vegetable crops such as celery, snap beans and Brussels sprouts. They continued to be the most important pest in home gardens. The European corn borer, *Ostrinia nubilalis* (Hübner), was more injurious in field corn in some parts of Ontario than for a number of years. This may be related to the economic cropping system (monoculture) for corn.

The cereal leaf beetle, *Oulema melanopus* (Linnaeus), was found in Essex and Lambton counties and the alfalfa weevil, *Hypera postica* Gyllenhal, in counties along the north shore of Lake Erie and in Leeds County.

Ornamental Plants

The severe infestations of cottony maple scale, *Pulvinaria innumerabilis* Rathvon, as reported in 1966 declined in Central Ontario in 1967 but persisted in parts of Essex County. The bronze birch borer, *Agrilus anxius* Gory, continued to be very destructive to the cut-leaf weeping birch, killing many trees. The birch leaf miner, *Fenusa pusilla* Lepeletier, was conspicuous on ornamental birch. Various species of aphids were abundant, late in the season, on many trees such as linden, tulip, willow and copper beech.

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ECONOMICALLY IMPORTANT PLANT PARASITIC NEMATODES IN ONTARIO

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Several destructive plant parasitic nematode genera occur in Ontario soils. These are, in descending order of economic importance, the root-lesion nematode, *Pratylenchus* Filipjev, the root-knot nematode, *Meloidogyne* Goeldi, the cyst nematode, *Heterodera* Schmidt, the bulb and stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjev, and the pin nematode, *Paratylenchus hamatus* Thorne and Allen.

Root-lesion nematodes are migratory animals which feed and reproduce in the cortex of roots of a wide range of host plants. During the summer of 1967, an intensive nematode survey of important agricultural crops was carried out in 21 counties west of Peterborough. At least four species of *Pratylenchus* were encountered. *P. neglectus* (Rensch.) Filip. and Stek. was found to be widely distributed throughout Southern Ontario, where *P. penetrans* (Cobb) Sher and Allen occurred in large numbers in the Niagara Peninsula and in the Counties of Norfolk, Essex and Kent. This finding is at variance with the view expressed in an earlier report in these Proceedings (Townshend, 1966) that *P. penetrans* had displaced *P. neglectus* as the dominant root-lesion nematode species. Although *P. neglectus* appears to be more widespread than *P. penetrans,* the latter is more pathogenic (Pitcher, 1965). *P. neglectus* occurred in most corn fields sampled but there was no evidence of any damage. *P. penetrans* caused a considerable amount of brown root rot of flue-cured tobacco in Norfolk county; it was responsible for stunting of *Juniperus* and *Taxus* seedlings and for decline and replant failures in cherry and peach orchards in the Niagara Peninsula and perhaps in apple orchards in Norfolk County. Two additional root-lesion nematodes, *P. crenatus* Loof and *P. pratensis* (de Man) Filipjev, were found occasionally.

The survey showed the northern root-knot nematode, *Meloidogyne hapla* Chitwood, to be common in a sandy loam region west of Simcoe. It was also found on tobacco at Alliston, on carrots and parsnips in the Bradford Marsh area and on forage crops in the Grand River Valley, extending into the Georgian Bay area. The wide-spread occurrence of this animal in Ontario soils represents a potential problem when susceptible crops, such as tomato, tobacco or carrots are grown continually.

An interesting case of root-knot nematode damage was found in ginseng (*Panax quinquefolium* L.). The nematode caused heavy galling of the roots, stunting of the plants and bronzing of the leaves. The southern root-knot nematode, *Meloidogyne incognita* (Kofoid & White) Chitwood continues to be a problem in greenhouse soils, mainly of cucumbers and tomatoes.

Several species of the cyst nematode, *Heterodera,* occur in Ontario soils. The sugar beet nematode, *H. schachtii* Schmidt, has been a problem in the sugar beet growing areas of Lambton County for over 35 years (Brown, 1932). Partially because of the nematode, the sugar beet industry is dying out and *H. schachtii* will cease to be a problem on this crop. However, a few years ago they were detected in the vegetable growing areas surrounding Hamilton and Toronto, where they are extremely destructive to susceptible crops such as table beets (Townshend and Olthof, 1967).

The oat cyst nematode, *H. avenae* Wollenweber, appears to be confined to oats grown on loamy soils. They were frequently found on oats at Kitchener, Walkerton, Flesherton and near Lake Scugog. Growing oats in the same field year after year may result in total crop failure. However, a four- to five-year rotation with forage crops, avoiding small grains, or three or more years of corn, will hold the nematode under control.

Another cyst nematode, probably the clover cyst nematode, *H. trifolii* Goffart, was also occasionally encountered. The knot weed cyst nematode, *H. weissi* Steiner, was found for the first time in Canada in 1966. It occurred on knot weed (*Polygonum aviculare* L.) at Aylmer, Ontario. This nematode appears to have a very restricted host range, as greenhouse experiments failed to reveal the existence of other host plants (Unpublished).

Two species of spiral nematodes, *Helicotylenchus canadiensis* Waseem and *H. digonicus* Perry were discovered in association with corn. The effect of these nematodes on corn has not been determined.

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IMPORTANT FOREST INSECTS OF ONTARIO IN 1967

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The insects mentioned in this review are being brought to the attention of entomologists because they currently are forest pests in Ontario, because they are introduced insects which are extending their range limits in our forest lands, or because they are species whose damage potential has been suspect or only recently recognized. Accounts are grouped under indigenous and introduced insects and are, in turn, subdivided according to their affinity to broad-leaved or coniferous host trees. More detailed information on these and other insects affecting forest trees is available in the Annual Report of the Forest Insect and Disease Survey, published by the Canada Department of Forestry and Rural Development, or from this department, Box 490, Sault Ste. Marie, Ontario.

Indigenous Insects

On Coniferous Trees

Among the defoliators, incipient infestations of spruce budworm, *Choristoneura fumiferana* Clemens, at widely-separated locations were cause for concern. The most notable was near Burchell Lake in the Port Arthur Forest District where moderate-to-severe defoliation of the current growth of fir and spruce occurred over about 40,000 acres and where egg mass surveys in the fall indicated the possibility of light-to-severe defoliation over roughly 300,000 acres in 1968. Extensive stands of mature spruce-fir forest lie to the north and east of this area. A second trouble spot was in the Ottawa Valley where spruce and fir in scattered woodlots between Mattawa and Ottawa and in Lanark County were moderately or severely defoliated. Defoliation of similar extent and intensity is expected in 1968. In the Chapleau District a light infestation occurred over parts of seven townships. Pockets of moderate-to-severe defoliation of spruce were found at numerous widely-scattered points in southern Ontario. Infestations of the closely related jack pine budworm, *Choristoneura pinus pinus* Freeman were as numerous

and widespread as at any time in the past three decades. By far the largest infestation, covering 8,500 square miles, mostly in the Kenora District but with a small area in the Sioux Lookout and Fort Frances districts, resulted in moderate-to-severe defoliation in extensive stands of jack pine, and some tree mortality in a small number of stands which have been under attack for two or more consecutive years. In addition, medium-to-heavy infestations were reported at many widely-separated locations from the Sault Ste. Marie District eastward to the North Bay and Cochrane districts as well as in the Parry Sound, Pembroke, and Lake Simcoe districts. Moderate-to-severe defoliation by the larch sawfly, *Pristiphora erichsonii* (Hartig) recurred in many tamarack stands in northwestern Ontario and an increase in extent and intensity was reported in the remainder of northern Ontario. The redheaded pine sawfly, *Neodiprion lecontei* Fitch, was sufficiently abundant to warrant control measures in parts of its range in central and southeastern Ontario.

Of interest to the epidemiologist was the coincidence of a number of forest insect infestations in the Ottawa Valley. In addition to the budworm infestations previously mentioned, heavy infestations of *N. nanulus nanulus* Schedl, on red pine, *N. pratti banksianae* Rohwer, on jack pine, and of *N. abietis* complex on balsam fir were common, as were a number of defoliators of hardwoods mentioned below. The occurrence of these outbreaks may be related to the drought conditions in the Ottawa Valley in the early summers of 1964 and 1965.

Damage by insects other than defoliators was more prevalent than usual in 1967. For instance, three species of *Dioryctria* were important: large numbers of *D. reniculella* (Grote) were associated with spruce budworm infestations on white spruce; unusually heavy attack on red pine shoots by *D. zimmermani* Grote was noted in parts of southern Ontario; and heavy attack by *D. disclusa* Heinrich on the cones of various pines was widespread. The following records are noteworthy because they represent new or unusual host or distributional information for the Survey. Collections of the scale, *Abgralaspis ithacae* Ferris, on balsam fir in the Pembroke District and the olethreutid, *Petrova comstockiana* Fernald, on pitch pine in the Kemptville District were first Ontario records. *Pyrrhia* sp. prob. *exprimens* Walker, a noctuid, caused severe damage to white spruce tubelings planted following a forest fire in the Chapleau District. *Cytilus alternatus* Say, a byrrhid, caused heavy damage to red pine seedlings in a small area of the Gogama nursery.

On Broad-leaved Trees

Several infestations of the forest tent caterpillar, *Malacosoma disstria* Hubner, remained active in different parts of the Province. Medium-to-heavy infestations persisted over 3,500 square miles of the southern part of the Fort Frances District and egg cluster counts indicate a similar potential for damage to aspen stands in 1968. Two infestations between Sault Ste. Marie and Elliot Lake which expanded, causing moderate-to-severe defoliation in an area of 1,000 square miles, are expected to persist. On the other hand, infestations in the Sudbury, Parry Sound, Pembroke, and Kemptville districts, except over relatively small areas at the east end of Lake Nipissing and near Pembroke, collapsed as a result of unfavorable spring weather conditions. Severe defoliation of yellow birch north of Sault Ste. Marie by a birch sawfly, *Dimorphopteryx* sp., referred to as *D. pinguis,* in 1966, did not recur because virtually all overwintered larvae remained in diapause in 1967. Crowns of yellow birch trees which had been completely defoliated in late summer 1966 showed considerable deterioration. As mentioned earlier, hardwood defoliators such as *Arge pectoralis* Leach and the cankerworms, *Alsophila pometaria* Harris and *Paleacrita vernata* (Peck), were much more numerous than in past years in the Ottawa Valley.

Unusual outbreaks of native insects were reported. The saddled prominent, *Heterocampa guttivitta* Walker, which has only twice in the past thirty years been known to cause severe defoliation in sugar maple woodlots erupted northwest of Lake Simcoe and along the east side of the Bruce Peninsula. The presence of larvae killed by *Beauveria* fungus and of numerous predators in the duff where larvae pupated suggests possible explanations for the short-lived nature of past outbreaks.

The cottony maple scale, *Pulvinaria innumerabilis* Rathvon, rarely a serious pest, caused considerable public concern in the Amherstburg area where silver maple over an area of at least five square miles was severely infested. Little-known insects which were present in outbreak numbers were an aspen petiole miner, *Nepticula* sp., recently reported in Quebec, that was increasing in number in the Lake Simcoe District to 40 percent incidence of leaf infestation, and a leaf roller on birch, *Gracillaria* sp., that caused severe damage to foliage in parts of the Cochrane and Kapuskasing districts. A cicada, *Okanagana rimosa* Say, caused severe oviposition damage to aspen in the Sault Ste. Marie District.

Introduced Insects

On Coniferous Hosts

First efforts to contain the European pine sawfly, *Neodiprion sertifer* Geoffroy, on Manitoulin Island using virus sprays, were prompted in 1966 owing to the proximity of extensive stands of jack pine on the mainland; these attempts appeared to be successful. Intensive follow-up surveys in 1967 seldom revealed numbers in excess of 0.01 colonies per tree, and the sawfly was discovered in only one additional Scots pine plantation on the Island, namely, at West Bay. The sawfly was prevalent throughout most of southwestern Ontario and has continued to spread eastward in the southern half of the Lindsay District and at a few points in the Tweed District. No further spread was detected for other introduced pests such as the European pine shoot moth, *Rhyacionia buoliana* Schiffermuller, the larch casebearer *Coleophora laricella* Hubner, the European spruce sawfly *Diprion hercyniae* (Hartig), the introduced pine sawfly, *D. similis* Hartig, or the nursery pine sawfly, *D. frutetorum* (Fabricius). The last two, however, showed appreciable increases in numbers in the Lake Simcoe District.

On Broad-leaved Trees

The spread of the birch leaf miner, *Fenusa pusilla* Lepeletier, both north and west, was striking (Fig. 1). In the Fort Frances District, the pest was found at four widely-separated points, one of which was in the town of Fort Frances. A spread northward to the shores of Lake Nipigon, into the Gogama District, to the town of Kapuskasing, and to Swartman Township in the Cochrane District represents considerable increases in the range of the sawfly. The occurrence of first or early records in towns and cities continues to support an earlier theory that the use of balled nursery stock from southern Ontario has been a major contributing factor in the spread of this pest into northern Ontario. Damage to ornamental birches in towns and cities resulted in many inquiries concerning control. The mountain ash sawfly, *Pristiphora geniculata* (Hartig), continued its spread northward in the White River District into Pic Township. The eastward spread of the smaller European elm bark beetle, *Scolytus multistriatus* Marsham, in a narrow band along the north shore of the St. Lawrence River from Ganonoque to Prescott coincided with an appreciable increase in elm mortality attributable to the Dutch elm disease.

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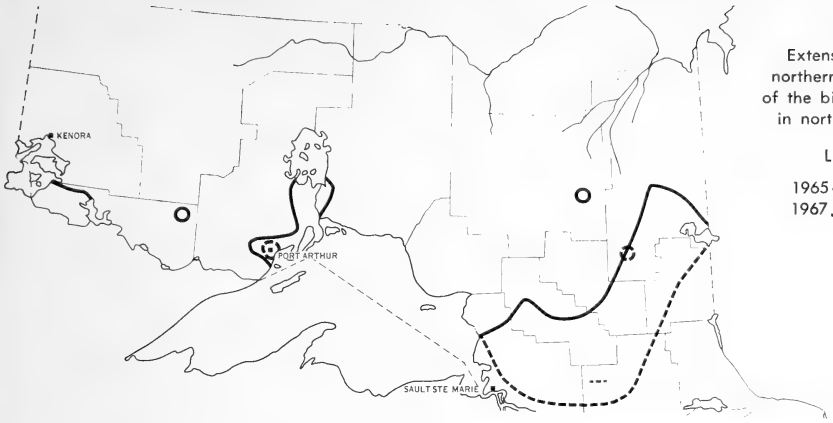

Fig. 1

Extensions of the northern range limits of the birch leaf miner in northern Ontario

LEGEND

1965 - - - - - - - - - -

1967 ——————

INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1967 IN HOUSEHOLDS AND ON LIVESTOCK IN ONTARIO

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Household

Cluster flies, *Pollenia rudis* (Fabricus), were very abundant in homes, offices, warehouses, restaurants and in many churches, particularly in the fall of 1967. Reports of high populations of this pest came from all parts of Ontario. The flies were active for a long period of time as the weather remained very mild and warm into late fall and they did not settle down for winter until just before Christmas. European earwigs, *Forficula auricularia* (Linnaeus), which previously were found only in the Bruce Peninsula district, have now spread widely and during the past year were reported in large numbers from an area which included most of Western Ontario and part of the Niagara Peninsula. In most instances they concentrated in gardens but in some cases they invaded houses in large numbers.

Early in the year larvae of black carpet beetles *Attagenus piceus* (Olivier), were quite a problem in many homes. It is thought that they were scavenging on dead bodies of overwintering flies.

Millipedes, *Narcus sp.,* were again very numerous and many reports were received where patios, garages, car ports and swimming pools were invaded by large numbers of these creatures. Sowbugs, *Oniscus sp.,* and centipedes, *Scutigera sp.,* were found in damp cellars and basements.

In kitchens and pantries the normal run of cereal products insects was not as great as in previous years. Saw-toothed grain beetle, *Oryzaephilus surinamensis* (Linnaeus), was the most common insect found together with small numbers of drug store beetles, *Stegobium paniceum* (Linnaeus), present in such products as bird seed and dog biscuits.

Livestock

The most frequently reported insect on livestock during 1967 was the face fly, *Musca autumnalis* (DeGeer). This fly appeared to be generally distributed in Central and Western Ontario on both beef and dairy cattle.

Horn flies, *Haematobia irritans* (Linnaeus), while not as numerous as in previous years, were readily found on cattle where no provision had been made for fly control. Warble flies, *Hypoderma bovis* (Linnaeus), were not as plentiful in cattle as in the past. A reduction in population is no doubt due to increased use of control materials. This was also the situation as far as cattle lice, *Bovicola bovis* (Linnaeus) and *Linognathus vituli,* (Linnaeus) were concerned.

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THE GYPSY MOTH, PORTHETRIA DISPAR L., A THREAT TO ONTARIO HORTICULTURE AND FORESTRY

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Introduction

The gypsy moth, *Porthetria dispar* L., was first brought to North America by a scientist attempting to develop a silk industry. Larvae hatching from imported egg masses in 1869 escaped to surrounding trees in the vicinity of Medford, Massachusetts. For several years nothing was done and the insect became firmly established over a considerable area. Since that time it has spread throughout the Northeastern states and small isolated outbreaks have been found as far west as Central Michigan. Outlying infestations such as this are difficult to anticipate and are frequently well established before they are discovered.

Over 40,000,000 acres of forest have been destroyed in the United States by the pest and $100,000,000 has been spent in preventing spread and eradicating or controlling isolated outbreaks.

Although egg masses were found in southern Quebec as early as 1924, these were effectively treated and it was not until 1954 that the moth seriously threatened Canada. Egg masses were found at Locolle, Quebec, and it was determined that infestations were general in adjacent New York State and Vermont. These provided a continuing source of reinfestation which required annual attention.

Biology

The gypsy moth is a defoliator, feeding voraciously on many broad-leaved deciduous trees and shrubs. It has an annual life cycle. Eggs are deposited in batches of up to 600 imbedded in a protective mass of buff-colored hairs from the body of the female. These are usually laid in protected places such as rock piles, under large bark scales, or on the undersurfaces of logs, parked vehicles and farm equipment and machinery. Where protected sites are not available or a population is high, masses may be found on tree trunks, the undersurfaces of branches, on fence posts, or on almost any solid medium on or above the ground.

In southern Quebec, hatching begins between May 5 and 25, depending on the season, and is completed within a week or ten days. Larvae are quite durable and can reach the foliage of the tallest trees. Because they are the most prevalent trees present in the area, birch and elm have been the main hosts. Maples are attacked to a lesser degree. Oak appears to be resistant, apparently due to its delay in leafing out in the spring. Wild apples are a preferred but relatively insignificant host at present, but unsprayed orchards would undoubtedly present a serious problem should the insect become established in the area.

Larvae feed voraciously for six to eight weeks, then pupate either after dropping to the ground or seeking a sheltered spot in the crown or on the trunk of the tree. The pupal stage lasts from ten days to three weeks. The females are too heavy to become airborne and can only flutter about clumsily or crawl a few feet from the pupal case. Male moths, however, are active flyers and will travel considerable distances in search of females. Mating is completed within a few days of emergence and the adults die.

Methods of Spread

Since the female moth cannot fly, natural spread during the adult stage does not occur. However, larvae are particularly light and buoyant during the first instar and, when disturbed, they spin down on a silken thread. Almost undetectable convection currents will lift them high above the trees. Activity is confined to bright, warm days and during such weather light winds may carry them in any direction for several miles.

Artificial dispersion has been considered responsible for the beginning of outlying infestations and to some degree for local spread. For example, it is impossible to believe that natural dispersion could account for an infestation in Calhoun County in central Michigan when the nearest source is five hundred miles to the southeast. Artificial dispersion is most likely to occur during the egg stage but may also occur during the larval or pupal stages. Larvae may drop on automobiles or trucks and be transported for several miles before being blown off or thrown out of a window where they may find their way to a suitable host to continue their life cycle. Final instar larvae may seek a protected place on any vehicle or on packing cases or any type of container to pupate and the pupae may be carried across the continent before the adults emerge.

Perhaps the greatest potential for a long range spread is on camping equipment. Many parks and private campsites are maintained within the area affected by the gypsy moth. Larvae preparing to pupate may drop on camping equipment and will seek out sheltered places on the frames or bodies of trailers, in folds of tents or even in crevices of food containers. Emerging adults seek similar niches in which to lay eggs. Campers stopping at an infested campsite may carry hitchhiking larvae, pupae, or eggs for hundreds of miles.

Egg masses have been found on quarry products, logs, logging and farm equipment, and on wood and lumber which has been stacked in the woods awaiting shipment.

Survey Procedures

Canada has, with some modification, adopted survey procedures developed in the United States. Specially designed traps are placed on a grid pattern in suspect areas at approximately one-mile intervals during the flight period. A trap consists essentially of a disposable Dixie cup. Openings are cut in both ends to permit entrance. Tanglefoot is smeared on the inside of the cup and it is baited with sex-attractant liquid which evaporates slowly from a small cube of cotton

batting attached inside. Male moths are attracted by odor, and after entering are held firmly by the tanglefoot. Male emergence from the pupal stage begins a few days prior to female emergence and, where this occurs, trapping can be an effective method of locating minor infestations. As female moths emerge, their presence to some degree offsets the effectiveness of the traps and this may result in a new infestation being missed until the following year.

Scouting for egg masses is carried out late in the fall in an area around each trap in which an adult is caught. Egg masses, if present, are not difficult to detect and an experienced crew of two or three men can delineate an infestation of up to 400 acres in half a day.

The Canadian Problem

Two small infestations of gypsy moth were found in Canada in 1924. These were both in Quebec and were eradicated during the next two years. In 1936, an infestation was discovered at St. Stephen, New Brunswick. Four years of diligent work were required to eliminate it as it had become established over several acres. These areas were trapped again in 1943, using three hundred traps supplied by the United States Department of Agriculture, with negative results.

No survey program was conducted again until 1954, when reports from New York State and Vermont showed that populations were building up within twenty miles of the Quebec border. Since that time patrol has been expanded from 300 traps to 1,200 traps annually and surveys include an area up to fifteen miles wide from the St. Lawrence eastward to New Hampshire. In addition, periodic surveys are conducted in New Brunswick and along the St. Lawrence River in Ontario.

Every year from 1959 to 1965 surveys uncovered new minor infestations in southern Quebec. Following treatment each spring, surveys showed that they had been eradicated.

Table I shows the areas treated during these years.

Table I
Gypsy Moth Treatment
Southern Quebec

Year	*Acres*
1960	900
1961	1,600
1962	1,600
1963	2,000
1964	2,000
1965	900
1966	300

The survey season of 1965 was poor and this resulted in only three captures and the discovery of only one small infestation of approximately 300 acres. In 1966, natural bait was used and male moths were captured over a wide area and at scattered locations throughout the territory trapped. Scouting revealed that several infestations must have been missed the previous year, and these had spread and consolidated over a wide area. In addition, several localized populations were present within the survey area. Approximately 24,000 acres were mapped for treatment.

In late May 1967, spray was applied to 18,000 acres, thus leaving approximately 8,000 acres of known infestation. During the 1967 survey, an additional 29,000 acres were found to be infested. Some of this was due to spread from outlying infestations but most of it was in the area between the main infestation and the New York State border. In fact, 35,000 infested acres lie within a triangle with apex just north of St. Chrysostome and base along the border between Rockburn and Hemmingford. The remaining 2,000 acres consist of several localized populations, including one north of Ormstown and fifteen in the Lake Champlain-Richelieu River area.

Containment and Control

Canadian involvement in gypsy moth control began in November, 1922, when a conference was called at Albany, New York, to review the problem and discuss ways of combatting it. As a result of this meeting, a barrier zone extending from the St. Lawrence River southward through Quebec, New York State and Western New England to Long Island Sound was established. It was agreed by the United States Bureau of Entomology and the Canadian Plant Protection Division that every reasonable effort would be made to clear this area and keep it free from infestation. The aim was to prevent the westward spread of the insect to valuable hardwood forests of the Mississippi watershed. The operation of this barrier has undoubtedly been a major factor in preventing more rapid spread westward.

Infestations were found periodically in and west of the barrier and in spite of intensive efforts they became established and consolidated over much of the eastern half of New York State. It would appear that a similar situation is developing in southern Quebec, and it may well be that all the region east of Lake Ontario and south of the St. Lawrence River as far east as New Hampshire will be generally infested within a very few years.

In Canada we are concerned with two aspects of control. Applied control was successful until 1966 in preventing establishment of a continuing population. With available resources and the limited time during which sprays may be effectively applied, the possibility of eradication is uncertain. Attempts will be continued, at least for the current year.

Artificial spread can be effectively controlled only by international cooperation with officials of the United States Department of Agriculture. Federal quarantines were imposed in the United States on potential carriers of eggs or pupae and these quarantines were accepted by Canadian authorities. Quarry and forest products were permitted to move from infested areas only after inspection and certification by a qualified quarantine officer. Many lumber mills in southern Quebec and eastern Ontario depend on the adjacent states for their supplies of logs. These must all be certified before they are permitted to enter Canada. In recent years the United States has supplied the Canadian authorities with a list of all Canadian visitors camping in infested parks. In several instances, examination of camping equipment used by these visitors has yielded remnants of pupal cases, and in one instance, two male and one female pupal cases were discovered in a protected spot on the undersurface of a house trailer. These lists are carefully checked out and, although it has not yet been necessary to send reciprocal lists, several private campsites are in operation not far from the large infested area in Quebec.

Current Outlook

Populations of gypsy moth are cyclic to a considerable degree and it would appear that conditions are favorable to the insect at the present time. Should this not prove true and a recession in numbers follow, it is doubtful if it will be eradicated from southern Quebec. The St. Lawrence River presents a natural obstacle for spread to Ontario but larvae have been carried much farther than its width by air currents. Moreover, it will be almost impossible to prevent movement of logs and other potential carriers interprovincially from Quebec. If the insect obtains a foothold in eastern Ontario, it will be difficult to prevent its spread throughout the southern part of the province.

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II SUBMITTED PAPERS

THE IMPORTANCE OF SOLANUM CAROLINENSE L. AS A HOST OF THE PEPPER MAGGOT, ZONOSEMATA ELECTA (SAY) (DIPTERA: TEPHRITIDAE) IN SOUTHWESTERN ONTARIO

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Horse nettle, *Solanum carolinense* L. is the only known wild host of the pepper maggot, *Zonosemata electa* (Say) in Ontario. It is a prickly perennial with creeping subterranean rhizomes and bears yellow fruits which grow to a maximum of 1.5 cm in diameter (Figure 1). The abundance and importance of the weed in Essex County was examined from 1962 to 1967 in conjunction with a study of the biology and control of the maggot in peppers (Foott, 1963). Information was also sought on the possibility that two distinct host races were involved in pepper and horse nettle infestations. As pointed out by Bush (1965), little is known about the formation of host races and species in phytophagous insects.

Figure 1. Horse nettle plant with mature fruit

Methods

Prevalence of the weed was determined by an examination of numerous farms in the county and by questioning growers. Once a patch was found, the fruits were examined periodically to determine if there was a maggot infestation,

the severity of attack, and to compare the maggot's development in the fruits of horse nettle and pepper. The possibility that two distinct host races had developed was investigated by caging flies which had been reared in the fruits of pepper with horse nettle plants and vice versa.

Results and Discussion

The incidence of horse nettle in the county was not great. Seven patches were found and these were limited to five farms. Four of the patches were found in fields in which corn had been the principal crop for several years, one was in a fencerow, one in uncultivated soil near a bush, and the other in a pepper field. Corn fields appeared to be a very favorable environment for the weed, as the lack of cultivation throughout the season permitted all plants to develop mature fruit. Three of the patches had severe infestations, three had light infestations, and one was uninfested. Dr. J. F. Alex, Plant Research Institute, Ottawa, advised that two specimens of horse nettle were received from Harrow in 1931. Because the majority of growers were totally unfamiliar with the plant, it was apparent that it never became a serious problem in the intervening years.

There were notable differences between development of the insect in pepper and horse nettle. Adult emergence in pepper fields commenced in very late June or early July and increased to about mid-July. Very few flies were observed after the third week of July, although there was evidence from larval infestations that the occasional female had oviposited during the first half of August. Eggs were found as early as July 4 and never later than July 18. The maximum number of eggs laid in a single pepper in the field was 18. Caged flies oviposited in a single pepper for as long as it was available to them and in a few instances the number of eggs per pepper exceeded 50. The majority of the larvae pupated throughout August, but a few larvae were usually present until mid-September.

Development in horse nettle was much later. No fruits were present on horse nettle plants during the period when the bulk of the eggs were deposited in peppers. Eggs were never found prior to the first week of August or newly-hatched larvae prior to mid-August. Commonly, only one egg was laid in a fruit, but two or three were found on a few occasions. Pupation started about September 8 and continued well into October. In 1967, a larva less than one-third grown was obtained on October 2.

The larval, pupal and adult stages were all smaller when development occurred in the fruits of horse nettle. The majority of the mature larvae from pepper fruits were 11 to 12 mm in length, whereas the average length of 50 larvae which matured in horse nettle fruits was 9.1 mm. The average length of 100 pupae after larval development in peppers was 7.5 mm and in horse nettle 6.9 mm. The average body length and wing span of a small number of adult females which developed from larvae reared in peppers was 8.3 and 16.1 mm, respectively, and in horse nettle 7.8 and 13.8 mm. For males, the respective figures were 7.0 and 14.3 mm in peppers and 6.7 and 12.5 in horse nettle. The differences in size are undoubtedly directly related to the quantity and quality of food available to the larvae.

Despite the differences in host plants, periods of infestation, and size, there was no evidence that distinct host races had developed. Flies reared from larvae which had developed in pepper fruits oviposited in the fruits of horse nettle and vice versa, and larvae matured in both instances. However, as indicated by Bush (1965), the establishment of allochronically isolated populations on different hosts might permit divergence to progress rapidly and could eventually result in the formation of two distinct host races.

All patches of horse nettle were severely attacked by the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), and flea beetles. The horse nettle in a

fencerow also had many fruits infested with *Frumenta nundinella* (Zeller) and the stems with the potato stalk borer, *Trichobaris trinotata* (Say) each year. This was the first report of *F. nundinella* in Canada (Foott, 1967). Neither of the above insects was found in other patches of horse nettle.

In the early 1960's, numerous reports of infested pepper fields were received, but once effective control measures were established the incidence of infestations decreased rapidly. No infestations were found or reported from 1965 to 1967 inclusive. However, it was apparent from this study that scattered patches of horse nettle have sustained a breeding population of the maggot which could produce future outbreaks in peppers if control measures become lax. An example of this was observed when a pasture containing horse nettle was cultivated one year and planted to peppers in succeeding years. In the first year of planting, 90 percent of the fruits were infested and unmarketable.

The first incidence of pepper maggot in Essex County was in 1956, when infested fruits were found on a farm near Harrow. It is possible that horse nettle was the native host of this insect for a number of years prior to its establishment in pepper fields.

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LABORATORY REARING OF THE PEPPER MAGGOT, ZONOSEMATA ELECTA (SAY) (DIPTERA: TEPHRITIDAE)

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In the past, attempts by United States workers to rear a complete generation of pepper maggot failed. Peterson (1923) and Burdette (1935) used various types and sizes of cages and provided the flies with pepper plants, sprigs of the plant with peppers on them, and young peppers by themselves. Captured flies never lived over three days when exposed to direct sunlight, but survived for more than a week when placed in the shade and fed sweetened water. No oviposition occurred in any instance.

In the initial stages of the present investigation, flies reared from pupae collected in the field were provided with wicks of dental cotton soaked in a 7 percent sucrose solution and inserted in vials, plus strips of absorbent cotton soaked in the sucrose solution and placed on the floor of an insect cage. Peppers of various sizes and varieties were also placed on the cage floor. The average longevity of the flies was less than six days and no eggs were deposited.

The first evidence that females would oviposit in captivity occurred when flies were caught in the field and placed in a cage which contained a potted pepper plant. These flies died within a few days of confinement.

It appeared that successful rearing of the maggot depended almost entirely on inducing the flies to feed at frequent intervals. Strips of absorbent cotton were soaked in a sucrose solution twice daily and placed in the bottom of a cage. The flies were observed for long periods each day until they died. It was found that all activity occurred at the top of the cage and no flies fed on the sucrose solution during the periods of observation. Except for very brief downward flights, no prolonged habitation of the lower areas of the cage was noted until the flies became weak and had difficulty in flying or crawling back to the top of the cage. On the basis of these observations, the sucrose-moistened strips of absorbent cotton were placed on the top of the cage. Flies fed thus lived an average of 17 days, copulated, and deposited viable eggs in the walls of fruits on a potted pepper plant. The larvae matured and pupated to complete a full generation.

Subsequently, rearing techniques were refined. The most suitable height for a cage was found to be 30 inches. This was high enough to contain a mature, potted pepper plant and to ensure that the fruits were near the top of the cage. The length and width of the cage was less important and depended on the number of plants used. The top and three sides of each cage were constructed of saran screening (32 x 32 mesh)[1], with a zipper inserted in one side to facilitate the introduction of flies. The fourth side was a sliding glass door through which potted pepper plants were inserted and removed. To provide food, strips of absorbent cotton were soaked in a 4 to 7 percent sucrose solution and placed in close proximity across the top of the cage. It was found that if excess liquid was squeezed out of the cotton the pores of the screen were filled with the solution, but no drip occurred.

Pupal storage and adult emergence

The most satisfactory results were obtained when pupae were buried in moist, sterilized sand and stored in a refrigerated room at approximately 35°F for several months. If pupae received no, or a very short, cold treatment, adult emergence occurred over a long period and the number of individuals of each sex available at any given time was low. When the storage period was five months or more, emergence was complete in a short interval and a large breeding population was available. The number of days required for total emergence after various periods of cooling is shown in Table I.

TABLE I. Duration of adult emergence when pupae were refrigerated for various periods of time

Refrigeration[a] period (months)	No of replicates	Average no pupae per replicate	Average duration of adult emergence (days)
0 — 1	8	14.5	150.3
2 — 3	3	20.7	67.0
5 — 8	10	21.7	10.7

[a]Refrigeration temperature was approximately 35°F.

The percentage emergence and sex ratio of the adults were similar under the different periods of storage. The sterilized sand medium provided a pupal survival rate of 73.6 percent when pupae were reared in the laboratory. This compared with survival rates of 61.3 percent when pupae were obtained from the field in the fall and 20.7 percent when pupae were collected from the field

[1]Supplied by Barday Co. Ltd., Galt, Ontario.

in the spring. A similar low survival rate of field-collected pupae was noted previously by Burdette (1935) and Foott (1963) when pupae were buried in three inches of soil throughout the winter.

Oviposition

The preoviposition period varied widely when small numbers of flies were in the cage but, if large numbers of each sex were available, eggs usually were deposited seven to eight days after adult emergence. Dissection of females at various intervals after emergence showed that no full-sized eggs with the typical stalk-like projection at one end were present until the fly was six to seven days old.

In many of the rearing experiments, both the green and red stages of the bell-type sweet peppers were provided, but oviposition was generally limited to the green stage. In one test, both types of peppers were included in a cage with five females and ten males for eight days. A total of 62 eggs were deposited in the green peppers, but none in the red. For the next six days, only red peppers were provided and one egg was deposited. During the final six days of the experiment the green stage only was provided and 56 eggs were found. In a few instances, eggs were deposited in red peppers when large numbers of females were present.

The potential fecundity per female was examined in three ways. The first method was limited to a dissection of flies which had not oviposited. The number of eggs present ranged from 10 to 22 and averaged 14.3. These figures were lower than the range of 6 to 39 reported by Peterson (1923) and the average of 20.6 noted by the author (Foott, 1963) for flies captured in the field. More accurate data on fecundity under greenhouse conditions were obtained by permitting flies to oviposit until death and totalling the number of eggs deposited with the number still present in the insect's ovaries. With this method the average potential fecundity per female increased to 28.2 eggs. In the final examination of fecundity, 17 females and 10 males were placed in a cage in the greenhouse and fed sucrose solution for one week. They were then released in a large, cheesecloth cage which enclosed 60 pepper plants in the field and left undisturbed for several weeks. Examination of the peppers showed that each female had deposited an average of 41.6 eggs. Because some of the flies undoubtedly died before they had oviposited their full complement of eggs, it might be assumed that the potential fecundity of the maggot under field conditions is close to 50 eggs.

Although female flies usually required fertilization before oviposition occurred, there was evidence that virgin females occasionally oviposited. In one instance, 131 eggs were deposited between April 9 and June 3 in a cage in which the last two surviving males had died on March 23 and 25. None of the eggs hatched and there was no evidence of larval development within the eggs. In a second instance a female was placed alone in a cage and deposited 10 nonviable eggs.

Egg and larval development

The eggs required a long incubation period. The average time from deposition to hatch for 24 eggs in a greenhouse compartment where the temperature ranged from 52 to 106°F was 12 days. In a rearing room which had an average temperature of 72.3°F during 16 hours of illumination and 69.3°F during 8 hours of darkness, the incubation period for 23 eggs was 13.1 days. The number of day-degrees (above a base of 50°F) required for hatch was found to be 294.3 in the greenhouse and 291.6 in the rearing room. These can only be considered as approximate figures because the exact hours of egg deposition and eclosion were difficult to determine.

The average developmental period from egg deposition to mature larva was 26.3 days in a greenhouse and 30.1 days in a rearing room with average temperatures as above. Since the incubation period of the eggs in these two environments was 12 and 13.1 days, respectively, the time required for larval maturation was 14.3 days in the greenhouse and 17 days in the rearing room. These figures are comparable with estimated larval development periods of 18 days (Foott, 1963) and two to three weeks (Burdette, 1935) in the field.

Adult longevity

The longevity of flies fed a 4 to 7 percent sucrose solution in the greenhouse varied from 2 days to 96 days for females and 2 days to 55 days for males. The average longevity of 68 females was 22.5 days and of 83 males 16.4 days.

A principal source of carbohydrates in the field might be honeydew secreted by the green peach aphid, *Myzus persicae* (Sulzer), which commonly infests pepper plants. Caged females supplied with an aphid-infested pepper plant in the greenhouse lived up to 21 days and oviposited. When flies were placed in a cheesecloth cage enclosing pepper plants in the field they were observed to be alive and active eight days after their release. The subsequent difference in larval development in the peppers in which eggs were deposited indicated that oviposition had occurred over a period of approximately two weeks. The only apparent source of nutrition throughout this period was aphid honeydew.

The successful development of a rearing technique will permit investigators to learn more of the biology of the maggot and to test new insecticides on a small scale. Because of the need to supply a large number of pepper plants to the caged females, and to have sufficient space to retain the plants for approximately one month after their removal from the cages, further refinements of the technique will be necessary to make mass rearing feasible.

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THE CEREAL LEAF BEETLE — A NEW INSECT IN ONTARIO

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The cereal leaf beetle, *Oulema melanopus* (Linnaeus), has long been known as a pest of small grains in Europe and Asia. It was first identified in North America in June 1962, from collections made in Berrien County, Michigan. It

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had been noticed by farmers in 1959, but remained in a small area in the southwest corner of Michigan for a number of years. Infestations were also found in an adjacent Indiana county in July 1962. In the next five years the beetle spread rapidly to the east and north until it was found in all of lower Michigan, all of Ohio, the northern half of Indiana, and northwestern Pennsylvania. The westward spread has been much slower with a slight invasion of Illinois since 1965.

Entomologists in Canada expected the cereal leaf beetle to arrive in Ontario as early as 1965. A single adult was found in May 1965, near Harrow (Brown, 1966), but subsequent intensive surveys that year and in 1966 failed to locate any more specimens. In May and June 1967, eggs, larvae and adults were found in a number of townships of Essex County, so the cereal leaf beetle will likely become established in Ontario.

The first adults taken in 1967 were collected May 18 by McClanahan and Boyce in wheat fields near Amherstburg, Ontario. One field on Highway 18 yielded two beetles per 1,000 sweeps, and another had three in 200 sweeps with further sampling curtailed by rain. Earlier on the same afternoon two nearby fields had given negative results with 400 and 500 sweeps. These five adults were positively identified by W. J. Brown, of the Entomology Research Institute, Ottawa. A sixth beetle was swept from wheat about 3 miles northeast of Amherstburg.

The cereal leaf beetle seemed to leave these fields where they were first found, since none could be swept there on May 23. However, 13 additional adults were found at widespread points in Essex County during the rest of May and early June, with the distribution indicated in Figure 1. No more than three adults were ever found in one field and in most cases there was only one adult. Plant Protection Division officers from Windsor conducted the surveys in the northern two-thirds of Essex County.

The beetles of May 18 likely represented a migratory wave of adults moving into Ontario with wider dispersal later. The earliest possible sampling of oats, when they were 3 to 6 inches high, on June 2, yielded only one adult in 2,500 sweeps. This find was some 6 miles east of Amherstburg. Wheat fields in the same township were swept with only one cereal leaf beetle found in 2,150 sweeps. The only other adults from oats were the two found at the eastern-most point indicated in Essex County. This distribution pattern did not seem to indicate that the beetles had been present in 1966.

A single adult was found in May in Lambton County, near Bickford. This represents the only specimen found in Ontario outside of Essex County. The surveys in Lambton, Kent, Middlesex and Elgin Counties were extensive, especially of oat fields, and the general negative results were considered good evidence that the cereal leaf beetle had not progressed east of a north-south line through Sarnia, Ontario.

A survey near Amherstburg was made on June 21 to determine the incidence of cereal leaf beetle larvae on oats. They were found in three out of four fields but only in small numbers. Between 1,000 and 1,200 sweeps collected 10, 1, 0 and 3 larvae. Net sweeping became impossible soon after this because the oats were heading out. A larva and considerable feeding damage were found on oats at the Harrow Research Station on June 22.

A colony of cereal leaf beetle was established at Harrow with two field-collected adults. At 70°F they laid a total of 761 eggs over a 52-day period (both beetles were female). The peak of oviposition was 16 eggs per female per day. Egg and larval mortality was high, with only 273 larvae maturing from the 761 eggs, but mortality in the soil was normal and 203 adults emerged.

Since 1962 there has been a great deal of research concerning the cereal leaf beetle in North America. A bibliography on *Oulema melanopus* (L.), with

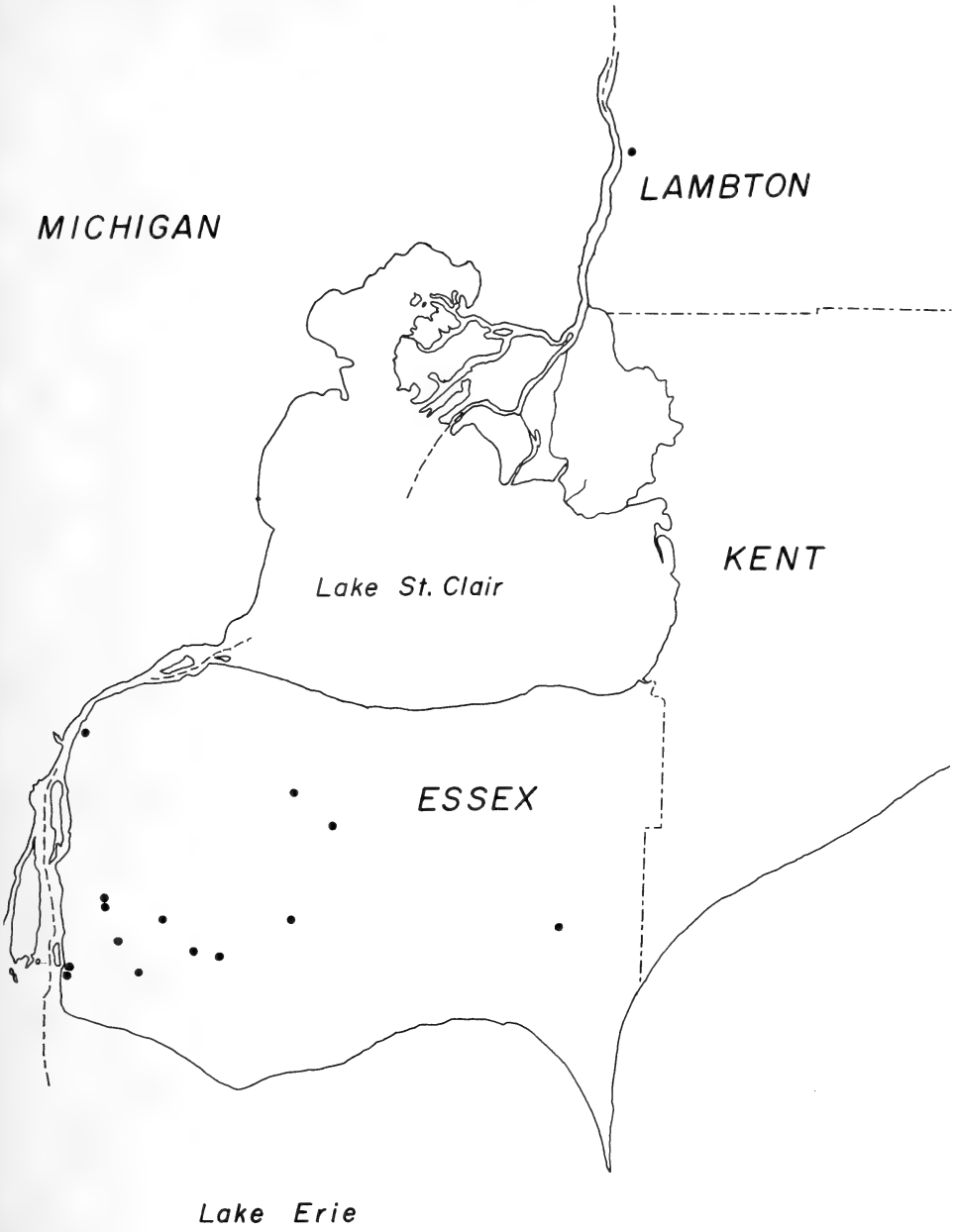

FIGURE 1. Occurrence of cereal leaf beetle adults in southwestern Ontario in 1967

references up to November 1967, was published in the Cooperative Economic Insect Report (U.S.D.A., 1967). A brief review of the major investigations is included in this paper to provide a background for future research in Canada.

Although the scientific name *Oulema melanopa* (L.) has been used extensively in the literature, *melanopa* is an emendation, and *Oulema melanopus* (L.) is now the recognized name for the cereal leaf beetle (Castro, 1965). The details

of the spread of *O. melanopus* in North America are found in various issues of the Cooperative Economic Insect Report. Reviews of the problem in late 1965 (Ruppel, 1966; Wilson, 1966) indicated that it was considered at that time to be beyond the containment stage, but the degree of the infestation was lighter than it was in the original area.

The adult beetle dispersion took place mainly in the spring and was closely related to wind direction and force when temperature conditions were favorable (Shade and Wilson, 1964). Airplane trapping showed a peak flight at midday, and beetles were found as high as 1,000 ft. (Wilson and Ruppel, 1964). This movement of summer (prediapause) adults was less obvious and was a search for sheltered hibernation sites (Koval and Apple, 1966).

The seasonal history of the cereal leaf beetle in Michigan was studied by Castro (1965), and he established a colony in the laboratory (Castro and Guyer, 1963). The critical factor in rearing was the prevention of diapause by a 16-hour photoperiod (Ruppel, 1964a) or rapid termination of diapause by cold temperatures. The effects of a wide range of controlled temperatures on the development of all stages was consistent with field observations (Yun, 1966). The use of a plaster of paris substrate facilitated pupal recovery (Connin *et al.,* 1966) and external sex-distinguishing characteristics were found (Myser and Schultz, 1967).

Considerable research was directed toward evaluation of small grain varieties for resistance to the beetle. Field plot studies (Gallun, Ruppel and Everson, 1966) with 687 varieties of barley, oats and wheat, showed a general preference for barley and then oats on the basis of feeding damage and larval numbers. The egg counts were equal for oats and barley but considerably lower on wheat. One wheat variety with pubescent leaves was avoided for oviposition. These field resistant wheat accessions were tested in laboratory studies (Schillinger, 1966) by evaluating larval growth on them. It was evident that larvae did not like to feed on some varieties but this accounted for only 15 percent of the resistance observed in the field.

The examination of a broad range of host plants revealed a close relationship between the leaf-vein spacing and the suitability of the plant for larval feeding (Shade and Wilson, 1967). The native grasses with closely spaced veins were not as favorable as the small grains. Adult beetles also had feeding preferences for young succulent small grains (Wilson and Shade, 1964).

The degree of damage to yields caused by cereal leaf beetle was greater for oats than for wheat. Heavy feeding on oats caused complete loss (Wilson, 1964) but heavy feeding on wheat reduced yield by 12 percent (Gallun, Everly and Yamazaki, 1967).

Chemical control of all stages of the cereal leaf beetle was provided by a number of compounds. Carbamate materials were particularly effective against adults (Yun and Ruppel, 1965) in laboratory screening tests. Carbaryl was excellent in field trials but led to aphid problems later on (Ruppel and Yun, 1965). Malathion controlled adults very well when applied as technical material at very low rates by aircraft (Wilson, Ruppel and Treece, 1965). Mini-spin nozzles were found most suitable for this type of application (Wilson and Treece, 1966). Topical application to adults provided dosage-mortality lines for carbaryl, dieldrin and malathion (Monroe and Polityka, 1965).

Eggs of cereal leaf beetle were killed by carbaryl at 1 lb per acre, but malathion at the same rate gave 55 percent mortality. Tedion was ineffective as an ovicide (Yun and Ruppel, 1964).

Although many materials controlled larvae in laboratory tests (Yun and Ruppel, 1965), the problem of field coverage was more critical than with adults. Minimum dosages were established and 8 gal per acre was found adequate

(Ruppel *et al.*, 1964). The ultra low volume aircraft sprays were not outstanding for larval control (Wilson and Treece, 1966). Seed treatments were ineffective but granular applications of systemics gave varying degrees of control (Wilson *et al.*, 1964; Koval, 1966).

Pupae in harvested grain fields were quite well controlled by discing the soil to a depth of 2 inches. Broadcast treatments of dieldrin killed 62 percent of pupae and 67 percent of the emerging adults (Ruppel, Cobb and Gomulinski, 1965), but this treatment would result in soil residues.

Non-chemical control methods have been explored in laboratory tests. Irradiation of adults produced sterility but it was accompanied by severe reduction of oviposition and longevity (Hoopingarner, Kumaraj and French, 1965). Chemosterilization of adults by apholate (Ezueh and Hoopingarner, 1967) was possible with a slight reduction of longevity.

Natural biological control factors in the original area of infestation were mainly predators, especially coccinellids (Ruppel 1964b, Castro *et al.*, 1965). An egg parasite was recorded (Maltby, 1967) and a fungus disease of adults (Paschke, 1965). Parasites of *Oulema melanopus* and a related species were investigated in France (Angelet, 1965). One egg parasite has been imported and released (Oman, 1967).

The general conclusions are that the cereal leaf bettle is in North America to stay, there are effective chemical controls, and a combination of weather and natural enemies usually operates to keep populations at reasonably low levels.

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PIERIS VIRGINIENSIS EDWARDS IN ONTARIO (LEPIDOPTERA: PIERIDAE)

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Introduction

Much has been written about *Pieris virginiensis* and its status as a species or subspecies of *Pieris napi* (L.) and its relationship to other species of the genus *Pieris*. Up until now, we in Ontario were not too interested in this discussion because we thought *Pieris virginiensis* belonged among the species which had fallen victim to cultivation. In collections, there was only one specimen from Hamilton which came from the Hy Edwards collection into the Canadian National Collection, two specimens from London in the Royal Ontario Museum, one specimen from Etobicoke, Ontario, in the same collection, and one specimen cited by Warren (1963) from Grande La Cloche Island (NW Georgian Bay) which is probably in the collection of the British Museum (Natural History). The other Canadian specimens, quite numerous in the Canadian National Collection, are from Isle Perrot near Montréal, Qué.

Previous uncertainty in the status of P. virginiensis and the final settlement by making use of the androconial scales

However, in 1965, Mr. Holmes, an ardent amateur collector of butterflies in Toronto, discovered a flourishing colony of this butterfly in the Halton County Forest. Now it is possible to study the species in the field and the old question "what is *Pieris virginiensis*?" comes to life among Ontario entomologists. Edwards (1868-1897) himself, who described *virginiensis* as a species, was not quite clear about it; otherwise he could not have written, (1881): "*Virginiensis* . . . has become a true species, although unquestionably, in a higher latitude, it appears as an occasional aberration only of *oleracea.*" Of course, based on specimens in collections alone, this erroneous idea can be derived, especially when the specimens are slightly worn and the otherwise heavy scaling of *oleracea* Harris becomes somehow transparent as *virginiensis* normally is. Nevertheless Edward's remark is almost not understandable and is responsible for the confusion resulting from relating *virginiensis* with *oleracea.* The worker in the field knows that there is a very big and easily perceivable difference between both in habitus, appearance and flight pattern. Klots (1951) rightly says: "Until very recently, *virginiensis* has been confused with *napi,* but it is now known to be a distinct species of more southern (Transition Zone) distribution." Klots (1935) made a special study of *virginiensis* in the field where he got authentic proof of the female using *Dentaria* as a plant for ovipositing, and was able to show considerable differences in the pupae of *oleracea* and *virginiensis.* The caterpillar of *virginiensis* does not resemble the caterpillar of *oleracea* but rather that of *rapae* (L.)!

This clear picture was again more recently disturbed by Hovanitz (1963), who says: "The eighteenth century idea of a "species" contributed a lot to general confusion of the nature of the relationship between *oleracea* and *virginiensis.* It was then, and too often now, the general idea that a species was represented by a specific morphological type, without regard to the varation which a population may have within itself. Some of the best collectors and breeders of Lepidoptera

have therefore become confused, having the all-pervading desire to designate some biological unit as either a "species", subspecies or variety when the true relationship may not be possible with only these tools of nomenclature." Consequently he comes to the conclusion that *virginiensis* and *oleracea* are only races of one and the same species: *napi.* He includes a list of localities in which he concludes there exists *oleracea* with tendencies toward *virginiensis* and vice versa, but nevertheless underlines the fact that their populations do not blend into one another as by a continual gene flow. This list causes considerable confusion. Hovanitz's final conclusion is: "I choose to use the racial designation for the reason that the groups are almost completely allopatric, that is, the populations are geographically separated and do not occur in the same place with certainty without interbreeding and complete fusion. Also intermediates do occur with high frequency in intermediate geographical areas." This is wrong as far as the known Canadian populations of *virginiensis* are concerned. I admit that in the Halton County Forest no *oleracea* have been taken up to now, but the extinct Etobicoke population of *virginiensis* flew every year at the same time together with the first generation of *oleracea,* without any sign of hybridization. Of course, *virginiensis* is only single-brooded and so only the first generation of *oleracea* flies together with it, wherever this may happen.

New light, and I would say, a definite solution to the question, using the androconial scales, which differ considerably from species to species in the genus *Pieris,* have been produced recently by Warren (1961, 1963). He wrote on the *napi*: *bryoniae* problem which in Europe is similar to the *oleracea* : *virginiensis* problem in North America. Also, Chang (1963) used the androconial scales in separating species in the genus *Pieris* with very good success. However, he did not include *virginiensis* in his study as he worked only with western North American species. Warren showed in his very detailed studies of all the species involved that our so-called "*napi*" are not *napi* at all and that *napi* is a predominantly Palaearctic species *sui juris* and our *virginiensis* is related to the western *venosa* Scudder. Both are species *sui juris* and quite separate from *oleracea.* The androconial scales of both *virginiensis* and *venosa* are similar and primitive while the androconial scales of the other pierid species are more developed and specialized. Hereby, I think, the question "What is *Pieris virginiensis*?" is finally settled.

Concluding remarks

Our vigorous colony of *virginiensis* in the Halton County Forest is a very welcome addition to the Ontario butterfly population. It is the northernmost colony of this species, which is confined to rich deciduous woods. It is not present everywhere the food-plant grows as, for instance, in Rondeau Provincial Park where, up to now, no *virginiensis* has been taken, although two species of *Dentaria* cover virtually the whole park. *Virginiensis* has, as remarked already and also especially stated by Klots (1935), only one single brood at the end of May to the early days of June, depending on the weather. Thus it was taken in 1965 on May 9, in 1966 on May 15, and in 1967 from April 30 to May 16, having its peak around those dates. A very easily recognizable character is the weak, fluttering movement of this butterfly. However, when disturbed, it has the capacity to change momentarily to a rapid flight upwards directly into the treetops, a habit which I observed among pierids only in this species. This, probably, is of importance for survival of this early spring species which, indeed, is very conspicuous in the only barely foliated forest. As the Halton County Forest has been set aside as a conservation area it can be hoped that *Pieris virginiensis* has a place there for survival and further study.

Acknowledgment

I wish to thank Mr. A. Holmes, Toronto, Ontario, for having drawn my attention to the Halton County Forest locality of *Pieris virginiensis* and for the first specimens from this locality which he brought to the Royal Ontario Museum and which are deposited in its collections.

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A MODEL OUTBREAK OF THE MITE TETRANYCHUS MCDANIELI MCGREGOR IN ONTARIO

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Tetranychus mcdanieli McGregor first attained notoriety as an agricultural pest about 1950, when it suddenly and inexplicably replaced another species, *T. pacificus* McGregor as the most important mite in the apple orchards of northwestern United States (Newcomer, 1954). Within ten years it had reached outbreak levels from the interior of British Columbia to New Mexico, and developed strong resistance to miticides in parts of the western region (Hoyt and Harries, 1961). *The Canadian Insect Pest Review* and the *Cooperative Economic Insect Report* reveal that the host plants of this mite in the west include apple, raspberry, pear, peach, and grape. McGregor (1950) listed plum and prune as well. In Manitoba, where extensive loss of crop and canes occurs in raspberry plantings, Robinson (1952) found it on more than 20 different cultivated trees, shrubs, and flowering herbs, and rated it as the predominant phytophagous mite in that province. The situation in Ontario and adjacent parts of the United States is different. Here outbreaks of *T. mcdanieli* are unknown, and the only recorded host plant appears to be raspberry, the one on which it was originally collected and described (McGregor, 1931). Eastern raspberry growers are warned of *T. mcdanieli,* but are advised that other species of mites pose a greater threat

in southern Ontario, and that natural enemies in combination with the recommended cultural measures will usually keep spider mites under control (Chamberlain and Putman, 1955; Ricketson *et al.* 1960).

The rapid displacement of *T. pacificus* by *T. mcdanieli* is now accepted as a nomenclatural rather than a biological event, *T. mcdanieli* having existed in the west since 1939 (R. S. Downing, pers. comm.). Even so, the intriguing fact remains that the behavior of *T. mcdanieli* in the west, and in the region east of the Central Plains, is very different. This prompted speculation regarding the factors responsible for maintaining the species at non-outbreak levels in the east, and whether *T. mcdanieli* could be experimentally released from control by manipulation of its environment. If such a model outbreak could be produced, it would suggest that outbreak and non-outbreak populations are produced environmentally rather than genetically. It would also indicate that eastern raspberry plantings possess outbreak-preventing factors that are absent in the west. Identification of these factors would be a desirable step toward prevention of crop losses in the west.

Predation has been generally, though not universally, believed an important factor in acarine pest control in outdoor crops (Collyer, 1958; Dosse, 1960; Chant, 1963; Putman and Herne, 1964). Therefore any attempt to disrupt the stability of *T. mcdanieli* should effectively eliminate predators from the check plots. Various methods have been employed in the past to produce such predator-free plots (Fleschner, 1958; DeBach and Bartlett, 1964), the most effective being Fleschner's (1952, 1958) hand-picking method. Though tedious and time-consuming, this had the advantage of being free of the complex toxic effects associated with the more widely-used insecticidal check method of DeBach (1946). Fleschner's attempts successfully evoked outbreak in several phytophagous insects and mites on parts of plants from which predators were persistently removed. The same species remained at non-outbreak levels where predators were undisturbed.

This paper gives results of attempts to manipulate predators of *T. mcdanieli* by the hand-picking method, describes a method that successfully evoked outbreak in this pest, and discusses the effects of the predator complex found in eastern Ontario raspberry plantings.

Experiment I

Purple raspberries (*Rubus neglectus*) are grown in large quantities in Prince Edward County for the canning industry (Ricketson *et al.,* 1960). Preliminary collections of nine-leaf samples in ten of the larger plantings near Belleville in late August indicated that *T. mcdanieli* was usually present though rarely in large numbers. In two plantings, levels of 350 and 450 mites and eggs per leaf were found. The predatory mite, *Amblyseius fallacis* (Garman), and a diverse assemblage of insects and arachnids were also found in these plantings, the principal groups being Anthocoridae, Aphididae, Cicadellidae, adult Diptera, larval and adult Coleoptera, Chrysopidae, and Araneida, or spiders. The principal predatory groups were Anthocoridae, Coccinellidae, and spiders.

The following experiment was conducted near Belleville in 1962 as an attempt to produce different levels of *T. mcdanieli* in small plots by manipulating the number of predators that normally inhabit raspberry plantings in this area.

Method

The method consisted of visual searches at two- to four-day intervals in four three-plant plots of purple Columbian raspberry, with hand-removal of predators from two of the plots (checks) and the transfer of these predators

alive to the remaining, or treated, plots. In addition, one check and one treated plot were enclosed by screened insectaries (Nicholls, 1958, 1963) to reinforce the effects of removal and augmentation respectively. Constructed of rather porous material (20-mesh saran screen), the insectaries did not measurably affect the air temperature or humidity inside them, though they depressed the light intensity during daylight hours by some 27 to 51 percent. This resulted in rank growth of the plants, as already noted for other crops grown in insectaries constructed of the same material (Farrer, 1963). The raspberries were first-year plants brought from a grower's nursery in May. Purple raspberry was chosen because it is non-suckering and produces an upright "hill" of relatively accessible canes. The use of first-year, i.e., non-bearing, plants obviated certain sampling problems that would have arisen in normal plants containing a mixture of first- and second-year foliage. The mite populations developed from overwintered individuals already on the plants when the raspberries were transplanted.

The numbers of *T. mcdanieli* were estimated five times between early August and late September. Each sample contained three excised leaves per plant, each leaf consisting of a terminal leaflet and a pair of lateral leaflets. Plant feeders other than *T. mcdanieli,* e.g., Homoptera and lepidopterous larvae, were counted *in situ.* Predator transfer, carried out from July 16 to October 1, was restricted to insects and spiders (hereafter called macropredators) that could be seen macroscopically and collected into vials with a camel hair brush. Care was taken to hold the predators as briefly as possible and to avoid injuring them. The insectary plots were adjacent to each other, and the non-insectary plots were 6 and 12 meters east of the insectaries. The surrounding vegetation consisted of wild shrubs on the south and east, a pine planting on the west, and plots of corn, sunflowers, and potatoes on the north. The plots were kept weed-free, and the only pesticides used were small amounts of 5 percent chlordane emulsion applied as necessary to ant nests in the soil.

Observations on Predators

The macropredator population in the plots consisted mainly of the anthocorid *Orius tristicolor* (White) and various Coccinellidae and spiders. *O. tristicolor* occurred only as adult females until the third week of July, when the first nymph was seen. The ratio of adults to nymphs was about 1:1 until the end of July, and then changed rapidly in favour of nymphs (about 95 percent) until early September, when the insect disappeared from the plots. Adults and nymphs were frequently seen feeding on all stages of *T. mcdanieli,* though they also fed on the predatory mite *A. fallacis* (Garman) and on the larvae of the coccinellid *Stethorus* sp. Among the Coccinellidae, only *Stethorus* appeared to feed consistently on *T. mcdanieli.* The small dark larvae of this beetle appeared in numbers of up to 35 per plant during the period of maximum *T. mcdanieli* abundance, but were easily reduced by hand-picking as they moved little from plant to plant. Spiders found were mainly immature stages of the web-building families Theridiidae and Araneidae, and of the crab spiders *Philodromus* spp. These spiders fed on the large mobile stages of *T. mcdanieli* and also on nymphs and adults of *O. tristicolor* and on one another. One species of *Theridion* was observed to mature and reproduce on the treated plots, but spiders in general were easily kept at low numbers on the check plots by hand-picking. These three groups of predators formed virtually the entire macropredator population, others (mainly Chrysopidae) reaching mean maxima of only 2.7 per plant in any search. Repeated searches of the bare ground between plots and watching at the insectary walls indicated that all species of macropredators reached or left the plants by aerial routes. Searches of nearby vegetation also suggested that the principal reservoir of these predators was the adjacent area planted to sunflowers and corn.

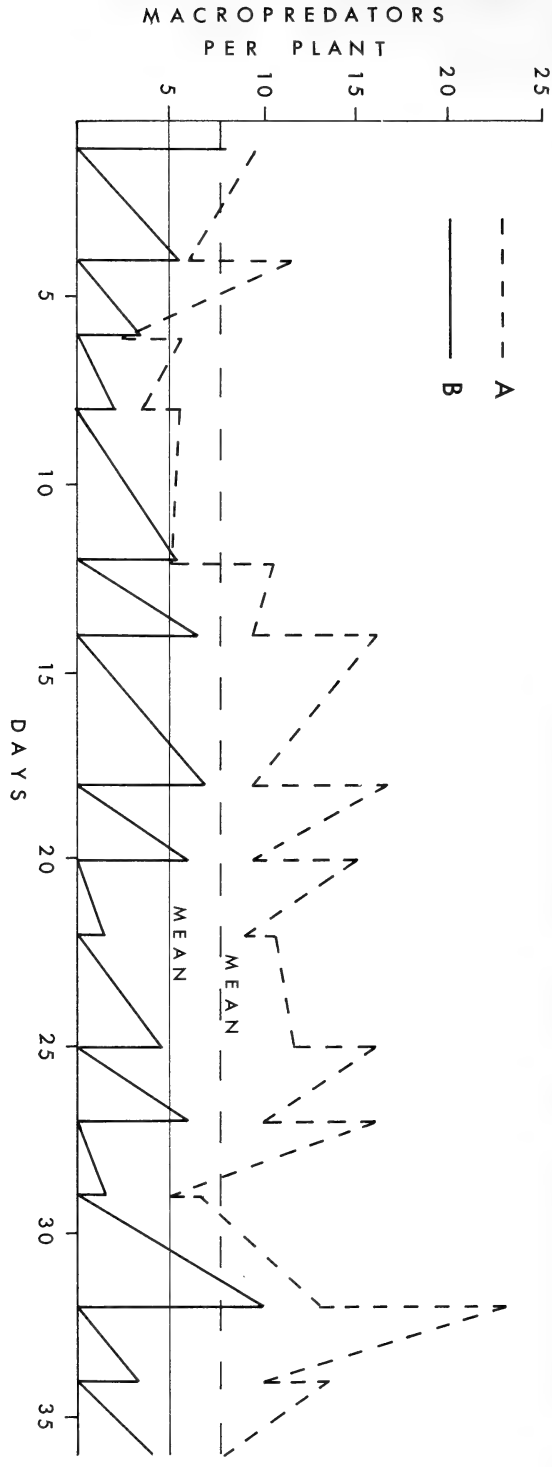

FIGURE 1. Macropredator population levels on two raspberry plots near Belleville, July 27 to August 31, 1962. A: Macropredators added, no insectary. B: Macropredators removed, no insectary.

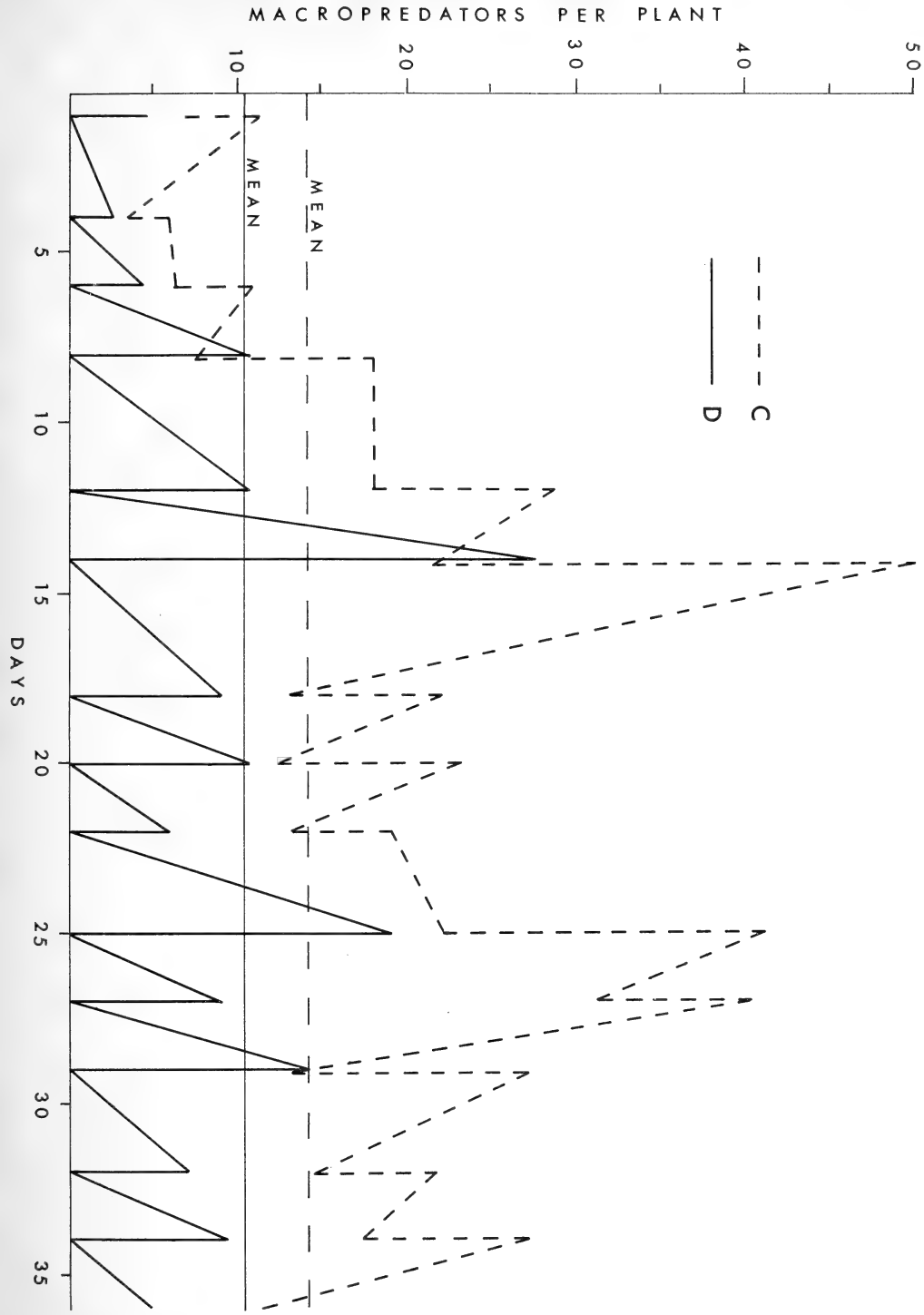

FIGURE 2. Macropredator population levels on two raspberry plots near Belleville, July 27 to August 31, 1962. C: Macropredators added, plus insectary. D: Macropredators removed, plus insectary.

The most specific and abundant predator (and the only micropredator observed) on *T. mcdanieli* was *A. fallacis*. This mite was present on all plots throughout the summer, its numbers becoming maximal at the end of August. Being small, it was not hand-removed from check plots, and observations on it were restricted to the times of microscopic examinations of fresh foliage samples from the plots at stated intervals. Young and adults of this mite were frequently seen eating eggs or the postembryonic stages of *T. mcdanieli* on such occasions, their bodies almost invariably containing the green pigment of the host, but they also acted as prey for the three macropredator groups.

The check plots in this experiment may be viewed as attempts to release *T. mcdanieli* from predation and thus allow it to increase to the limit of its food supply. The treated plots were simultaneous attempts to intensify predation on the mite by building up macropredator numbers to abnormally high levels. Figures 1 and 2 depict the relative effects of manipulation on numbers of macropredators in the four plots. The lines representing the check plots (B, D) show the numbers of animals found and removed at each of 14 searches; the rebound of the line to positive values after each depopulation represents the arrival of new individuals, which were then removed in the succeeding search. The lines representing treated plots (A, C) show the numbers found and left on the plants at each search, and also the numbers added (vertical components) from the check plots. Horizontal lines represent the mean numbers found on a seasonal basis. The check plots quickly regained many of their lost predators, the non-insectary check (B) having a seasonal mean of 4.8 individuals, and the insectary check (D) a mean of 10.3 per plant. The treated plots lost many of the macro-

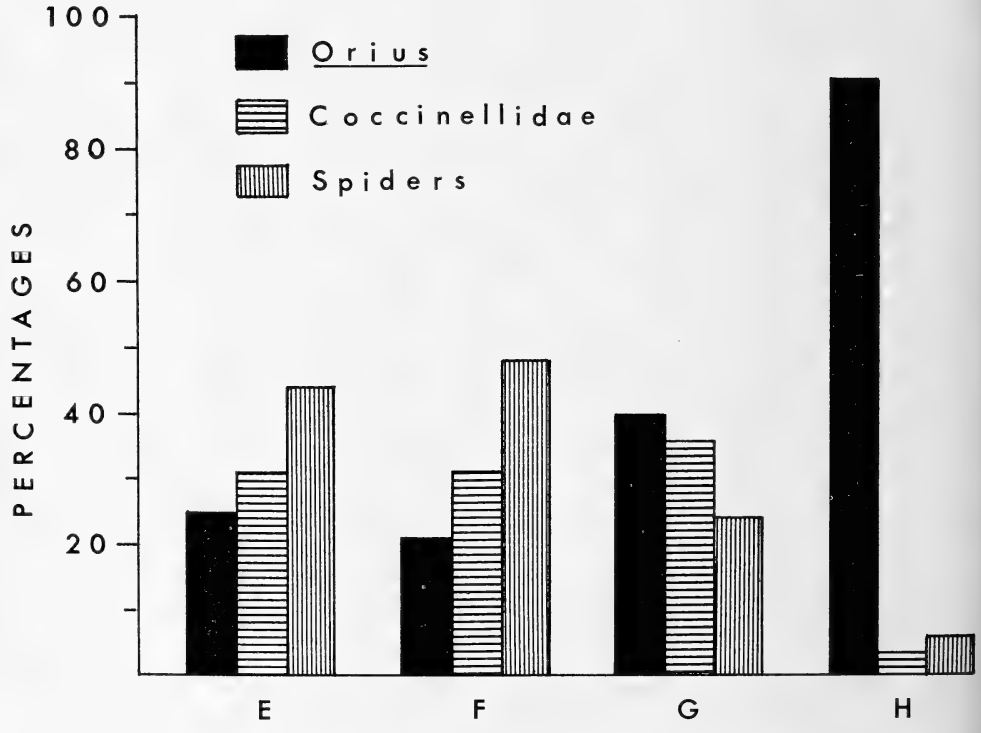

FIGURE 3. Seasonal percentage composition of macropredator populations on four raspberry plots near Belleville in 1962. E: Macropredators added, no insectory. F: Macropredators removed, no insectary. G: Macropredators added, plus insectary. H: Macropredators removed, plus insectary.

predators added to them (89 percent in the non-insectary plot (A), 95 percent in the insectary plot (C)). Seasonal means of the non-insectary and insectary treated plots were 8.0 and 14.6 respectively. Thus the mean differences between check and treated plots were 3.2 (non-insectary) and 4.3 (insectary), the treated plots having 67 and 42 percent more macropredators than the checks.

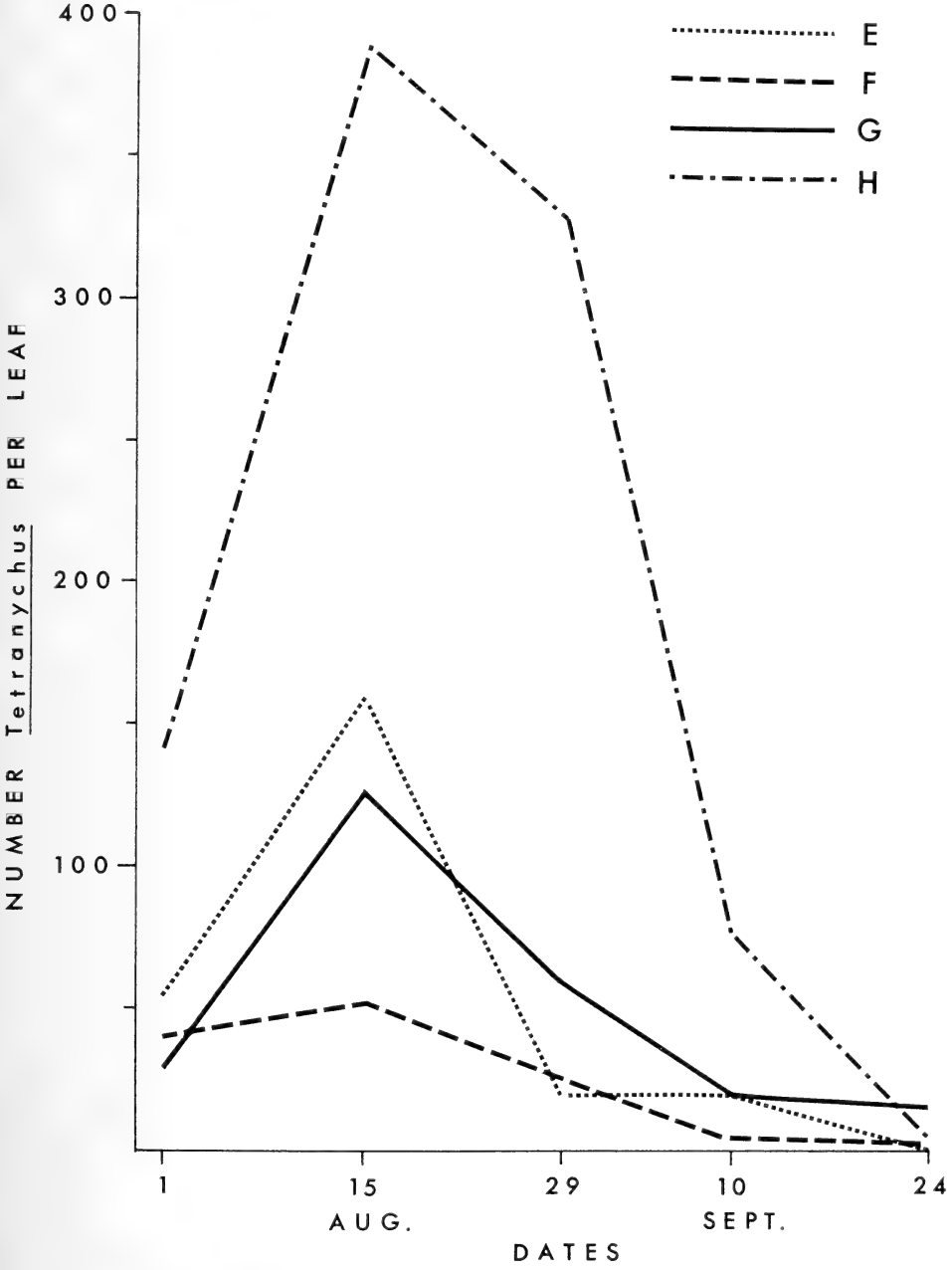

FIGURE 4. Population levels of *Tetranychus mcdanieli* McGregor on weekly samples of nine raspberry leaves near Belleville in 1962. E to H as in Figure 3.

One of the plots diverged qualitatively from the others in its macropredator population (Figure 3). This was the insectary check plot, in which the population was severely unbalanced in favor of the single predator *O. tristicolor,* which was able to penetrate the insectary walls (Figure 3, H). Furthermore, this species existed almost entirely as newly-arrived adults, as eggs, and as newly-hatched nymphs. The persistent removal of the adults and nymphs resulted in the virtual elimination of the heavily-feeding, later-instar nymphs. The insectary treated plot (Figure 3, G) also had a slight preponderance of *O. tristicolor* (apparently at the expense of spiders), but in this plot the various stages were left to develop undisturbed. Thus the insectary check differed from the others in two important respects: firstly, in the loss of macropredator diversity and, secondly, in the destruction of the predatory effectiveness of the single species of macropredator living on the plants.

Observations on T. mcdanieli

The reduction of the macropredator population of the insectary check plot was reflected in the *T. mcdanieli* population. Figure 4 shows the patterns of the mite's population development on samples of nine leaves from each of the four plots. Non-random distribution of the population made statistical tests inappropriate, but the insectary check plot, which had a seasonal maximum that was 2.4 to 7.8 times as large as that of the other plots, alone appeared to have experienced a definite mite buildup (Figure 4, H). This plot also showed considerably more damage from the mite, the plants losing many leaves and having large quantities of *Tetranychus* webbing on the leaf undersides. Phytophagous arthropods other than *T. mcdanieli* were scarce on all plots, consisting almost entirely of Cicadellidae and lepidopterous larvae numbering up to four per plant in the insectary plots and up to nine per plant outside.

Conclusion

This experiment strongly suggested that the intermittent removal of macropredators could not, of itself, eliminate the macropredator population, though the effect was statistically significant. This failure was probably due to the high mobility of the predators and to the removal being less persevering than that practised by Fleschner, who found that vigilance had to be maintained constantly during daylight hours to be effective. Chant's (1963) attempt, based like the present one on discontinuous searching, probably failed for the same reasons. The insectary, however, reinforced the hand-removal program so that predation was effectively disrupted and *T. mcdanieli* accordingly experienced a population rise of prolonged duration.

Experiment II

In Experiment I *T. mcdanieli* was accompanied by the predatory mite *A. fallacis,* which in the insectary check plot reached maximum numbers of about six per leaf, two weeks later than did *T. mcdanieli. A. fallacis* has a known feeding rate on tetranychid mites (Ballard, 1954), and has been credited with the untimely destruction of entire experimental cultures (Putman, 1962). It also shows some preference for this type of prey over others with which it has been tested (Herbert, 1959; Burrell and McCormick, 1964). An experiment was therefore planned in 1963 to test the hypothesis that *A. fallacis* could, by itself, prevent or suppress an outbreak of *T. mcdanieli,* the macropredators being hand-removed to provide a simplified predator-prey association.

Method

Outbreak conditions for *T. mcdanieli* were provided in a pair of ten-plant, insectary-covered plots of purple raspberry by the same program of macropredator

removal used in Experiment I. Removal and mite sampling began in the week of May 27, 1963. On one plot *A. fallacis* was allowed to develop unhindered, and on the other it was to be denied access to the plants by means of sticky barriers placed low on the canes in early spring. The use of barriers was based on Putman's (1959) inference that *A. fallacis* in peach orchards "must hibernate chiefly in litter or possibly in the soil." *T. mcdanieli* was assumed to winter on the canes. As the season progressed, however, it became obvious that the barriers for unknown reasons had failed and that *A. fallacis* was developing equally well on both plots. The original objective was therefore abandoned, and the interaction between predator and prey could only be observed on what was now a single plot. This proved instructive, however, inasmuch as a very intense outbreak occurred, and as sufficient evidence was obtained to provide an assessment of the capabilities of *A. fallacis*.

Observations

Two methods of expressing mite population levels were assayed. One was simply the mean number of mites and eggs per leaf, but as the terminal leaflets were found to carry significantly more individuals than the lateral leaflets, this method was judged to have unnecessarily high sampling error. The alternate method was based on units of leaf area. Cooper's (1960) formula for calculating leaflet areas was modified by trial and error to 5/8 length x width of the leaflet. The calculated areas of 43 leaves ranging from 860 to 7,300 cm^2 in area were then found to correspond closely to their actual areas as determined by tracing them on squared paper. The regression coefficient was 0.997 (highly significant), and the slope of the plotted line +0.979. This method provided a smooth curve of seasonal development for both prey and predator mite, with the frequency distributions strongly skewed to the left. The population estimates, unless otherwise stated, have therefore been transformed to $\log_e (n + 1)$ numbers of individuals per square centimeter of leaf undersurface.

Between-plant sampling error for *T. mcdanieli* was approximately 18 percent when the population was low, but the plants were heavily oversampled when the mite population was high, only four plants per date being required for 10 percent error. This is based on samples of three leaves per plant, the maximum that could be examined microscopically in the time available and that was judged to avoid excessive defoliation of the plants. This sample size produced a between-leaf standard error of the mean of 21 percent for high populations and a much greater error (approximately 66 percent) for low ones. This extremely high error appears to be inherent in mite distributions on plants, and no ready method of dealing with it seems to be available. It was also estimated that 120 and 13 leaves per plant, respectively, would have been necessary for an error of 10 percent in low and high populations, and this would certainly have defoliated the plants. Error estimates were not attempted for the predator *A. fallacis* because its numbers were too low.

All of the macropredators seen in the insectary plot of Experiment I were observed in this 20-plant plot. *O. tristicolor* formed 87.4 percent of the macropredators found and removed in contrast to *Stethorus* (9.0 percent) and spiders (3.2 percent). *O. tristicolor* appeared in early July and increased to 50.9 adults and young nymphs per plant per week, falling to 1.8 per plant in late August. More than 3,300 individuals of this bug were removed during the course of the summer.

Two species of mite predator appeared in 1963 that were not seen in 1962, both in low numbers though not subjected to the hand-removal process. These were *Scolothrips 6-maculatus* (Pergande), which reached a maximum of four postembryonic stage individuals per leaf in late July, and the larva of an unidenti-

fied Cecidomyiid fly, which appeared in trace numbers from early July to mid-August, then pupated, evidently suffering heavy mortality due to internal parasitism.

Figure 5 depicts the course of development of the populations of *T. mcdanieli* and *A. fallacis* in Experiment II. The main characteristics of the prey curve are

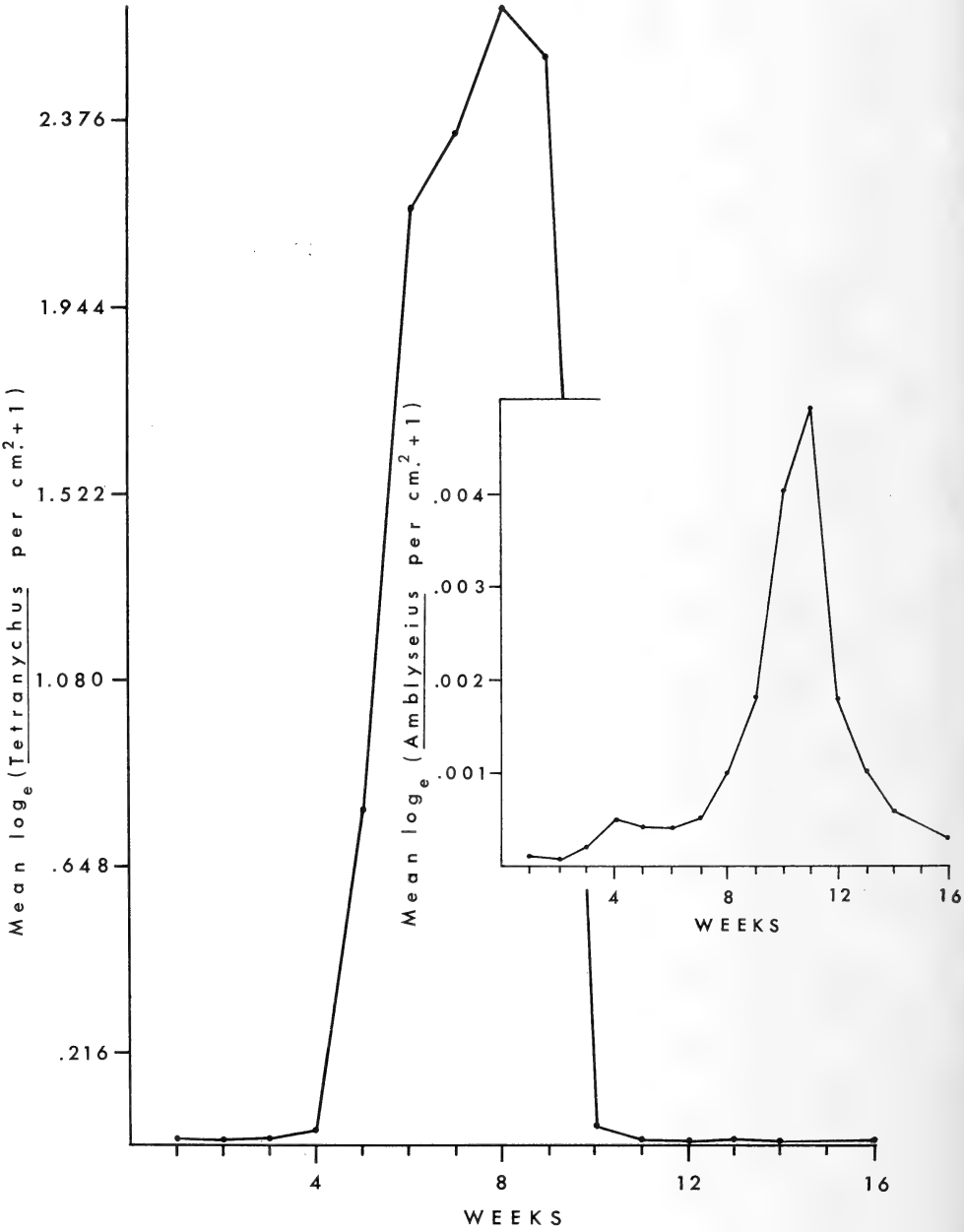

FIGURE 5. Population levels of *Tetranychus mcdanieli* McGregor and *Amblyseius fallacis* (Garman) on weekly samples of 60 raspberry leaves near Belleville in 1963.

low levels during weeks 1 to 4, a rapid increase during weeks 5 and 6, a decrease in growth rate in weeks 7 to 9, and a sudden return to pre-outbreak levels (not to extinction) in week 10 where it remained for the rest of the sampling period. The predator population also experienced outbreak, but apparently made its most rapid growth in weeks 8 to 11, and declined less precipitously than did *T. mcdanieli*. In terms of untransformed numbers, *T. mcdanieli* ranged from 0.47 to 92.71 individuals per cm^2 in week 9; similarly, *A. fallacis* ranged from 0.001 to 0.040 per cm^2 in week 11. Individual whole-leaf counts ranged to 9,946 *T. mcdanieli* and 436 *A. fallacis* during the same weeks. Apparent damage to the plants, in spite of the numbers of *T. mcdanieli* present, was less than expected. Seven to twelve leaves per cane on only four plants showed extensive feeding damage, and none of the leaves died. The remaining plants showed only slight damage in contrast to the severely damaged and dying foliage seen in the insectary check plot of Experiment I where the mite outbreak was less intense. The only apparent reason for this difference was that the 1963 outbreak occurred much earlier in the season when the plants were still growing vigorously.

Assessment of Predation by A. fallacis

The questions as to the effect of the predator *A. fallacis* on *T. mcdanieli* in this experiment are: (1) Did the predator prevent its host from rising to outbreak levels? and (2) Did the predator suppress the host outbreak? The answer to (1) is obviously negative, as *T. mcdanieli* clearly experienced outbreak in the continual presence of the predator. Question (2) requires consideration of the evidence. The predator was frequently seen killing all stages of *T. mcdanieli*. Moreover, the predator was able to penetrate the host's webbing and appeared to be as free-roaming on individual leaves as was the prey. The gut of nearly every feeding-stage individual of *A. fallacis,* during the progression stage of the host's outbreak, was green, the colour of the host's body, but became colourless when the prey was scarce. *A. fallacis* was the only predator continuously present and acting during the outbreak, the predator's own natural enemies having been destroyed, and *T. mcdanieli* was the predator's principal and probably sole source of animal food. No evidence (*e.g.,* dead bodies) was seen for predation on *A. fallacis*. Finally, it was during the critical period of weeks 7 to 9, during which the rate of increase in *T. mcdanieli* was slowed and changed to a collapse, that *A. fallacis* experienced its greatest increase in numbers (Figure 5). Thus there appears to be a correlation between the buildup of *A. fallacis* and the decline of *T. mcdanieli*.

The case for *A. fallacis* is, in spite of the foregoing, strongly countered by evidence from the predator's rate of prey consumption and its rate of dispersal relative to that of the host.

Clinical studies on the prey consumption of *A. fallacis* provide a coarse estimate of five *Tetranychus* eggs or mites per day (Ballard, 1954). If the predator is assumed to attack all stages of the prey in whatever proportion they occur and at a constant rate regardless of prey population level, if predator and prey reproduce at approximately equal rates, and if the population estimates of predator and prey are reasonably accurate, then the number of active predators necessary to reduce the prey from outbreak to zero level can be calculated from Ballard's figure. The prey level, during weeks 7 to 9, may be taken as 2.500 per cm^2, and predator numbers at the end of this period as 0.001 per cm^2, of which 2/3 or 0.0007 were postembryonic stages. (Numbers of non-feeding or larval stage mites were not recorded.) This number of predators eating five prey daily would consume only 0.0735 prey, or 34 times fewer than the number present. It seems unlikely that, even if *A. fallacis* consumes more prey from a high population than from a low one, its daily kill would increase Ballard's estimate 34 times. Further-

more, the ratio of predators (all stages) to prey in week 9 was only 1:2500. In contrast to this, workers who obtained apparent suppression of mite outbreaks with predatory mites (various species) invariably had ratios of predators to prey much higher than this when prey numbers began to decline. In Chant's (1961) experiment it was approximately 1:5, in Herbert's (1962) it was 1:5 to 1:12, and in Bravenboer and Dosse's (1962) it was approximately 1:10 (exceptionally 1:40). Collyer (1958) earlier concluded that a ratio of not less than one predator to ten active-stage prey was necessary to maintain the European red mite at non-outbreak levels in England. Thus *A. fallacis* appeared unable to reproduce sufficiently fast to overtake *T. mcdanieli* in this experiment.

Stronger evidence against *A. fallacis* comes from a comparison of its rate of dispersal through the raspberry planting compared with the speed shown by *T. mcdanieli.* In week 1 both predator and prey were detected in only a few, widely-separated plants, but whereas *T. mcdanieli* appeared in the samples from all 20 plants by week 4, *A. fallacis* did not appear in all samples until week 9, when *T. mcdanieli* was already in full-scale outbreak. Moreover, whereas *T. mcdanieli* maintained itself on virtually all of the 180 leaflets in each sample from weeks 6 to 10 inclusive, *A. fallacis* was never found on all leaflets in any week, and it rapidly disappeared from most of the leaflets as soon as the period of abundant food had passed (Figure 6). Thus although the plants were dense and growing almost in contact with each other, and although the prey was dispersing and multiplying in abundance, the predator did not achieve the necessary distribution in the planting to arrest the prey outbreak. The power to disperse in relation to the host's distribution is a prime requisite in predatory mites (Huffaker, 1958; Chant and Fleschner, 1960; Doutt and DeBach, 1964).

It remains to be explained how, in the absence of significant predation, the outbreak of *T. mcdanieli* suffered such sudden disintegration five weeks after it began. This situation is customarily explained by suggesting that the nutritional status of the host plant has changed. This is thought to be caused by the heavy feeding of the mites and to be expressed as a large scale reproductive failure in the phytophagous animal. The hypothesis seems plausible but has proven hard to demonstrate. Hamstead and Gould (1957) showed that phytophagous mite population levels in orchards could be related to nitrogen content of the leaves, mite declines regularly following the seasonal peaks in nitrogen. According to Henneberry (1962), however, plant responses more complex than simple mineral-element supplies may be involved, and he concedes that the precise mechanism of mite declines in the absence of predation is still unknown. Experiment II indicated that the reproduction of *T. mcdanieli* changed during the course of the outbreak. Its eggs outnumbered the postembryonic stages by two to four times until week 8, when the ratio was reversed. Egg numbers remained at depressed levels during the latter part of the outbreak and until week 13, when the ratio appeared to stabilize at approximately 1:1. No such trend was observed in the *A. fallacis* data, postembryonic stages consistently outnumbering eggs throughout the sampling period by two to seven times.

Assessment of Predation by Macropredators

A. fallacis was seemingly the most promising of all the predators found in raspberry plantings, yet it apparently failed either to prevent or to suppress by itself an experimental outbreak of *T. mcdanieli.* The possibility that one of the macropredator groups could cause either prevention or suppression, or both, must be examined. In contrast to the predatory mite, which apparently overwinters in close association with the prey, *O. tristicolor, Stethorus,* and spiders are believed to winter in a variety of places without reference to raspberry plants or *T. mcdanieli.* The macropredators were thus slower to appear on the infested plants in the spring than *A. fallacis.*

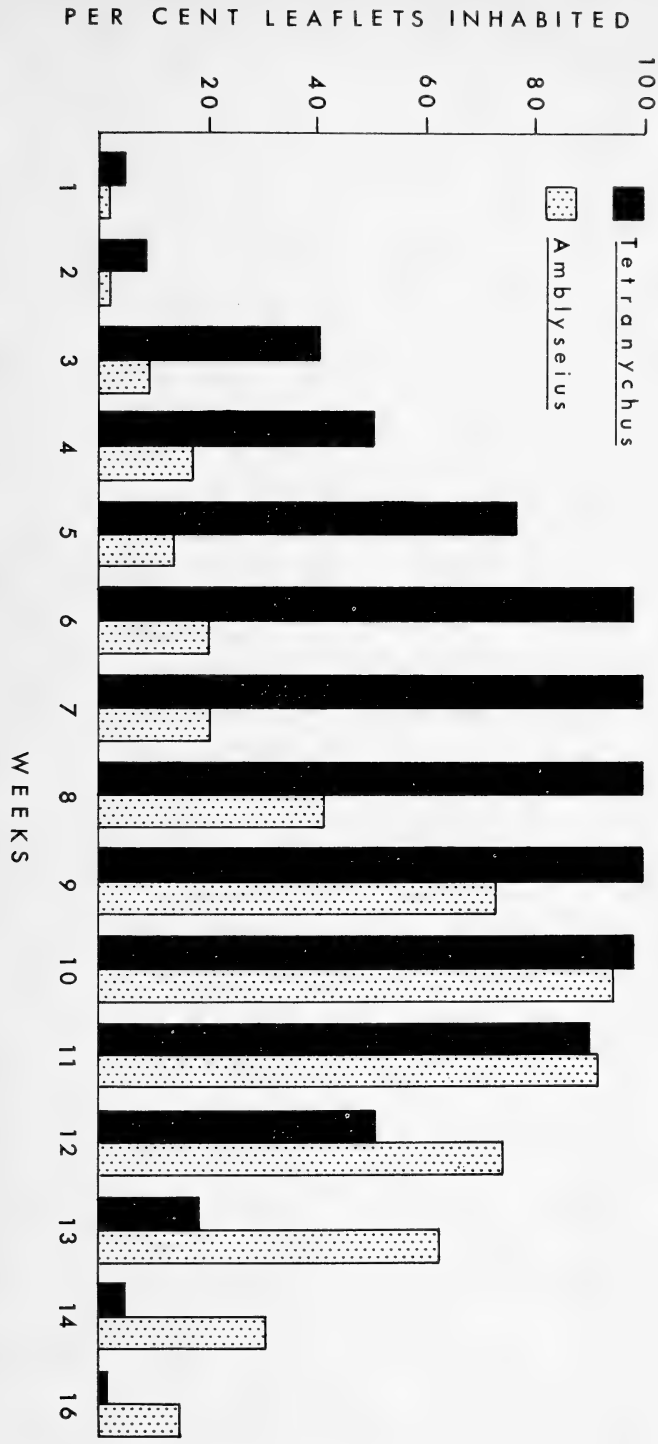

FIGURE 6. Rates of dispersal and evacuation of *Tetranychus mcdanieli* McGregor and *Amblyseius fallacis* (Garman) on samples of 180 raspberry leaflets near Belleville in 1963.

Stethorus is thought to be a valuable natural enemy of tetranychid mites (Robinson, 1952, 1953; Putman, 1955), though the insect was very slow in dispersing in these experiments and never reached high population levels. Its larvae were eaten by *O. tristicolor* and it in turn fed to some extent on *A. fallacis*. *O. tristicolor* penetrated the insectary easily in the adult stage, and no nymphs appeared until the *T. mcdanieli* outbreak was well developed. This bug did, however, show great affinity for mite-infested foliage, where it laid eggs in large numbers. The finding of large concentrations of overwintered females during June in growers' pollen-laden raspberry plantings in 1963 suggests that pollen may play a part in raising the early-season levels of *O. tristicolor,* and this in turn may contribute to outbreak prevention in phytophagous mites. On the other hand, *O. tristicolor* is both cannibalistic and partly phytophagous (Anderson, 1962), and also feeds on *A. fallacis* and *Stethorus*. Spiders were scarce in these experiments, and the species inhabiting raspberry are known to require a year or longer to mature. They are polyphagous, attacking other predators as well as *T. mcdanieli.* They have not proven impressive in pest control in English apple orchards (Chant, 1956) or Canadian peach orchards (Putman, 1967) and forests (Loughton *et al.,* 1963; Watt, 1963).

Thus none of the predators of *T. mcdanieli* in Ontario raspberry plantings appears to have the searching ability, prey specificity, reproductive potential relative to that of the host, or the ability to occupy quickly all host-inhabited places in the environment that an effective natural enemy should have. In spite of this, the experiments described here show that some potent set of conditions exists in the raspberry plantings of Ontario that effectively restrains development of outbreaks of *T. mcdanieli* year after year. Predation was neither proven nor disproven as a critical control factor, and the only reasonable hypothesis is that the aggregate effect of predatory mites, bugs, beetles, and spiders (or some combination of them) is effective. Putman and Herne (1964) recently developed this hypothesis regarding the predators of the European red mite in Ontario: "But all known predators of *P. ulmi* in Ontario are inefficient by the same criteria, according to various published and unpublished studies at this laboratory; yet there is reason to believe that they can regulate the density of *P. ulmi,* collectively if not individually." They elaborated, citing the tendency of non-specific predators to concentrate their attack on whatever prey is temporarily abundant, to attack more prey when the prey is abundant than when it is scarce, and to respond numerically to increasing prey population levels. All of these tendencies are present to various degrees in the collective predator complex. Putman and Herne (1966) more recently broadened the application of their hypothesis to include all the various mites attacking peach in Ontario, and inferred that certain species of predator are instrumental in preventing outbreaks while others come into play once outbreak is in progress. The hypothesis was also accepted by van den Bosch and Telford (1964, p. 477), who commented that "Although general predation may not regulate pest populations in the strict sense, it can effectively retard the rate of pest increase and militate against explosive outbreaks."

Summary and Conclusions

The production of experimental, or model, outbreaks is an instructive exercise in population dynamics. Chant (1957), Mozley (1960), and others promote this approach as one that may illuminate the mode of outbreak production and eventually lead to more intelligent control of pest outbreaks in agricultural crops. In the present work it was hoped also to discover the mode of outbreak prevention in *T. mcdanieli* in eastern Ontario. The insectary in combination with selective and intermittent hand-removal of various predators appears to be as effective as Fleschner's (1952, 1958) rigid hand-removal program, because outbreak was

twice produced in *T. mcdanieli.* The combined method presumably acted through simplification of the predator complex much as a chemical pesticide would do, though without the unassessed side effects of chemicals. The deliberate lifting of predation pressure from *T. mcdanieli* without directly disturbing the mite itself or its habitat appeared to be the cause of the experimental outbreaks, and led to a new population level controlled by reproductive failure brought on by insufficiency of food. If this is a true interpretation of natural populations of *T. mcdanieli,* these experiments find their parallel in the experimental outbreak of deer on the Kaibab plateau (summarized by Allee *et al.,* 1949, p. 706), or of the fish-food organisms in a temperate freshwater lake (Ball and Hayne, 1952). Like these animals in their respective habitats, *T. mcdanieli* is normally in comparative balance with the raspberry plant and its associated predatory insects and arachnids, varying little in population level over long periods.

This work does not explain fully why *T. mcdanieli* experiences frequent outbreak in the west but not in Ontario. If, as the work suggests, predation by a diversity of predators normally maintains the mite in non-outbreak condition in the climatic and biotic setting of eastern Ontario, then an investigation of western outbreaks should include a detailed comparison of predator populations (kinds, numbers, and response to *T. mcdanieli*) in both regions. Attention should also be given the question of many host plants in the west in contrast to a single one in the east.

Acknowledgments

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STUDIES OF THE BYRON BOG IN SOUTHWESTERN ONTARIO XXXII.

OBSERVATIONS ON THE SEASONAL DISTRIBUTION OF ODONATA IN THE BOG

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The Byron Bog has been described by Judd (1957). There are three zones in it. The central part, Zone A, is a floating mat of sphagnum moss almost completely covered by bushes of leather-leaf, *Chamaedaphne calyculata.* In Zone A is Redmond's Pond. Surrounding Zone A is Zone B, a region which is damp or flooded throughout the year and which supports a considerable growth of trees and shrubs. The outer region is Zone C, consisting of relatively dry, wooded slopes. Accounts of the vegetation in these zones are given by Judd (1957, 1966) and a map showing the extent of the zones is included by Judd (1957).

During the course of studies of the Byron Bog since 1956 observations have been made on damsel-flies and dragonflies. In 1956 they were collected in connection with a study of insects associated with the *Chamaedaphnetum calyculatae* association (Judd, 1960) and in 1956 and 1957 some were trapped on Redmond's Pond in traps set out on the water (Judd, 1958, 1961). In more recent years, particularly 1964 and 1965, further observations and collections have been made. The insects were collected mainly in Zone A, but a few were found in Zone B. Specimens were identified with keys in Needham and Westfall (1955) and Walker (1953, 1958) and are deposited in the collection of the Department of Zoology, University of Western Ontario.

Lestidae

Lestes eurinus Say — 1♂ , June 11, 1956 (Judd, 1958). As reported by Judd (1958), this is the only record of occurrence of this species in the bog.

Lestes congener Hagen — two couples flying in tandem over small ponds south of Redmond's Pond and settling on vegetation, September 8, 1964; two couples in tandem in the same situation, September 9, 1964. The presence of this species in September is in accord with the report of Walker (1953) that it is the latest species of *Lestes* to reach the adult stage.

Lestes unguiculatus Hagen — 3♂♂, July 2, August 16, 1956 (Judd, 1960); 1♂ , September 7, 1964; 2♂♂, September 8, 1964; 2♂♂, 1♀ , September 9, 1964. The period of flight of these damsel-flies is within the range of dates, June 8 to September 9, which Walker (1953) records for this species in Ontario and Quebec.

Lestes dryas Kirby — 4♂♂, June 21, 26, 30, July 1, 1956; 5♀♀, June 12, 20, 30, 1956 (Judd, 1960). The presence of this species in the bog is in accord with the report of Walker (1953) that it occurs about permanent and temporary ponds.

Lestes rectangularis Say — 1♂ , September 7, 1964. The presence of this species in September is in accord with the report of Walker (1953) that it is one of the later *Lestes* to emerge.

Coenagriidae

Nehalennia irene (Hagen) — 2♀♀, June 14, 27, 1956 (Judd, 1958); 1♀ , June 12, 1956 (Judd, 1960). The presence of this species in the bog is in accord with the report of Walker (1953) that it is probably the most abundant damsel-fly in eastern Canada and occurs around still marshy or boggy waters.

Enallagma boreale (Selys) — 1♀ , May 27, 1956 (Judd, 1958); 2♂♂, Junell, 12, 1956 (Judd, 1960); 2♂♂, 3♀♀, May 24 — June 7, 1957 (Judd, 1961); 1♀ , May 21, 1965. The presence of this species in the bog is in accord with the report of Walker (1953) that it occurs about boggy or marshy lakes.

Enallagma ebrium (Hagen) — 1♀ , June 10, 1957 (Judd, 1961). Walker (1953) records that this species is generally more abundant on calcareous soils than in Precambrian regions.

Enallagma hageni (Walsh) — 1♀ , June 24, 1957 (Judd, 1961). Walker (1953) records that this is one of the most abundant of summer damsel-flies.

Enallagma asperum (Hagen) — 1♂ , September 9, 1964. The presence of this species is in accord with the report of Walker (1953) that it has been found about sphagnum-bordered lakes in Ontario.

Ischnura posita (Hagen) — 1♂ , 1♀ , September 7, 1964; 1♂ , September 8, 1964. The presence of this species is in accord with the report of Walker (1953) that it frequents a wide variety of waters with plenty of aquatic vegetation.

Ischnura verticalis Say — 1♀ , August 30, 1956 (Judd, 1958); 1♀ , August 12, 1♂, August 13, 1956 (Judd, 1960); 1♂ , 6♀♀, September 7, 1964; 1♀ , and one pair in tandem, September 8, 1964. The presence of this species in abundance in the bog is in accord with the report of Walker (1953) that it is the commonest of all Odonata in the hardwood and mixed forest regions of the eastern provinces.

Aeschnidae

Anax junius Drury — one adult, May 23, 1956 (Judd, 1960); one adult, August 4, 1957 (Judd, 1961); two blue adults in flight over Redmond's Pond,

one on April 28, 1964, and the other on May 21, 1965; one adult in flight over ponds in the northwest part of Zone C on May 9, 1965; one teneral adult settling on leather-leaf bushes on September 4, 1966. The occurrence of adults in flight in April and May is in accord with the report of Walker (1958) that this species is the earliest of all Odonata to appear in the spring in southern Ontario.

Aeschna umbrosa Walker — 1♂ , captured while flying along a ditch in northeast Zone B on September 17, 1964. The presence of this species in flight in late summer is in accord with the report of Walker (1958) that, while most records of this species are for July and August, the insect continues to fly in September.

Aeschna constricta Say — 1♀ , captured while flying along a ditch in northeast Zone B on September 17, 1964. The presence of this species in September is in accord with the report of Walker (1958) that its flight period extends from July to October.

Libellulidae

Libellula pulchella Drury — 1♀ captured while settling on bushes of highbush blueberry, May 27, 1965. The presence of this species in May is in accord with the report of Needham and Westfall (1955) that it is in flight from May to October.

Libellula semifasciata Burmeister — 2♀ ♀ settling on bushes of highbush blueberry, May 20, 21, 1965. The presence of this species in May is in accord with the report of Needham and Westfall (1955) that it is in flight from April to August.

Leucorrhinia intacta Hagen — 1♀ , June 12, 1956 (Judd, 1960). The presence of this species in June is in accord with the report of Needham and Westfall (1955) that it is in flight from April to August.

Sympetrum obtrusum Hagen — 1♂ , one pair in tandem, September 7, 1964; 3♂♂, September 8, 1964; 2♂♂, September 9, 1964; 2♂♂, 2♀ ♀, September 16, 1964. This and the two following species were in flight together over the bushes of leather-leaf around Redmond's Pond and were captured while settling on the branches of these shrubs.

Sympetrum rubicundulum Say — 2♂♂, September 7, 1964; 1♂ , 1♀ in a spiderweb on sedges and 1♂ in a spiderweb on leather-leaf, September 8, 1964; two pairs in tandem and 2♂♂, September 9, 1964; 1♂ , 1♀ , September 16, 1964.

Sympetrum vicinum Hagen — 1♀ , August 26, 1956 (Judd, 1958); 2♂♂, August 22, September 12 and 1♀ , September 14, 1956 (Judd, 1960); 2♂♂, 5♀ ♀, July 26 — August 18, 1957 (Judd, 1961); 1♂ , 1♀ , September 7, and 4♂♂, one pair in tandem, September 8, and 1♂ , September 16, 1964.

Pachydiplax longipennis Burmeister — 1♂ flying at the edge of Redmond's Pond, June 8, 1965.

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STUDIES OF THE BYRON BOG IN SOUTHWESTERN ONTARIO XXXIII. DISTRIBUTION OF DYTISCIDAE AND HYDROPHILIDAE (COLEOPTERA) IN THE BOG

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INTRODUCTION

The Byron Bog has been described by Judd (1957). During 1961, studies were made of the aquatic insects of bodies of water in the bog. An account of the aquatic Hemiptera so collected is given by Judd (1963). The present account concerns the distribution of predacious diving beetles, Dytiscidae, and water scavenger beetles, Hydrophilidae. The project was supported by funds from the Government of Ontario granted through the Ontario Research Foundation. Mr. M. S. Beverley aided in making collections and in sorting specimens in the summer of 1961.

In 1961 regular daily collections of insects were made from May 8 to September 29 in the four zones of the bog. These zones are wooded slopes (C), a lower wooded region (B), the open floating bog (A) and the open pond, Redmond's Pond (D) (Figure 1). In zones A, B, and C, plots were marked out with stakes, each plot 250 feet by 50 feet in size. Each plot was divided into five smaller subplots of dimensions 50 feet by 50 feet, numbered from 1 to 5 (Figure 1). Starting on May 8, collections were made in subplots numbered "1" in zones A, B, and C. The next day collections were made in subplots numbered "2". This procedure was followed, in sequence, on successive days in plots numbered "3", "4" and "5". The procedure was repeated through the summer. This procedure prevented repeated disturbance each day of the population in any one subplot. Collections in zone D, Redmond's Pond, were made daily by making three sweeps about three yards long through the water with a dip-net having a mouth 10 inches in diameter. Aquatic insects were collected with the dip-net in pools present in zones A, B, and C.

Dytiscidae and Hydrophilidae were identified by Dr. F. N. Young, Department of Zoology, University of Indiana, Bloomington, Indiana. All specimens are deposited in the collection of the Department of Zoology, University of Western Ontario. The distribution of the several species among the zones of the bog and the dates of their collection are shown in Table I.

ACCOUNT OF COLLECTIONS

No beetles were found in zone C, which comprised wooded slopes on which a few smaller pools, present in spring, dried up early in the summer. Zone A yielded only a few beetles, all Hydrophilidae. It is a sodden mat of sphagnum moss which includes only a few temporary shallow pools which dry up by early summer. Zone B yielded four species in each of the families Dytiscidae and Hydrophilidae. It included scattered pools beneath the shade of black spruce, larch and various deciduous trees. Although the pools were shallow, and decreased gradually in diameter during the season, they persisted throughout the summer. The four species of Dytiscidae found in these pools did not occur in other zones of the bog and the four species of Hydrophilidae collected in this zone were found only in this zone or were present there in greater numbers than in the other zones (Table 1). Zone D yielded the greatest number of both species and specimens, accounting for slightly more than three-quarters of the total collection. It is a permanent, unshaded pond surrounded by the sphagnum mat of zone A and with branches of bushes of leather-leaf, *Chamaedaphne calyculata,* extending out over it.

Dytiscidae

Laccophilus maculosus Germ. — This species was found only in the pond in zone D. It has been reported as common in stagnant waters by Chagnon and Robert (1962).

Hygrotus impressopunctatus (Schall.) — This species was found only in zone B. It has been recorded from Quebec by Chagnon and Robert (1962) and from New York by Leonard (1926).

Hygrotus sayi J.B.-Browne — This was the commonest beetle in the collections. Under the name *Coelambus punctatus* (Say), it is noted as one of the commonest hydrophilid beetles in Quebec (Chagnon and Robert, 1962) and in New York (Leonard, 1926). Its occurrence only in zone D of the bog indicates that it is a beetle characteristic of permanent, unshaded ponds.

Hygrotus nubilus LeC. — Only one beetle was collected. Under the name *Coelambus nubilus* LeC., it is recorded from Indiana by Blatchley (1910), and from Quebec by Chagnon and Robert (1962), and is reported by Leonard (1926) to be common from New England to Texas.

Laccornis conoideus (LeC.) — Its presence only in zone B indicates that this is a beetle of woodland pools. It is recorded from Quebec under the name *Hydroporus conoideus* LeC. by Chagnon and Robert (1962).

Hydroporus niger Say — Only one beetle was collected. This species is recorded from Indiana by Blatchley (1910), Quebec by Chagnon and Robert (1962), and New York by Leonard (1926).

Hydroporus niger/tenebrosus GROUP — These beetles were taken only from the pond in zone D.

Hydroporus striola Gyll. — This was found only in the pond, zone D. It has been recorded from Quebec by Chagnon and Robert (1962), and from New York by Leonard (1926).

Hydroporus undulatus/consimilis GROUP — This was found only in the pond, zone D.

Hydroporus consimilis LeC. — Like all other species of *Hydroporus* found in the bog, this species was found only in the pond in zone D. It has been recorded from Indiana by Blatchley (1910), Quebec by Chagnon and Robert (1962), and New York by Leonard (1926).

Coptotomus interrogatus Fab. — This was found only in the pond in zone D. It is reported as a common species in ponds in Quebec (Chagnon and Robert, 1962), and in New York (Leonard, 1926).

Colymbetes sculptilis (Harris) — This was found only in zone B. It is reported as being present sparingly along the shore of Lake Michigan (Blatchley, 1910), and common in ponds in Quebec (Chagnon and Robert, 1962), and in New York (Leonard, 1926).

Acilius semisulcatus Aube — This was one of the commoner species in the pond in zone D.

Graphoderes liberus (Say) — This was found only in the pond in zone D. It has been reported from Indiana by Blatchley (1910), Quebec by Chagnon and Robert (1962), and New York by Leonard (1926).

Agabus semipunctatus (Kirby) — The presence of this species in zone B is in accord with the report of Leonard (1926) that it occurs in woodland and pasture pools.

Deronectes griseostriatus DeG. — This was found only in the pond in zone D. Its range is reported to extend from New York and Canada to Michigan (Blatchley, 1910).

Hydrophilidae

Hydrochus squamifer LeC. — This was one of the few beetles found in a pool in zone A, and it also occurred in the pond in zone D. It is reported as being common in Quebec (Chagnon and Robert, 1962), and as occurring in New York (Leonard, 1926).

Helophorus sp. — This was found only in a pool in zone A. Several species of *Helophorus* are reported from ponds and pools by Chagnon and Robert (1962), Dillon and Dillon (1961), and Leonard (1926).

Berosus striatus (Say) — This was one of the commoner species in the pond in zone D. It is reported as common in ponds in Quebec (Chagnon and Robert, 1962), and found particularly in a sphagnum bog in New York (Leonard, 1926).

Tropisternus mixtus (LeC.) — This was found only in the pond in zone D. It is reported from Indiana by Blatchley (1910), and recorded as being common in New York by Leonard (1926).

Paracymus subcupreus (Say) — The presence of this species in the pond in zone D is in accord with the reports of Dillon and Dillon (1961), and Leonard (1926) that this beetle is found in bogs.

Cymbiodyta minima Notman — This was found in a woodland pool in zone B. This species is recorded from New York by Leonard (1926).

Cymbiodyta vindicata Fall.? — These beetles occurred most commonly in the woodland pools in zone B. *C. vindicata* Fall. is recorded from New York by Leonard (1926).

Helocombus bifidus LeC. — This was found only in the woodland pools in zone B. It is reported as being common in Quebec (Chagnon and Robert, 1962), and in New York (Leonard, 1926).

Anacaena limbata Fabr. — This was the only species found in all three of the zones of the bog which yielded dytiscid and hydrophilid beetles and it predominated particularly in woodland pools in zone B. Dillon and Dillon (1961) record that it occurs in bogs.

Cercyon sp. — This was found only in the pond in zone D. The presence of this species in the pond is in accord with the report of Blatchley (1910) that, while most species of *Cercyon* are terrestrial and live in dung, carrion or fungi, some are found on the borders of pools and swamps.

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TABLE I: *Numbers of Dytiscidae and Hydrophilidae collected from Byron Bog in 1961*

	Zone A		*Zone B*		*Zone D*		
Species	*No.*	*Dates*	*No.*	*Dates*	*No.*	*Dates*	*No.*
Laccophilus maculosus	0		0		6	8.V-21.VIII	6
Hygrotus impressopunctatus	0		7	16.VI-24.VIII	0		7
Hygrotus sayi	0		0		127	8.V-22.IX	127
Hygrotus nubilus	0		0		1	19.VIII	1
Laccornis conoideus	0		2	18.VI, 30.VI	0		2
Hydroporus niger	0		0		1	11.VI	1
Hydroporus niger/ tenebrosus	0		0		7	12.VI-2.VIII	7
Hydroporus striola	0		0		1	17.VI	1
Hydroporus undulatus/ consimilis	0		0		1	27.VI	1
Hydroporus consimilis	0		0		3	16.VII-22.VI[1]	3
Coptotomus interrogatus	0		0		7	11.V-21.VIII	7
Colymbetes sculptilis	0		1	11.VII	0		1
Acilius semisulcatus	0		0		16	12.V-28.VIII	16
Graphoderes liberus	0		0		2	16.V, 26.V	2
Agabus semipunctatus	0		1	30.VI	0		1
Deronectes griseostriatus	0		0		1	13.VI	1
Hydrochus squamifer	1	8.V	0		1	17.V	2
Helophorus sp.	1	8.V	0		0		1
Berosus striatus	0		0		11	13.V-25.VI	11
Tropisternus mixtus	0		0		4	14.V-8.VIII	4
Paracymus subcupreus	0		0		4	2.VI-27.VIII	4
Cymbiodyta minima	0		1	18.VI	0		1
Cymbiodyta vindicata?	1	17.VI	10	3.VI-27.VIII	0		11
Helocombus bifidus	0		2	12.VIII, 21.VIII	0		2
Anacaena limbata	6	8.V-17.VI	31	12.V-27.VIII	17	14.V-11.VIII	54
Cercyon sp.	0		0		1	19.VIII	1
TOTAL	9		55		211		275

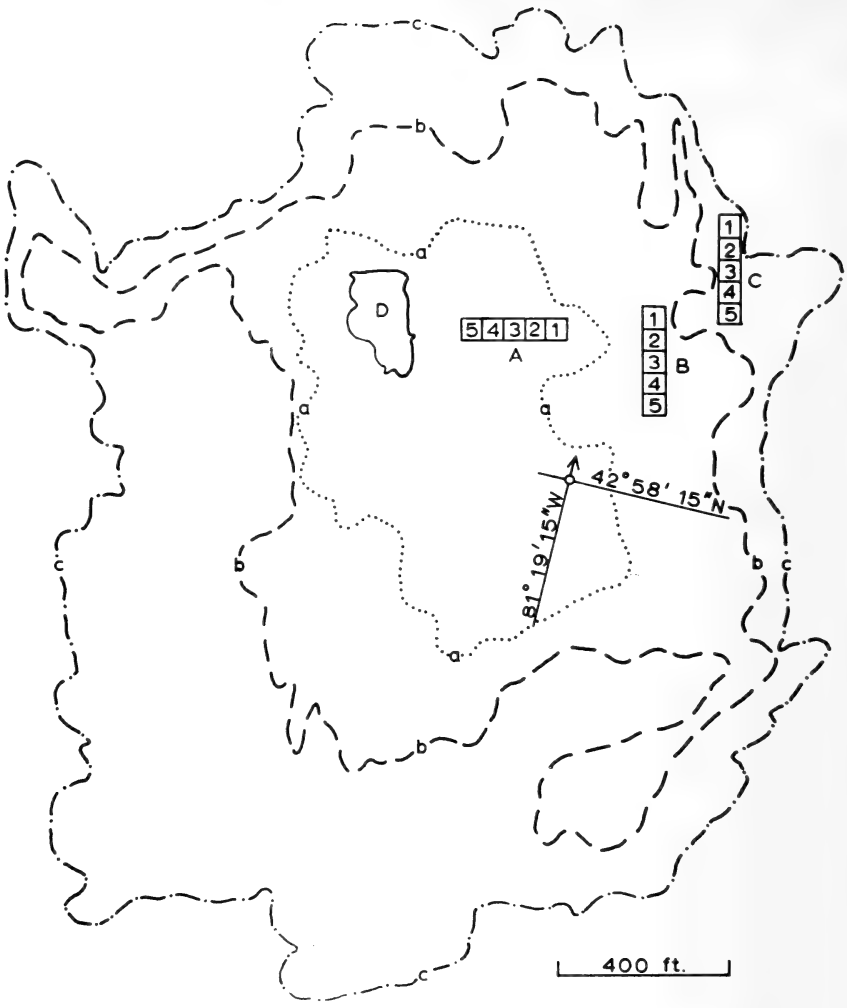

FIGURE 1. Map of Byron Bog

Legend for Figure 1

a - a: outer border of open floating bog, Zone A

b - b: outer border of lower woods, Zone B

c - c: outer border of wooded slopes, Zone C

D: Redmond's Pond

A, B, C, D: collection sites

A MONOXENIC RELATIONSHIP, NOCARDIA RHODNII ERIKSON IN THE GUT OF RHODNIUS PROLIXUS STAHL. (HEMIPTERA: REDUVIIDAE)

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INTRODUCTION

Insects, like most other metazoans, have microorganisms in their gut. The first observation of a microorganism in the blood-feeding hemipteran, *Rhodnius prolixus,* was reported by Duncan (8) who found a Gram-positive bacillus in the gut contents of all the insects he examined. In 1935 Erikson (9) cultured this microorganism, described its growth on various media, and named it *Actinomyces rhodnii.* It was later reclassified as *Nocardia rhodnii* by Waksman and Henrici (16).

Wigglesworth (17) observed that *N. rhodnii* is usually located within *R. prolixus'* midgut, being restricted to intercellular crypts formed by epithelial folds. Following a blood meal the microorganisms are expelled into the gut lumen where they become mixed with the ingested blood and are passed out with faecal material. Maintenance of natural infestations of *N. rhodnii* in *R. prolixus* is assured by the newly-hatched nymphs' acquisition of bacilli from their contaminated egg chorion and/or the excreta of older confrères (5). Such a method of transfer ensures that most first instar nymphs will also come in contact with other microbial species.

Reports that *N. rhodnii* existed in the gut of *R. prolixus* in pure culture (2, 5, 10, 12) are interesting. This condition, described by Dougherty (7) as "monoxenic" is rarely found under natural conditions. The possibility of its occurrence in *R. prolixus* is made more noteworthy for there are no special transferral mechanisms of *N. rhodnii* from generation to generation in *R. prolixus* that would ensure the maintenance of the monoxenic condition.

It is difficult to establish unequivocally that any microorganism exists in pure culture within the gut of a metazoan host. There is the constant danger of contamination, and the resulting difficulty of determining whether one is dealing with a mixed culture that was isolated from the host animal or a pure culture that has become contaminated during the isolation procedure. Such difficulties are apparent in the reports published concerning *N. rhodnii* and *R. prolixus.* Brecher and Wigglesworth (5) concluded that the *Staphylococcus* sp. found in their subcultures of *N. rhodnii* was a contaminant. However, Bewig and Schwartz (3), using a beef agar culture medium, found *N. rhodnii* in all of their cultures of the gut contents of *R. prolixus.* They also found a coccus form of microorganism, that they stated was not *N. rhodnii,* in half of their cultures. Halff [as cited in Buchner (6)] discounted this observation claiming that the coccus form probably resulted from contamination of their cultures. Gumpert and Schwartz (11) have presented evidence for the existence of more than one species of microorganism in the gut of *R. prolixus.* From both *Triatoma infestans,* a blood-feeding hemipteran closely related to *R. prolixus,* and *R. prolixus* they cultivated not only *N. rhodnii* but also a *Corynebacterium* sp., and a *Mycobacterium* sp. When symbiont-free insects were infected with these other microorganisms it was found that each species acted as a symbiont for the insects and contributed to normal development. Reinfection with other Actinomycetes (species not named) produced no symbiotic effect. Since *N. rhodnii* exists in several characteristic morphological forms throughout its life cycle (14), and also since *Nocardia* sp., *Mycobacterium* sp.,

and *Corynebacterium* sp. all belong to the family Mycobacteriaceae (4) and there are only slight differences between genera, it is possible that what Gumpert and Schwartz described as distinctly different species were only different morphological stages of *N. rhodnii*. Goodchild (10) maintained that *N. rhodnii* had a very mild antibiotic effect towards "some other bacteria" and always appeared in pure culture in *R. prolixus*. He isolated no other species of bacteria from *R. prolixus*. In his study of *T. infestans* however, he found that other microbial species did occur but only if *N. rhodnii* was absent.

Before investigating the nutritional effects of microorganisms on *R. prolixus* it seemed necessary to reinvestigate the possible monoxenic relationship between *N. rhodnii* and the *R. prolixus* reared in our laboratory. In conducting this study we extended the diagnostic techniques used by other workers (2, 5, 10, 12) but we lacked the facilities to run these tests under various degrees of oxygen tension including anaerobiasis.

MATERIALS AND METHODS

Our population of *R. prolixus* came from Cambridge, England, where it had been maintained under artificial conditions for many generations. It had been kept for approximately 17 generations at Toronto before being used in these experiments. Twice during this pre-experimental period the insects were neglected. The colony was severely depleted by starvation and desiccation and only two to three percent of the adults survived. This selection may have caused our insects to differ from those in other populations of *R. prolixus*.

Fifth instar insects, fed 16 to 19 days previously, were surface sterilized by immersion in 50 percent Lysol for five minutes, a procedure which killed the insects. They were then washed in two changes of sterile water and placed in sterile petri dishes lined with sterile filter paper to dry. The insects were dissected under sterile conditions. The gut contents were inoculated onto a series of diagnostic media and the inoculated media were incubated 14 to 35 days at 37°C until definite cultural characteristics were observed. The media used were those described by Waksman (15) for studies of the cultural and biochemical characteristics of the Actinomycetes. To check the sterility of the media used and the conditions under which the inoculations were made, a control series was run for each set of inoculations. Control tubes containing the different media were opened in the inoculating atmosphere for 20 seconds, a time equal to that required for inoculation of the experimental tubes. These tubes were then closed and incubated with the inoculated tubes. The following media supplied by British Drug Houses (Canada) Limited were used: Nutrient Agar, Dorset Egg Medium, Dextrose Agar, Glycerin Agar, Nutrient Broth, Czapek's Agar, Blood Agar and Sabouraud's Dextrose Agar. The growth observed on the different media is described in Table I.

The following numbers of smears were prepared from the growth obtained on certain of the diagnostic media: Nutrient Agar—19; Dorset Egg Medium—10; Dextrose Agar—4; Glycerin Agar—5; and Blood Agar—20. These smears were stained with the Brown and Brenn Gram Stain prepared as described by Humason (13). This particular Gram staining procedure was recommended by Ajello *et al.* (1) for staining *Nocardia* and *Actinomyces*.

The life cycle of the microorganism cultivated from the gut of *R. prolixus* was observed. Ten tubes of Nutrient Agar Medium were inoculated with the gut contents of normal fifth instar nymphs. At 24, 48 and 72 hours after inoculation five smears were made from the resulting growth. Another five smears were made 40 days after inoculations. The inoculations were made and smears were stained as previously described.

RESULTS AND DISCUSSION

Table I records the characteristics of the cultures resulting from inoculation of the gut contents of fifth instar *R. prolixus* on a series of diagnostic media. In all but two cases of the 197 insects examined in this study, growth of gut contents inoculum on any single medium was uniform with respect to shape and surface of the colonies, elevation of growth, and pigmentation. This is evidence that growth was produced by a single species of microorganism. Changes in pigmentation or growth form during incubation occurred uniformly throughout the culture in any single tube though there was some variability among tubes containing the same medium but inoculated with gut contents of different insects. This was particularly true of the growth on Dorset Egg Medium, Dextrose Agar, and Glycerin Agar. The variability on Dextrose Agar and Glycerin Agar may have resulted from the desiccation of some of these tubes before the termination of the 34 day incubation period. Such abnormal tubes were discarded. The Dorset Egg Medium did not desiccate, however, and the variability shown among tubes inoculated with the gut contents of different insects is puzzling. Gram-stained smears of the growth revealed that only one type of microorganism was present.

TABLE I

Cultural characteristics of the microorganisms isolated from the gut of *Rhodnius prolixus*

Media	*Number of insects used*	*Growth observed following incubation at 37°C*
Nutrient Agar	52	Dull white growth appeared within 48 hours, turning pink in 5 to 14 days; minute discrete colonies present at margins of larger colonies.
Dorset Egg Medium	12	Dull cream-colored granular growth was observed after 48 hours of incubation; salmon pink pigmentation in 33 percent of the cultures in 4 to 11 days; all growth piled up.
Dextrose Agar	18	Colorless colonies observed after 48 hours of incubation; 78 percent of cultures were cream-colored after 7 days, and coral in 34 days; growth was piled up.
Glycerin Agar	20	Cream-colored opaque growth observed after incubation for 4 days; pink-orange pigmentation in 60 percent of the cultures in 34 days; growth was round and umbilicated.
Nutrient Broth	20	White growth was observed at bottom of broth after 48 hours incubation; pellicle of white flakes in 7 days becoming slightly pink in 11 days and settling to bottom; slight discoloration of medium.
Czapek's Agar	19	Minute colorless colonies observed after incubation for 14 days.
Blood Agar (5 percent)	36	Cream-colored growth in 48 hours, becoming dark buff and piled up in 9 days.
Sabouraud's Dextrose Agar	20	A few colorless colonies were observed after 48 hours incubation; no further growth.

In two of the Blood Agar tubes a green fluorescent growth was observed as well as the normal buff-colored growth, indicating the presence of another microorganism, possibly a *Pseudomonas* sp. No growth was observed in seven control tubes containing this medium. These were the only mixed cultures found in the 197 cases examined.

The examination of 65 Gram-stained smears of the growth occurring on Nutrient Agar, Dorset Egg Medium, Dextrose Agar, Glycerin Agar, and Blood Agar revealed only a single species of Gram-positive microorganism, exhibiting a variety of morphological forms in cultures of differing ages. After 24 hours incubation at 37°C on Nutrient Agar Medium, Gram-stained smears of the growth revealed a moderate amount of branching and isolated cells in a large variety of shapes. Many cells had a granular appearance, staining more darkly in some cellular areas than in others. Two-day-old cultures on Nutrient Agar exhibited less branching and the granular appearance was lacking. Many cells had become ovoid, but some spherical cells were also present. Three-day-old cultures grown on the same medium contained only small clumps of single spherical cells or chains of cells. In very old cultures, 40 days or older, some cells stained more darkly than did others. The cellular morphology of the growth on the other media listed in Table I was the same as the growth on Nutrient Agar although the cultural characteristics differed.

The various stages of branching, the cellular shapes, and the differential staining observed during this study of the microorganism from the gut of *R. prolixus* agree with those described by Morris (14) for *Nocardia* sp. The pigmentation noted during growth of the microorganism on the different culture media agrees with that described by Erikson (9) for *Nocardia rhodnii*. No specific tests were carried out to determine whether any or all of the bacteria described by Gumpert and Schwartz (11) were also present, however, the existence of *Mycobacterium* sp. or *Corynebacterium* sp. would have been detected by the appearance of a different growth form on one or several of the various media used in this study (9, 15).

The green fluorescent growth observed in two of the Blood Agar tubes was the only indication that more than one microorganism could exist in the gut contents of *R. prolixus*. There is always the possibility that this mixed growth resulted from external contamination but it seems more likely that one percent of the *R. prolixus* population could vary enough in their internal environment to allow the growth of microorganisms other than *N. rhodnii*. The results of these tests indicate that *N. rhodnii* was the only aerobic microorganism present in 99 percent of the *R. prolixus* tested in our laboratory and consequently the monoxenic condition can be accepted as the normal situation in our *R. prolixus* colony.

The conclusion that *N. rhodnii* usually exists in pure culture in the gut of *R. prolixus* confirms the findings of Brecher and Wigglesworth (5), Goodchild (10), Baines (2) and Harington (12).

R. prolixus, with its symbiont *N. rhodnii,* appears to be an excellent system to use for a study of the nutritional effects of a symbiotic microorganism on a metazoan.

SUMMARY

The cultural characteristics of microorganisms isolated from the gut of *Rhodnius prolixus* and grown on eight different culture media at 37°C were observed. In only two of the 197 isolations were mixed cultures found. Examination of 65 Gram-stained smears of the growth occurring on Nutrient Agar, Dorset Egg Medium, Dextrose Agar, Glycerin Agar and Blood Agar revealed a single species of Gram-positive microorganism, exhibiting a variety of morphological

forms in cultures of different ages. This microorganism was identified as *Nocardia rhodnii* Erikson, an Actinomycete. It existed in pure culture in the gut of 99 percent of the *Rhodnius prolixus* examined and thus confirms the monoxenic condition in the gut of this insect.

ACKNOWLEDGMENTS

The authors thank the National Research Council and the Ontario Department of University Affairs for the support of this work through grants to W. G. Friend.

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(Accepted for publication: January 30, 1968)

III THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND FOURTH ANNUAL MEETING — ENTOMOLOGICAL SOCIETY OF ONTARIO

KINGSTON, ONTARIO

NOVEMBER 1-3, 1967

MEETING OF OUTGOING DIRECTORS

The 1966-1967 Board of Directors met on November 1, 1967, at 10:00 a.m. in Room 128, Earle Hall, Queen's University. Those present were President C. E. Atwood, Vice-president H. R. Boyce, Past-president H. A. U. Monro, Secretary-treasurer D. H. Pengelly, P. Belton, G. W. Green and E. H. Salkeld.

Directors P. E. Morrison and W. H. A. Wilde were unable to attend.

On a motion by the Secretary-Treasurer, seconded by H. R. Boyce, the minutes were adopted as circulated to the membership.

Business arising from the minutes:

1. The Secretary-Treasurer was directed to invest a further $600 of Society funds and reported that Investment Certificates of the Campus Co-operative at the University were purchased. These bear 6 percent interest, compounded annually. These funds, or any part thereof, are available to the Society at any time upon request.
2. The Secretary-Treasurer was instructed to make available copies of the Constitution for Directors. The Constitution has been re-cut on stencils and each member requesting a copy will receive one.

The Financial Statement for the year ending December 31, 1966, was accepted on a motion by G. Green, seconded by H. Salkeld.

The Interim Statement for the period ending October 31, 1967, was also accepted on a motion by H. A. U. Monro, seconded by P. Belton.

The names of the Directors of the Society for 1968 were made known.

The editor's report was accepted on a motion by H. R. Boyce, seconded by H. A. U. Monro. It was suggested that, as Volume 100 is to be printed in 1969, Dr. Judd should anticipate an increased cost in this special issue and contact the Publications Branch of the Department of Agriculture and Food for increased support.

The report from Dr. G. Wiggins, chairman of the Common Names Committee was accepted by the Directors. Action on this report would come at the Annual Meeting.

The Librarian's Report was accepted on a motion by H. Salkeld, seconded by P. Belton.

The Michigan Entomological Society requested a membership list of our Society. After much discussion it was moved by G. Green, seconded by P. Belton that an exchange of membership lists be made with the stipulation that these lists would not be made available to any other body.

The meeting adjourned at 12:00 p.m.

ANNUAL MEETING

The 104th Annual Meeting of the Society was held in Dunning Hall, Queen's University. Registration of members was conducted in the lobby of the hall on November 1 from 9:00 a.m. onwards. The opening session began at 1:45 p.m., under the chairmanship of President C. E. Atwood. Sixteen papers were presented during the three days of the meetings (some of these appear in the preceding sections of this volume).

Six papers, as follows, were presented as "President's Prize" papers at the afternoon session of November 1, under the chairmanship of Professor A. S. West (for results of the award see Appendix II):

KHAN, N. R. (University of Guelph). Sperm activation in *Sitophilus* (Curculionidae).

MJENI, A. M. (Queens University). Cotton pests and their control in South Arabia.

STOLTZ, D. B. (McMaster University). A virus disease in *Chironomus plumosus* L. (Diptera).

A virus disease has been discovered in larvae of *Chironomus plumosus* taken from Lake Pepin, Wisconsin. The disease is characterized by a marked hypertrophy of the fat body and by the appearance of DNA-containing inclusions in the cytoplasm of fat body cells.

The virions measure about 145 mμ in diameter, and present in cross-section hexagonal and pentagonal outlines characteristic of icosahedral viruses. Except for the presence of fine fibrils associated with the outer coat of the virion, there is every indication that this virus should be included in the iridescent insect virus groups. The fibrils, however, seem to prevent the formation of microcrystalline arrays of virus particles, so that diseased Chironomid larvae do not iridesce.

Preliminary evidence indicates that the hypertrophy of the fat body associated with this disease may be due to an invasion of hemocytes into the affected tissue.

STONE, B. F. (University of Western Ontario). Mechanisms of resistance to fenthion in *Culex fatigans.*

TRIPATHI, R. K. (University of Guelph). Ontogeny of haemolymph esterases and glucose 6-phosphate dehydrogenase in larval honeybees (*Apis mellifera* L.).

ZIV, M. (University of Western Ontario). Esterases in organophosphorus-selected strains of *Aedes aegypti.*

At 8:00 p.m. on November 1 members were conducted on a tour of the Biology Department in Earle Hall in order to see particularly the facilities for research in Entomology. Coffee was served afterwards.

On November 2 at 8:45 a.m. in Dunning Hall, a session on "Systems in Insect Control" was conducted under the chairmanship of Professor B. N. Smallman, with the two following papers presented:

CHANT, D. A. (University of Toronto). The systems approach to insect control.

ANGUS, T. A. (Sault Ste. Marie). Microbiological aspects of approaches to insect control programs.

At 12:30 p.m., a luncheon was served for members at the 401 Inn. The President's Prize was presented to Mr. B. F. Stone and the following paper was presented as an after-luncheon presentation:

BALDWIN, W. F. (Chalk River, Ont.). Ecology of the olive fruit fly in Greece.

At 2:00 p.m., a session was held in Dunning Hall at which the following paper was presented:

MONRO, H. A. U. (London, Ont.). Some observations on India's grain storage problems.

At 3:00 p.m., the Annual Business Meeting for members was held in Dunning Hall, and non-members and other interested persons were directed to the art exhibits in the Agnes Etherington Art Centre and to Bellevue House, residence of Sir John A. MacDonald. At 8:00 p.m., a smoker was held at the Queen's University Faculty Club.

On November 3, at 8:45 a.m., a paper-reading session was held in Dunning Hall under the chairmanship of Dr. H. L. House and the following papers were presented:

FERNANDO, C. H. and H. T. HUI (University of Waterloo). An ecological study of aquatic insects colonizing small habitats.

Many species of aquatic Coleoptera and Hemiptera-Heteroptera colonize habitats seasonally by flight. Potential colonizers were caught in enamelled trays 30" x 60" containing 1 to 2 inches of water. A series of ponds ranging from ephemeral to permanent were sampled at the same time (weekly). Catches in the artificial habitats included over 33 species belonging to the Hydrophilidae, Dytiscidae, Haliplidae, Corixidae and Gerridae. The Hydrophilidae and Dytiscidae were the most numerous. The natural habitats had, in addition to the families mentioned, Notonectidae, Nepidae, and Belostomatidae. The

predominant families varied, being Hydrophilidae and Dytiscidae in the more temporary habitats and Corixidae in the more permanent ones.

Three flight periods were noted, one in spring and early summer (breeding), a second in mid and late summer (dispersal), and a third less definable in the fall (overwintering). Different species had different flight peaks. Of the three most numerous species caught in artificial habitats, *Helophorus* c.f. *brevipalpis* Bedel had a clearly defined breeding flight (April-May) and a flight extending from late May to October. The early portion of this was a dispersal of the new generation and the latter portion presumably an overwintering flight. *Paracymus subcupreus* (Say) has a very similar pattern but the highest numbers in artificial habitats alternated with the highest catches of *Helophorus* c.f. *brevipalpis*. *Hydroporus niger* (Say) and *Hydraena pennsylvanicus* Kisenw. has a very poorly represented breeding flight and a dispersal flight which began in July in *Hydroporus* and in September in *Hydraena*. *Hydroporus niger* continued to fly in relatively cold weather and was recorded in artificial habitats in mid-November. The only other family represented in any numbers were the Corixidae which had a marked dispersal flight involving perhaps a number of generations in summer. There was also an increase of flight activity in the fall indicating an overwintering flight.

The net result of flight is to spread individuals into temporary habitats in spring and to collect them for overwintering in deeper habitats.

Correlation of catches from natural habitats and artificial habitats indicates a selection of habitats based on size by different species. Certain species e.g. *Helophorus* spp. and *Paracymus subcupreus* seem to use temporary habitats for a short intensive feeding period followed by movement into soft mud in the vicinity of these habitats, and there is a definite staggering of flight peaks in the different species which probably reduces competition considerably.

DONDALE, C. D. (Belleville, Ont.). Experimental outbreak of the McDaniel mite, *Tetranychus mcdanieli* McGregor in Ontario.

RIOTTE, J. C. E. (Royal Ontario Museum, Toronto, Ont.). Notes on the insect population of Queen's University Biological Station at Chaffeys Locks, Leeds Co., in the light of recent findings in phytogeographic research.

Insect collections made by members of the Department of Entomology and Invertebrate Zoology of the Royal Ontario Museum, University of Toronto, during the summer months of 1963, 1964, 1966 and 1967 at the Biological Station which Queen's University, Kingston, Ontario, operates in Chaffeys Locks, Leeds County, Ontario, show the eminent importance of this place for zoogeographic research. The insect population here supports the recent findings in phytogeographic research, done mostly by Beschel, Hainault, Soper and associates. It can especially be demonstrated that a few insect species show the same distributional gap between the Niagara Section of the Deciduous Forest Region and the Eastern Section in Leeds County as do certain southern plant species. As far as it is known to date, these insect species are: NEUROPTERA: *Dendroleon obsoletus* Say, *Mantispa brunnea* Say, *Mantispa interrupta* Say; LEPIDOPTERA: *Apatelodes angelica* (Grote), *Callophrys* (*Mitoura*) *gryneus* (Hübner), *Sphecodina abbottii* (Swainson), *Orgyia* (*Hemerocampa*) *plagiata* (Walker), *Holomelina opella* (Grote), *Callarctia* (*Callarctia*) *anna* (Grote), *Cisthene unifascia* Grote & Robinson; COLEOPTERA (Scarabaeidae and Lucanidae only): *Onthophagus janus* Panzer, *Copris anaglypticus* Say, *Xyloryctes jamaicensis* (Drury), *Euphoria fulgida* (Fabricius), *Euphoria inda* (Linné), *Dorcus parallelus* Say.

There may be, of course, more species involved, and there should be mentioned at least the following Lepidoptera, which do not show the distributional gap but are more common at Chaffeys Locks than elsewhere: *Heterogynea shurtleffi* Packard (only here found in Ontario), *Ampeloeca versicolor* (Harris), *Datana angusii* Grote & Robinson. Southern plants and insects in Leeds County are, in our opinion, not only very interesting "relics" of a long-past warmer period in quaternary development, but represent a distinct entity in today's endemic animal and plant population in the easternmost section of the Deciduous Forest Region in Ontario.

MUSGRAVE, A. J. (University of Guelph). Participating pedagogy and undergraduate team research with stored products weevils in experimental population and nutritional studies.

BAKER, W. V. (University of Toronto). Photoperiod and diapause in a sawfly, *Diprion similis* Hg.

The sawfly *Diprion similis* undergoes a number of developmental stages as a feeding larva. It then moults to a non-feeding or eonymphal stage which spins a cocoon. This is the stage at which any delay in development takes place and the pronymphal stage which follows takes from 8 to 10 days and proceeds to the development of the adult.

There is no delay in this development once morphogenesis has been initiated. If the period of development in the cocoon is delayed the insect is said to be in diapause. Experiments were done to determine the conditions of light and temperature which would induce or otherwise influence this period of delayed development within the cocoon.

Results so far suggest that diapause induction is affected by both photoperiod and temperature and that there is considerable variation in the time spent in diapause. It also appears that some diapause occurs at all photoperiods. It thus becomes difficult to fit this insect into either the "long day" or "short day" category.

HEGDEKAR, B. M. and B. M. SMALLMAN (Queen's University). Lysosomal activation during metamorphosis of the housefly, *Musca domestica*.

The distribution and behavior of five acid hydrolases (acid phosphatase, B-glucuronidase, B-galactosidase, RNase and DNase) were studied during the metamorphosis of the housefly, Musca domestica L. Twenty to thirty-five percent of the enzyme activities were recovered in the lysosomal fraction and exhibited 50 to 70 percent structure-linked latency depending on the enzyme studied. The relative specific activity of the enzymes was 3 to 3.5 times higher than that of the homogenate. Changes were observed in the free and bound activity of lysosomal enzymes during metamorphosis. Considerable increase in the free activity of lysosomal enzymes as well as in the activity of soluble enzymes were noted during metamorphosis. Different enzymes increased at different times during the pupal stage. These and other evidences presented were interpreted to indicate that during metamorphosis of the housefly, the initiation of cytolytic processes by the hydrolytic enzymes are brought about by a change in the permeability of the lysosomal membrane.

At 2:00 p.m., a meeting of the incoming Directors was held in Room 218 of Earle Hall.

Annual Business Meeting

The annual business meeting was held on November 2, in the Dining Room of the 401 Inn.

The meeting was opened by President C. E. Atwood. The minutes of the 103rd Annual Meeting as circulated to the membership were adopted on a motion by T. Angus, seconded by F. W. Fletcher.

The investment of $600 of the Society's funds was made known to the membership as was the re-stenciling of the Constitution, making copies available to all requesting them.

The Financial Statement (Appendix II, Proceedings of 1966, vol. 97, p. 130) for the year ending December 31, 1966, was adopted on a motion by W. C. Allan seconded by H. R. Boyce. The Interim Statement was adopted on a motion by H. R. Boyce, seconded by C. J. Edwards-Anderka.

The results of the mail ballot showed the following elected as Directors of the Society:

H. R. Boyce
J. McB. Cameron
H. W. Goble
D. G. Harcourt
D. C. Herne
P. E. Morrison
E. Helen Salkeld

REPORT OF THE COMMITTEES

Editor's Report

Volume 97 of the Proceedings includes three reviews of infestations, ten papers on various entomological subjects, and the Proceedings of the 103rd Annual Meeting.

The pages of the Proceedings are open to papers on all branches of entomology and it is requested that members consider submitting papers for Volume 98, in particular reviews of infestations and studies on the insects of Ontario. Please prepare papers according to the guide on the back page of Volume 97 and submit them by January 15, 1968.

Dr. Davies, outgoing Editor, suggested in his report in Volume 97 of the Proceedings that Volume 100, which will appear in 1970 as the Proceedings for 1969, be a special publication. Any suggestions from members concerning the contents of this proposed publication will be welcomed.

I wish to acknowledge the help of Dr. D. M. Davies, outgoing Editor, and Dr. D. H. Pengelly, Secretary-Treasurer of the Society, for their aid in the production of Volume 97 during this first year of my being editor.

W. W. Judd, Editor

This was accepted on a motion by G. Manson, seconded by P. E. Morrison.

Considerable discussion followed on a point which may have been out of order but in the absence of the Editor could not be so ruled. A motion by A. J. Musgrave "that papers going into the Proceedings of the Society be refereed" was amended by A. S. West to "at the discretion of the editor", and seconded by T. Angus, although it was argued by some that the papers are refereed now, but the motion was passed.

Librarian's Report

During the first year the facilities of our Library have been used by society members, staff of the University and graduate students.

Approximately 75 exchanges with "Canadian Entomologist" have been placed in the Library and 20 other publications which were obtained by various means.

Twenty-one requests were handled through Library Loan during the year.

Once again the question of space is upon us and the pressure to vacate our present quarters is increasing. A request for guidance in this matter has been put to the Board of Directors by the Librarian and it is expected that this matter will be resolved in the near future.

W. C. Allan, Chairman.

This was accepted on a motion by W. C. Allan, seconded by W. A. Rowley. Discussion followed on W. C. Allan's proposal that an effort be made to have the Society's holdings incorporated into the Science Section of the new University Library and to have the Library accept responsibility.

Although there was agreement voiced by the members, no motion was made as to how the holdings should be handled. The Librarian can now investigate the feasibility of the suggestion and make plans for the transfer.

Common Names of Insects

The Report to the Entomological Society of Canada of the Committee on Common Names of Insects contained two main points. Firstly, there is relatively little traffic in names moving through the committee and secondly, there was agreement, in general, that the Regional Committees seemed to be of little value in this system which was logically the concern of the ESC.

The matter of a list of Common Names from the ESC to supplement that of the ESA has been considered and was the main topic of discussion at the meeting of this committee at Macdonald College in August. The consensus of this group was that no steps be taken by the ESC committee which would alter the well-established role of the ESA list as the standard for North American usage. This is the policy most likely to maintain uniform usage.

It would be advisable for the ESO to re-appraise the role of its own regional committee which I interpret as that of a stimulus for the submission of well-prepared name proposals, with the review of these proposals falling to the ESC committee. The regional committees have little effect in this area, amounting more to an unnecessary barrier between the proposer and the review panel of the ESC. There must be nation-wide representation on a review panel but our real need lies in closer integration between the review panels of the ESC and the ESA.

G. B. Wiggins (Chairman)
(Summarized by Secretary-Treasurer)

On a motion by H. R. Boyce, seconded by P. S. Corbet, it was approved that the Society appoint a representative to the National Committee of Common Names of Insects and that the Secretary-Treasurer be directed to contact G. B. Wiggins to see if he would be our representative.

President's Prize

P. E. Morrison reported on comments received in reply to a request to members for their views. There was agreement on the value of this part of the Society's program. It was recognized that there may be a problem in the future if the number of students wishing to participate increases greatly but as the problem is, as yet, theoretical, no direction was offered by the membership. The report was accepted on a motion by P. E. Morrison, seconded by H. A. U. Monro.

Resolutions Committee

1. Whereas Queen's University has contributed greatly to the success of the 104th Annual Meeting,
   Be it Resolved that the Society through its secretary extend to Principal Corry our sincere appreciation.

2. Whereas the Program Committee and the Local committee chaired by A. E. R. Downe, have made excellent arrangements for the meeting,
   Be it Resolved that our Society herewith express its appreciation.

3. Whereas Professors B. N. Smallman and A. S. West and their staff made it possible for members of the Society to visit the Entomological Research Facilities in Earle Hall,
   Be it Resolved that the Society express its sincere appreciation for their efforts.

4. Whereas the Annual President's Prize Competition composes an important phase of our Program,
   Be it Resolved that the Society extend its sincere appreciation to the Judges F. W. Fletcher, B. Loughton, and T. Angus.

5. Whereas R. H. Ozburn, who played an important part in the development of our Society, passed away on October 27, 1967,
   Be it Resolved that the Society through the Secretary express our sympathy to his family.

6. Whereas the affairs of the Society have been conducted satisfactorily during the year,
   Be it Resolved that membership extend their appreciation to the president and the executive.

It is with regret that the passing of R. H. Ozburn is herein recorded. The wishes of the family, in the establishment of the Ozburn Entomological Award at the University of Guelph, were made known to the membership. Details will be sent to each member of the Society.

An invitation, to meet at Sault Ste. Marie, was extended to the Society by J. McB. Cameron. The acceptance of this invitation was unanimous on a motion moved by G. W. Green and seconded by P. Belton.

It was moved by D. H. Pengelly that the Auditors for the Society be Saunders and Associates at the Provincial Savings Bank in Guelph, seconded by H. W. Goble. Passed.

Meeting adjourned 4:45 p.m.

Meeting of Incoming Directors

The meeting of the incoming Directors for 1968 was held on November 2 in the 401 Inn.

The Meeting was called to order by President Atwood. Those present were C. E. Atwood, H. R. Boyce, J. McB. Cameron, H. W. Goble, D. G. Harcourt, D. C. Herne, P. E. Morrison, E. Helen Salkeld, and D. H. Pengelly (Secretary-Treasurer).

The election of H. R. Boyce as President was unanimous on a motion by C. E. Atwood, seconded by H. W. Goble. President Boyce took the chair.

J. McB. Cameron was the unanimous choice as Vice-President on a motion by C. E. Atwood, seconded by P. E. Morrison.

W. C. Allan was re-appointed librarian and approval given for his plans concerning the Society library. D. H. Pengelly was re-appointed as Secretary-Treasurer.

The amount of $200 was approved for library maintenance on a motion by J. M. Cameron, seconded by E. H. Salkeld.

The Honorarium to the Secretary-Treasurer was discussed and on a motion by D. C. Herne, seconded by P. E. Morrison was set at $75. A fee of $25 for secretarial assistance was approved on a motion by J. M. Cameron, seconded by C. E. Atwood.

A letter to H. A. U. Monro concerning the possibility of a combined meeting of the Canadian Phytopathological Society was discussed and the Secretary-Treasurer was asked to discuss this further with S. G. Fushtey at Guelph.

The naming of a new candidate to represent the Entomological Society of Ontario on the Board of Directors of the Entomological Society of Canada was discussed. This is for a two-year term, beginning in the fall of 1967. H. R. Boyce will be our candidate.

Dr. Joan Bronskill was named chairman of the nominating committee, the other members being the Past President and the Secretary-Treasurer. The nominating committee was directed

to canvass the Society for those who might be honored as Fellows of the Society and to be responsible for getting the machinery rolling.

S. E. Dixon and W. H. A. Wilde were named as scrutineers of the mail ballot.

The Secretary-Treasurer read a letter proposing one member for consideration as a Fellow of the Society. This was accepted and approved by the directors. Details will be provided and voting done at the time of the mail balloting for directors.

A note was read from W. E. Heming concerning the present day images of entomology and of entomologists and suggesting action be taken to improve them. After some discussion it was evident that there was agreement and a suggestion made that forthcoming books by entomologists may be the answer.

Meeting adjourned.

APPENDIX I

FINANCIAL STATEMENT FOR 1967

RECEIPTS		EXPENDITURES	
Dues Received	$2,174.05	Dues to Ottawa	$1,622.00
Exchange included	12.25	Exchange on Cheques	22.42
Premium on U.S. Funds	27.19	Library Maintenance	200.00
Sale of Reprints	893.00	Stationery	131.78
Sale of Proceedings	37.73	Printing	572.65
Sale of Insect Cabinets	300.00	Postage	488.18
Bank Interest	82.20	Express	4.35
Bond Interest	18.00	Annual Meeting	
Grant from Ont. Gov't (66)	600.00	Room Rental (1966)	8.00
Receipts from Annual Meeting	433.00	Cash Advance	100.00
		Programs	49.98
	$4,577.42	Banquet	327.64
Bank Balance Jan. 1/67	1,930.19	Smoker	58.82
		Pres. Prize	50.00
	$6,507.61	Investment Certificates	600.00
Bonds and Investment Certificates	$1,000.00	Cheques Ret'd	20.30
		Honorarium-Sec.-Treas.	50.00
			$4,306.12
		Bank Bal. Dec. 31, 1967	2,855.11
			7,161.23
		Less Cheques Outstanding	653.62
			$6,507.61
		Bonds and Investment Certificates	$1,000.00

Signed
B. E. Saunders
D. Wright
Auditors

January 19, 1968

APPENDIX II

Six papers were presented by university students at the 104th Annual Meeting in the seventh annual competition for the President's Prize (see list of students, titles and abstracts above).

The prize was awarded to B. F. Stone, the presentation being made by Dr. C. E. Atwood at the luncheon.

Bernard Felix Stone was born in Brisbane, Queensland, Australia, in 1926. He received a Diploma in Industrial Chemistry in 1949, and an Associateship in the Royal Australian Chemical Institute in 1950. He received the B.Sc. degree (Zoology) in 1963, and M.Sc. degree (Entomology) from the University of Queensland. He was engaged in research on resistance to acaricides in the cattle tick, *Boophilus microplus,* in Australia. He arrived in Canada in April, 1966, under terms of a C.S.I.R.O. Overseas Post-graduate Studentship from the Division of Entomology, Yeerongpilly, Queensland, and is registered for study towards the Ph. D. degree in the Department of Zoology, University of Western Ontario.

IV IN MEMORIAM

GEORGE JOHNSTON SPENCER

January 18, 1888 — July 24, 1966

(obituary by G. G. E. Scudder, Canadian Entomologist, 99(1): 110-111)

CHRISTIAN W. FARSTAD

August 5, 1906 — November 18, 1966

(obituary by I. S. Lindsay, Canadian Entomologist, 99(2): 222)

JAMES GORDON THOMAS CHILCOTT

June 19, 1921 — April 20, 1967

(obituary by G. E. Shewell, Canadian Entomologist, 99(7): 780-781)

In Memoriam

REGINALD HOWARTH OZBURN (1898 - 1967)

Reginald Howarth Ozburn died suddenly at his home in Guelph on October 27, 1967. With his death, the Society lost one of its long-time members, and one of its most dedicated workers. His interest in the Society began during his undergraduate days, following service in the army in World War I. He entered the Ontario Agricultural College in 1920, and graduated in Entomology in 1924. He was appointed to the staff of the Department of Entomology and Zoology on graduation, and continued his studies in Entomology, which lead to an M.S. from the University of Minnesota in 1928. In 1926 he was appointed to the positions of Secretary-Treasurer and Librarian in the Society, positions which he held until joining the army in 1941 in World War II. After serving five years as an Entomologist with the Medical Corps, he again assumed the position of Secretary-Treasurer on returning to the College in 1946, a position which he held until he was elected president of the Society in 1955.

Reg, more than anyone, can be credited with holding the Society together during the 1930's. He cajoled members into paying dues when money was scarce, looked after all library exchanges, handled all the administrative work of the Society, and was responsible for getting the "Canadian Entomologist", which was the journal of the Society in those days, and the Annual Report published and distributed.

Many members will remember Reg from his classes within the Department, where his rapid fire delivery during lecture and laboratory periods in Embryology and Histology, his amazing two-handed chalk sketches, and his unwavering demand for perfect work were common topics of student conversations. The contribution he made to Entomology was mostly in the applied field. His publications on Pests of Structural Timbers, Cockroaches, Termites and Rodent Control are still used extensively as guides in many control programs. Reg retired officially from the College in 1963, but continued to be very active in Entomological work as a consultant to the Pest Control Operators Association of Ontario, and to the Board of Examiners of the Ontario Department of Health.

In addition to his work in Entomology, Reg was active, in his usual enthusiastic way, in Guelph Little Theatre, Ontario Drama League, and in the Order of Freemasons. His need for having things done perfectly necessitated personal effort, and it was not unusual to find him cutting stone, building a boat, laying a floor or making a toy for a small child.

Reg always expected a full effort from everyone, and he had little or no patience with those who were not giving their best. This is what he demanded of himself, and this is what he expected of others. For this reason many people considered him to be gruff and crusty at times, but to those who knew him well he was warm and generous and had all the attributes of a good friend.

While the Society has lost a valuable member and we mourn his passing, we are thankful for his service and for the time he spent with us.

W. C. Allan

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PROCEEDINGS

of the

ENTOMOLOGICAL SOCIETY OF ONTARIO

Volume Ninety-Nine

1968

Published September, 1969
by authority of
THE HONOURABLE WILLIAM A. STEWART
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ENTOMOLOGICAL SOCIETY OF ONTARIO

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1967 - 1968

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D. H. Pengelly, Department of Zoology, University of Guelph

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I. REVIEWS OF INFESTATIONS OF INSECTS AND OTHER PESTS

INSECTS OF THE SEASON 1968 RELATED TO FRUIT, VEGETABLES, FIELD CROPS AND ORNAMENTALS

H. W. GOBLE
Department of Zoology, University of Guelph, Guelph, Ontario

Fruit

The damage caused to tree fruit by insects and mites was slight in 1968. The low population of pests appears to be the result of an efficient control program. The European red mite, *Panonychus ulmi* (Koch), caused some damage late in the season in a few orchards. Fruit damage by the codling moth, *Carpocapsa pomonella* (Linnaeus), red-banded leaf roller, *Argyrotaenia velutinana* (Walker), and the Oriental fruit moth, *Grapholitha molesta* (Busch), was insignificant. Cherry fruit flies, *Rhagoletis* spp., were not important. Oystershell scale, *Lepidosaphes ulmi* (Linnaeus), increased in a few orchards in the Georgian Bay area. Apple maggot, *Rhagoletis pomonella* (Walsh), as shown by the overseas apple certification program, increased over 1967. Sap beetles are reported under Vegetables.

Vegetables

Sap beetles, the cabbage looper and the garden slug were important in 1968. Other pests caused damage to a lesser degree. The cabbage looper, *Trichoplusia ni* Hübner, was in outbreak numbers, the highest population in 20 years. It was plentiful on crucifers, with the greatest injury on cauliflower. Celery was infested. This looper was present in large numbers in tomato fields but it restricted its feeding almost completely to the foliage. The sap beetle. *Glischrochilus quadrisignatus* Say, continued to contaminate tomatoes. Raspberries were infested with this sap beetle in southwestern Ontario. Unfortunately there is no satisfactory or economic control program for the above three pests. The cabbage maggot, *Hylemya brassicae* Bouche, was a problem in several areas on early cabbage, cauliflower and turnips where correct and adequate control was not applied. One commercial planting near Kitchener sustained considerable injury to cabbage in September, the flies having laid their eggs on, and the maggots developed in, the base of the heads. The onion maggot, *Hylemya antiqua* (Meigen), was in moderate numbers with some damage resulting from a late fall generation. Flea beetles, *Phyllotreta* spp., caused some damage early in the season.

Field Crops

Slugs, especially *Deroceras reticulatum* (Müll), were injurious in some corn fields in May and June. Fields that were in sod in 1967, where considerable 1967

crop refuse was present or with wet soil, were more prone to injury. Slugs also damaged or contaminated some vegetable crops. Leafhoppers, aphids and spittlebugs were present as usual but no significant increase was recorded.

The cereal leaf beetle, *Oulema melanopus* (Linnaeus), was found in Essex, Kent, Lambton, Middlesex, and Elgin counties. A careful survey did not reveal any in other counties, indicating that this insect did not increase widely in 1968. The alfalfa weevil, *Hypera postica* (Gyllenhal), has spread widely over southern Ontario. Also the increase in numbers was phenomenal in Essex on a few farms. Two fields in this county had 60 to 70 percent foliage destroyed in 1968. It is now suspected that this insect was present in Ontario at least two years before it was discovered.

Ornamental Plants

Many local problems with pests of flowers, shrubs and trees were reported but few appeared in important numbers. Pests such as the bronze birch borer, *Agrilus anxius* Gory, birch leaf miner, *Fenusa pusilla* (Lepeletier), and various species of scale insects and aphids seemed to be present in the usual numbers. A small, green plant bug (species not determined) was very plentiful on Moraine locust and caused almost complete defoliation of certain trees. These trees recovered and appeared normal by late August. Slugs, as reported under Field Crops above, continued to be the most destructive home garden pest.

(Accepted for publication: January 17, 1969)

ECONOMICALLY IMPORTANT PLANT PARASITIC NEMATODES IN ONTARIO

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Research Station, Research Branch, Canada Department of Agriculture,
Vineland Station, Ontario.

The most important plant parasitic nematodes in Ontario soils are the root-lesion nematode, *Pratylenchus* Filipjev, the root-knot nematode, *Meloidogyne* Goeldi, the cyst nematode, *Heterodera* Schmidt, the dagger nematode, *Xiphinema* Cobb, and the pin nematode, *Paratylenchus* Micoletzky.

One of us (J.W.P.) surveyed forage crops for nematodes in 1968. A total of 130 soil samples were taken from 68 farms located throughout southern Ontario. Approximately 80 percent of the samples contained root-lesion nematodes, 75 percent pin nematodes, 52 percent spiral nematodes (*Helicotylenchus* Steiner), 27 percent cyst nematodes, 22 percent root-knot nematodes, 19 percent stunt nematodes (*Tylenchorhynchus* Cobb), 12 percent ring nematodes (*Criconemoides* Taylor), and 5 percent dagger nematodes.

A survey for nematodes of the flue-cured tobacco area in southern Ontario was also carried out by one of us (T.H.A.O.) in 1968. A total of 85 soil and root samples were collected at regular intervals in a 1,072-square-mile area covering Norfolk and parts of surrounding counties. Root-lesion nematodes were present in

83 percent of the samples, stunt nematodes in 34 percent, pin nematodes in 29 percent, root-knot nematodes in 7 percent, dagger nematodes in 3 percent, lance nematodes (*Hoplolaimus* Daday) in 3 percent, and cyst nematodes in 1 percent.

Fourteen growers, who believed they were producing below-average yields of forced winter rhubarb (cult. Victoria and Sutton), sent 18 samples for nematode analyses. These contained pin nematodes, lesion nematodes, cyst nematodes and ring nematodes. Pin nematodes were present in all samples, with populations ranging from 600 to 13,200 per pound of soil. The effect of this nematode on forced winter rhubarb is still under study.

The oat cyst nematode, *Heterodera avenae* Wollenweber, was first discovered in Ontario near the Holland Marsh in 1932 (Putnam & Chapman, 1925). Fifteen years later it was reported from 16 counties (Laughland, 1947). The nematode was discovered on corn crops in two new locations near Chatham, Ontario, in 1968. In one case the field had been sown previously to wheat; in the other to oats, wheat and soybeans in 1965, 1966 and 1967, respectively. In both cases, corn in the infested areas of the fields was severely stunted. As reported earlier (Olthof *et al.,* 1967), a 4- to 5-year rotation with forage crops or soybeans, avoiding small grains, will hold the nematode under control. Corn should not be planted for at least two consecutive years following a heavy infestation of the nematode on cereal grains.

The bulb and stem nematode, *Ditylenchus dipsaci* (Kühn) Filipjev, was recorded from onions, grown in muck soil in the Leamington Marsh, Ontario. The infestation, at 2,600 nematodes per pound of soil, was relatively heavy. This nematode is infrequently encountered in the province but extremely destructive where conditions favor its development (Sayre & Mountain, 1962).

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Sayre, R. M. and W. B. Mountain, 1962. The bulb and stem nematode *(Ditylenchus dipsaci)* on onion in southwestern Ontario. Phytopathology 52: 510-516.

(Accepted for publication: December 31, 1968)

NOTEWORTHY INSECTS IN ONTARIO IN 1968

A. H. Rose

Insect and Disease Survey Section, Ontario Region, Department of Fisheries and Forestry of Canada, Sault Ste. Marie

This review outlines important, potentially important or unusual current forest entomological problems of Ontario in 1968, as determined by the Forest Insect and Disease Survey. Greater detail will be found in the Survey's annual report now

being published under authority of the newly-formed Canada Department of Fisheries and Forestry. For the reader's convenience this report is again organized under indigenous and introduced species on coniferous and broad-leaved host trees.

Indigenous Insects

On Conifers

Spruce-fir forests in three widely-separated parts of Ontario were threatened by infestations of the spruce budworm, *Choristoneura fumiferana* (Clemens): around Burchell Lake some 50 miles west of the Lakehead, in a broad area of northeastern Ontario lying between Chapleau, Timmins and Kapuskasing, and in the Ottawa Valley. The Ontario Department of Lands and Forests treated the first infestation, which extended over approximately 275,000 acres, with insecticide to eliminate the threat to the almost 4.5 million acres of adjacent spruce-fir forest.

The Chapleau outbreak is apparently part of a more extensive outbreak with seven scattered infestations ranging in size from 100 to 500 acres and covering a total area of 2,000 square miles in northeastern Ontario. Some of the balsam fir stands under attack are located in an area where heavy mortality occurred about 1950 following an earlier budworm outbreak. Infestations were mostly light but pockets of moderate or severe defoliation occurred along the Chapleau-Kapuskasing district border, and in the Chapleau, Sudbury and Sault Ste. Marie districts. On the basis of egg mass counts, budworm numbers are expected to increase again in this outbreak area in 1969.

In the Ottawa Valley, balsam fir and spruce trees throughout an area of 3,000 square miles extending from Chalk River to Ottawa on the Ontario side of the river and contiguous with an infested area on the Quebec side suffered light to severe defoliation. The most severe defoliation occurred in Carlton County and egg mass counts indicate a recurrence of severe defoliation there in 1969. In addition, woodlots in Renfrew County will be heavily attacked.

The widespread outbreak of jack pine budworm, *C. pinus pinus,* in northwestern Ontario decreased slightly. The infestation, which extended over approximately 7,800 square miles, contained a band of severe defoliation about 20 miles wide extending from just west of Sioux Lookout to Kenora. In this area, three years of defoliation have caused some top killing of jack pine trees. In the Sault Ste. Marie district, 3,500 acres of red and jack pine plantations in the Kirkwood Management Unit and stands of jack pine in three scattered townships were severely defoliated. The outbreak west of Lake Nipissing and in Georgian Bay Provincial Park persisted with patches of moderate to severe defoliation. Some of the most severe defoliation by this insect ever observed in Ontario in a single year occurred just north of Pembroke, and heavy infestations were reported in the Lake Traverse area nearby. Egg surveys indicate that a considerable decline will occur in the Kenora and Parry Sound districts, but in the Sioux Lookout, Sault Ste. Marie and Pembroke districts, severe defoliation could recur in 1969.

The yellow-headed spruce sawfly, *Pikonema alaskensis* (Rohwer), was present in sufficiently high numbers in spruce plantations in parts of Hastings, and Lennox and Addington Counties to necessitate the use of chemical control measures to prevent tree mortality; and pockets of moderate to severe defoliation occurred in widely-scattered plantings across the province. Light infestations of the balsam fir sawfly, *Neodiprion abietis* complex, along the Ottawa Valley from Mattawa to Rockland, contained numerous small pockets of heavy infestation. This represented an increase in both intensity and extent over 1967. The collapse of infestations of the red-headed pine sawfly, *Neodiprion lecontei* (Fitch), for the second time in southeastern Ontario was attributed to chalcid egg parasites. In the

past, the collapse of most infestations has been marked by the presence of larvae killed by virus and it has usually been assumed that virus was the most important natural control agent. Heavy infestations still persist east of Sault Ste. Marie and east of Bracebridge, and new heavy infestations occurred in the Tweed district. Cedar leaf miners, mainly *Argyresthia thuiella* Packard, but also *A. freyella* Walsingham, *A. aureoargentella* Brower and *Pulicalvaria thujaella* Kearfott, continued their depredation of eastern white cedar groves, hedgerows and windbreaks in a broad band across southern Ontario from Port Elgin and Goderich through Peterborough and Trenton to the Quebec border. A red pine needle midge, *Thecodiplosis piniresinosae* Kearby, whose attack causes needles of red pine to turn brown and drop off in early fall, persisted at high population levels and a new heavy infestation was reported in the Pembroke district.

On Broad-leaved Trees

The northwestern Ontario outbreak of the forest tent caterpillar, *Malacosoma disstria* Hübner, that began in 1960 and defoliated aspen over an area of 35,000 square miles in 1965, gradually declined until in 1968 only 400 square miles in the Fort Frances district were affected. Elsewhere only two infestations east of Sault Ste. Marie and totalling about 800 square miles persist. Egg surveys revealed that a further substantial decline in the extent and intensity of these infestations can be expected in 1969.

Of particular interest were the numerous infestations of the saddled prominent, *Heterocampa guttivitta* Walker; these were more extensive and widespread than any ever recorded in Ontario in the past 30 years (Figure 1).

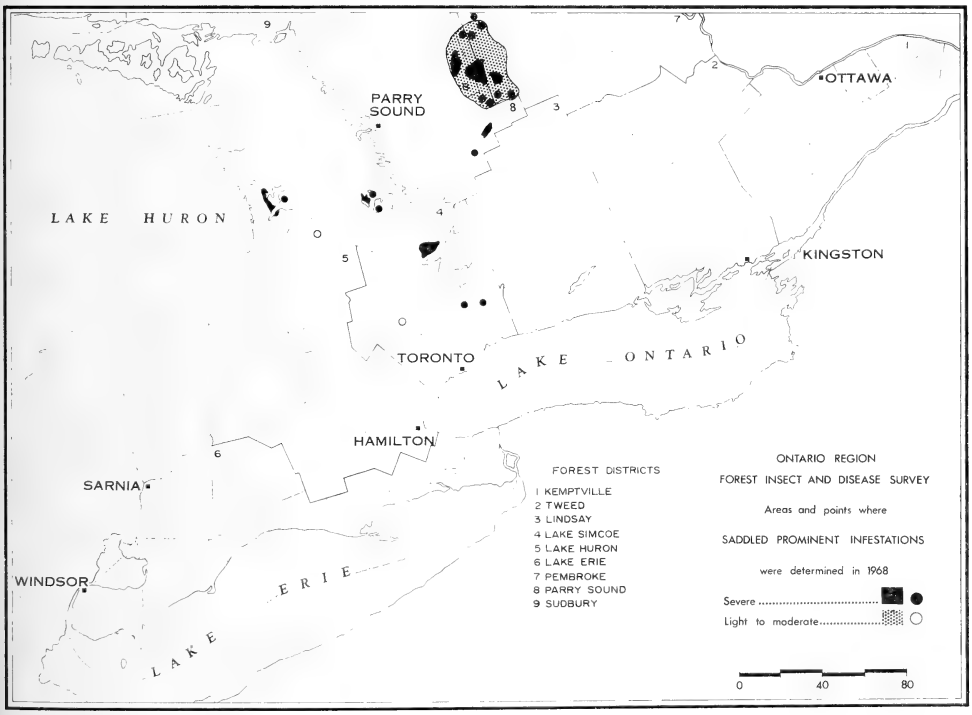

FIGURE 1

Most infestations of 1967 expanded and many new ones were reported. In Algonquin Park, for instance, a new light infestation containing pockets of heavy attack covered approximately 1,000 square miles. Most of the damage occurred on sugar maple, but white and yellow birch, beech, trembling aspen, basswood and ironwood were also infested. Pupal counts at a number of locations suggest that infestations will persist in 1969. A number of other hardwood defoliators were also more common than in recent years. After a near-absence for more than two years both the linden looper, *Erannis tiliaria* (Harris), and the green-striped maple worm, *Anisota rubicunda* Fabricius, were much more commonly found. Both the spring and fall cankerworms, *Paleacrita vernata* (Peck) and *Alsophila pometaria* (Harris), caused medium to heavy defoliation in the Kemptville district; the latter also fed very heavily on shade trees in Dryden and Fort Frances. Two *Datanas,* the yellow-necked caterpillar, *D. ministra* (Drury), and the walnut caterpillar, *D. integerrima* Grote & Robinson, caused pockets of moderate to severe damage primarily in southern Ontario.

No infestations of the large aspen tortrix, *Choristoneura conflictana* (Walker), have been reported since 1960, until this year, when a medium infestation was reported in a 10-acre stand of trembling aspen in Conmee Township in the Port Arthur district, not far from the Burchell Lake budworm outbreak. Heavy infestations of the maple trumpet skeletonizer, *Epinotia aceriella* Clemens, occurred in woodlots in the Lake Huron and Lake Erie districts. The heavy infestations of the cottony maple scale, *Pulvinaria innumerabilis* Rathvon, in Windsor and near Harrow were under heavy attack by a coccinelid predator *Hyperaspis* sp. and are expected to decline next year.

Three species that have rarely been collected by the Survey were found in high numbers in 1968. They were: *Chionodes obscurusella* Chambers, a gelechiid, which caused severe defoliation of Manitoba maple in the town of Chapleau; *Gypsonoma haimbachiana* Kearfott, an olethreutid, which was found in high numbers in balsam poplar shoots south of Barrie; and *Zale galbanata* Morrison, a noctuid, which caused severe defoliation of Manitoba maple at the St. William's Nursery. Two cutworms more noted in agriculture than in forestry caused damage in tree nurseries. The dark-sided cutworm, *Euxoa messoria* Harris, severely damaged silver maple seedlings at the St. William's Nursery, and the variegated cutworm, *Peridroma saucia* Hübner, severely damaged white spruce seedlings, germinated in plastic tubes, at the Fort Frances Nursery.

Introduced Insects

On Conifers

In 1968 the European pine sawfly, *Neodiprion sertifer* (Geoffroy), was discovered on ornamental pines in the cities of Sault Ste. Marie and North Bay. A search of Sault Ste. Marie nurseries in June revealed larvae on balled Mugho pine that had recently been brought from a southern Ontario nursery. Thus in two introductions of *sertifer* to northern Ontario, namely, on Manitoulin Island in 1965 and in Sault Ste. Marie in 1968, it has been shown that movement of infested nursery stock from southern Ontario was responsible. Surveys of Scots pine plantations on Manitoulin Island, treated with polyhedral virus in 1966, revealed a maximum count of six colonies per hundred trees.

No further spread was detected for other introduced pests of conifers but there were marked increases in population levels of the larch casebearer, *Coleophora laricella* (Hübner), on tamarack at widely-scattered locations. The most spectacular count occurred just east of Sault Ste. Marie where an average of 122 larvae

per 18-inch branch tip was recorded. Notable increases were also reported in the Chapleau, Swastika, Kemptville and Lindsay districts.

On Broad-leaved Trees

No striking changes in the distribution of either the birch leaf miner, *Fenusa pusilla* Lepeletier, or of the mountain ash sawfly, *Pristiphora geniculata* (Hartig), were found; but the latter caused widespread and severe defoliation in the Swastika district and in Lake Superior Provincial Park, at the northwest limit of its range. The smaller European elm bark beetle, *Scolytus multistriatus* (Marsham), extended its narrow band of distribution along the north shore of Lake Ontario, eastward along the St. Lawrence River to within 30 miles of the Quebec boundary, and was abundant within its distribution because of the extensive tree mortality attributable to the Dutch elm disease.

(Accepted for publication: March 11, 1969)

INSECTS AND OTHER ARTHROPODS OF IMPORTANCE DURING 1968 IN HOUSEHOLDS AND ON LIVESTOCK IN ONTARIO

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Household

Cluster flies, *Pollenia rudis* (Fabricius), were the most important insect pests in households during the past year. These flies were very numerous during the winter and early spring but tapered off in the fall of the year. European earwigs, *Forficula auricularia* (Linnaeus), have continued to spread and were reported from most parts of Ontario. They were usually found in large numbers both inside and outside the house. Fleas, *Ctenocephalides* spp., have become a major problem in many homes when cats or dogs are kept as pets. In instances where the pet has been removed or where the home has been closed for some time these insects have often made living conditions extremely uncomfortable.

In cereals and cereal products, confused flour beetles, *Tribolium confusum* Duv., were the most common of the usual run of this group of pests, with saw-toothed grain beetles, *Oryzaephilus surinamensis* (Linnaeus), a close second. Booklice, *Psocoptera: Psocids,* were frequently found in many homes as pests of books, magazines and concentrated pet food, particularly bird seed. Wood roaches, *Parcoblatta pennsylvanica* (DeGeer), were reported many times from resort areas where they invaded, and became quite a pest in cottages. Clover mites, *Bryobia praetiosa* Kosh, were not as plentiful as in the past, and very few reports of infestations in homes were noted during the year. Bird mites, *Dermanyssus* spp., were found in many homes where bird-nesting in the attic or under the eaves was common.

Millipedes, *Narcus* sp., and sow bugs, *Oniscus* sp., were reported many times as being in fairly large numbers in garages, patios, damp cellars and basements.

Livestock

Face flies, *Musca autumnalis* (DeGeer), were present in very large numbers in widely separated areas. These flies were found to concentrate on individual herds of both dairy and beef cattle in localized areas. This habit of high population concentrations was fairly general in all cattle farming areas of Ontario. Horn flies, *Haematobia irritans* (Linnaeus), while not as numerous as in previous years, still caused a great deal of annoyance to all types of cattle during 1968. Populations of warble flies, *Hypoderma* spp., did not change during the year in either beef or dairy cattle.

(Accepted for publication: January 1, 1969)

ESTABLISHMENT OF THE GYPSY MOTH, PORTHETRIA DISPAR L., IN CANADA

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The gypsy moth, *Porthetria dispar* L., has posed a threat to Canadian agriculture and forestry almost since its introduction into North America in 1869. Surveys conducted by the Plant Protection Division, Canada Department of Agriculture, were instrumental in detecting introductions occurring periodically in Quebec and New Brunswick from 1924 to 1965 (Brown, 1967). Eradication was achieved in all instances by the application of insecticides, earlier by means of ground equipment but by 1960, when annual treatment involved from 1,000 to 2,000 acres, through use of aircraft. During these latter years the gypsy moth became established all along the Quebec border in eastern New York and Vermont, thus providing a continuing population for movement into Canada.

In 1965 some pockets of infestation were apparently missed. During the next three years the pest became established in all of the counties of Quebec south of Montreal and west of the Richelieu River in spite of a major control program applied by the Plant Protection Division. Surveys have been continued and scouting in November 1968 located egg masses on Salaberry Island at Valleyfield and along the north shore of the St. Lawrence River westward to within 3 miles of the Ontario border. Approximately 400 square miles of mixed farmland and woodlots are now affected.

It is expected that the outlying infestations and camping sites will be treated in May 1969. This should include the area north of the St. Lawrence River, infested islands in the river at Valleyfield and much of Salaberry Island. This is only a small portion of the total infestation but it is hoped that with the aid of the St. Lawrence River as a natural barrier, a containment program will be effective in preventing

spread northward and westward for some years. Movement of logs from southern Quebec to large pulp mills in Eastern Ontario presents one of the greatest risks for movement in a westerly direction. Surveys are conducted adjacent to these mills each year and so far no gypsy moths have been detected. Larvae are also frequently carried for short distances by local delivery trucks. In certain instances egg masses have been found at every farmhouse along bread, milk or mail delivery routes, yet surrounding property has remained free.

Campers stopping overnight or longer in infested campsites present a risk of long distance spread (Brown, 1967). Larvae may pupate in sheltered locations on trailers, tents, or other equipment and emerging adults escape at a point hundreds of miles away. Egg masses laid on camping equipment or vehicles may be carried across the continent before they hatch the next spring. Camping sites within the infested area in Quebec will be treated each year to reduce this risk of spread. Checks will also be made on camping equipment and on forest and quarry products moving out of the area.

There seems little likelihood that the gypsy moth will again be eradicated from Canada. The area involved is a mixed farming area and no insecticide has been developed which does not present problems in its use. Consequently an unrestricted blanket program of application has not been possible. Quarantines may slow its spread until an effective treatment is devised but it may be that we will have to learn to live with it.

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Brown, G. S., 1967. The Gypsy Moth, *Porthetria dispar* L., a threat to Ontario horticulture and forestry. Proc. Ent. Soc. Ont. 98: 12-15.

(Accepted for publication: February 6, 1969)

II. INVITATION PAPERS

ENTOMOLOGY AND NON-SCIENTISTS

Presidential Address

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My text is taken from the Presidential Address to the 103rd annual meeting of our Society by H. A. U. Monro[1]. I quote "There are today many scientists working in some aspect of entomology who are unable to identify at sight the more common insects". It is not in disparagement that I say, from my experience, that too many technical and extension personnel employed by government and by agricultural industries (including agricultural chemical industries), have a similar lack of knowledge of the common insects most injurious to crops. This gap in their knowledge pertains mainly to inability to recognize adults, the various stages that attack the major crop plants, and the kind of injury causing crop loss.

The need for making such information available was recognized by the publication, in 1871, of the First Annual Report on the Noxious Insects of the Province of Ontario prepared for the Agricultural and Arts, and Fruit Growers' Associations of Ontario, on behalf of the Entomological Society of Canada by The Rev. C. J. S. Bethune, M.A., William Saunders and Edmund Baynes Reed. This publication, which deals with insects affecting the apple, the grape and the plum, must have been popular because it was reprinted in 1895.

Since that time many books and bulletins with even more extensive coverage have been published. In too many cases, really good illustrations useful for the recognition of adults and the stages of insects causing injury to crops are lacking.

I believe that much of the difficulty could be overcome in time by improvement of their training by (1) the use of well-preserved classroom materials which retain their natural coloration, supplemented as necessary with good color slides of developmental stages and injuries to crops, and (2) a thorough introduction to literature sources having illustrations of good detail and quality.

I hope that some members here will have the patience and interest to undertake or promote improvements in the training areas mentioned. Such improvements should increase the capacity of those students who may not become entomologists or scientists. In addition, quality training of the kind suggested would make such students much more useful with less on-the-job training.

(Accepted for publication: December 22, 1968)

[1]Proc. Entomol. Soc. Ont. 97: 11-13. (1966) 1967

GLACIAL HISTORY OF THE UPPER GREAT LAKES

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Glaciation was perhaps the most significant event in the recent history of central Canada. Huge ice sheets, estimated as being one to three miles thick, advanced from the north, displacing the existing fauna and flora, reshaping the physiography and rearranging the drainage systems. Loose material froze into the mass of this ice and was dragged along for hundreds of miles, abrading the underlying bedrock. Oceans shrank as water was withdrawn from them and concentrated on the land as ice or lake water. The weight of this ice depressed the crust of the earth by as much as 400 feet in the upper Great Lakes area.

The story of glaciation in North America is slowly emerging after about seven decades of painstaking work. The clues for this gigantic detective work are the deposits of the glaciers and the lakes impounded by them. In this review I have drawn freely on the results of studies by many workers, as well as my own work. This paper will describe the events in various lake basins and attempt to correlate them with those of Lake Agassiz during its easterly drainage.

Before examining the glacial history of this area, we might clarify a few general concepts. Continental glaciers flow because of the slope of the ice dome. The great weight of the ice renders it plastic and it flows as highly viscous fluid. The glacier advances if ice is accumulating (or invading) faster than the available heat can melt it. The ice front is said to be stationary when the rate of melting just balances the rate of forward movement. The ice sheet is waning when wastage exceeds the increment of ice.

The waning of an ice sheet is often incorrectly visualized as an orderly, progressive uncovering of land. In fact, the waning of ice sheets was often interrupted by minor readvances and halts, when the temperature regime or the increased nourishment of the glacier resulted in renewed activity. I suspect that the general advancing of ice sheets was similarly interrupted by periods of stagnation or increased melting.

The gathering ground of the North American continental glaciers is identified as the Hudson Bay area, as indicated by the greatest depression of the earth's crust by the weight of ice (Farrand and Gajda, 1962). Following the melting of ice the land surface rebounded, rapidly at first, then more slowly. Because the depression was the greatest in the Hudson Bay area, the uplift was also the greatest there and progressively less farther south.

It is believed that eastern Canada was covered by a large ice sheet, the Laurentide ice sheet (Prest, 1963), radiating from the Hudson Bay area. Movement in all parts of this large ice sheet was not synchronous, as some of its sections could move independently of others. Thus the Labradorean ice mass would be inactive while the Patrician mass was advancing, or the Keewatin ice mass was retreating. We also know that, at least during the waning stages of glaciation, there were local centers of outflow, such as in the Superior basin and in the Ontario basin, and west and east of Hudson Bay (Figure 1).

The sequence of glaciation and deglaciation is derived from the examination of glacial and associated lacustrine deposits. Radiocarbon dates of organic materials buried in, or deposited on, these deposits afford an approximation of absolute chronology. In the following account radiocarbon dates are used when available and are correlated to glacial features in areas lacking such dates. The dating of various events shown in the figures is tentative and should be used with caution.

A convenient starting point for this review of the glacial history of the upper Great Lakes is the latest general ice advance during the late-Wisconsin stage, some 28,000 years ago (Goldthwait *et al.*, 1965). For the next 15,000 years ice covered

FIGURE 1. Generalized direction of ice flow during the waning stages of glaciation. (Modified after Prest 1963.)

the Great Lakes region, extending well into the United States. As the following deglaciation proceeded, the southern part of the Great Lakes basin became free of ice and proglacial lakes were initiated in the ice-free portions of the basin. Thus Lake Chicago was dammed at the southern tip of the Michigan basin, and a succession of lakes (Lakes Maumee, Arkona, Whittlesey and Warren) were formed in the southern part of the Huron and in the western part of the Erie basin (Hough, 1963).

As the waning of the ice mass continued, Lake Lundy was established in the Huron-Erie basins, and Lake Chicago in part of the Michigan basin (Figure 2a). Both lakes drained south into the Mississippi River through the Chicago outlet (Hough, 1963). Lake Iroquois, draining to the Hudson River, occupied all of the Ontario basin. Lake Duluth was formed at the tip of the Superior basin by the coalescence of smaller proglacial lakes. Lake Duluth drained to the south into the Mississippi system through the St. Croix outlet. The ice border stood in the west at the Steep Rock moraine (Zoltai, 1965). Lake Agassiz covered large areas of the Canadian prairies.

Further retreat of the ice front allowed the establishment of Early Lake Algonquin (Hough, 1963) in parts of the Huron and Erie basins (Figure 2b). Lake Duluth was still dammed by ice in part of the Superior basin, but the ice front retreated to the Eagle-Finlayson moraine. Later the Kirkfield outlet of Lake Algonquin (Chapman and Putnam, 1966) became free of ice, lowering the water level and draining the lake into Lake Iroquois of the Ontario basin.

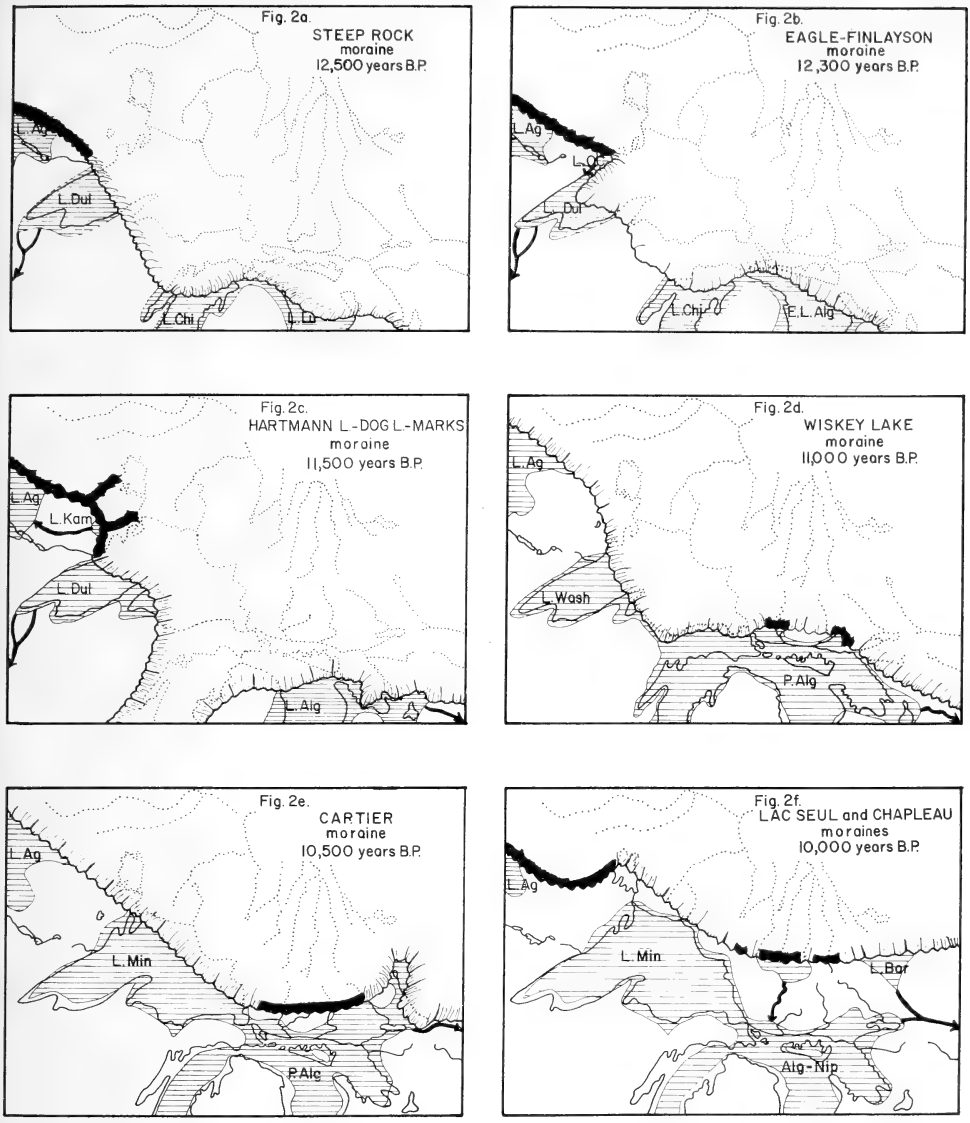

FIGURE 2. Various stages of deglaciation and the glacial Great Lakes.

The Valders readvance which occurred about 11,500 years ago (Broecker and Farrand, 1963) affected mainly the Michigan basin, restricting Lake Chicago to a smaller area. In the west a small marginal lake, Lake Kaministikwia, was dammed by ice standing at the Hartmann-Dog Lake-Marks morainic system. This lake drained westward into Lake Agassiz (Figure 2c). The Kirkfield outlet of Lake Algonquin was maintained at this time.

Further shrinkage of ice opened an outlet through the Huron mountains to the Michigan basin (Figure 2d), draining Lake Washburn, which occupied part of the Superior basin (Farrand, 1960). Lake Algonquin in the Huron-Michigan basins was still largely bordered by ice standing at the Whiskey Lake moraine (Boisson-

neau, 1968) and drained through the Kirkfield outlet into Lake Iroquois. However, uplift of the land caused by the reduction of the weight of ice, gradually tilted the basin to the south. This resulted in a series of lower standlines in the north and in progressive flooding of the shores in the south.

As the ice receded further, a lower outlet was opened at Fossmill (Figure 2e), lowering the level of the post-Algonquin lakes by as much as 160 feet (Chapman, 1954). The ice margin stood probably at the Cartier moraine north of the Huron basin (Boissonneau, 1968). Ice had disappeared from most of the Superior basin, and Lake Minong, having probably the same level as the post-Algonquin lake in the Michigan-Huron basins, was created (Farrand, 1960). The removal of much of the ice load from the land resulted in rapid uplift and further tilting of the lake basins to the south, again modifying the lake levels in the Huron-Michigan and the Superior basins. Finally the tilt was sufficient to return the drainage of the post-Algonquin lake to the Chicago and St. Clair River outlets.

Further melting of the ice uncovered a lower col to the Ottawa River valley about 10,000 years ago and the Algonquin-Nipissing transitional lakes were initiated in the Huron basin, draining eastward through the North Bay outlet (Chapman and Putnam, 1966). The ice front was at the Chapleau moraine, and Lake Barlow was established in the Timiskaming area (Figure 2f). Lake Minong occupied the Superior basin while the ice front was stationary at the Lac Seul moraine (Zoltai, 1965).

The Algonquin-Nipissing transitional lakes in the Michigan-Huron basins continued to drain eastward through the North Bay outlet, but the basin was still strongly depressed to the north by the weight of ice, exposing large areas which are now in Lake Huron and Michigan. Differential uplift was tilting the basins southward, however, resulting in a series of transitional lakes exposing more land in the north and inundating land in the south. In the west, the Kaiashk outlet of Lake Agassiz reached Lake Minong in the Superior basin (Figure 3a) while the ice front was stationary at the Nipigon moraine (Zoltai, 1967a). Lake Barlow-Ojibway occupied the low-lying areas south of the melting ice sheet in northeastern Ontario (Boissonneau 1966).

Melting ice uncovered lower outlets from Lake Agassiz into Lake Kelvin in the Nipigon basin (Zoltai, 1967a) while the ice stood at the Whitewater-Crescent moraines (Figure 3b). This water reached a post-Minong Lake in the Superior basin, draining through St. Mary's River. The Algonquin-Nipissing transitional lake in the Huron basin was draining east through North Bay.

Further shrinkage of the ice sheet allowed Lake Agassiz to drain into a narrow ice marginal lake, Lake Nakina (Figure 3c) while the ice front was stationary at the Nakina moraine (Zoltai, 1967b). This lake was a temporary extension of the post-Minong lake which occupied the Superior basin. Lake Barlow-Ojibway covered large areas in the north and drained through the Timiskaming trench. The lake in the Huron basin was draining eastward through the North Bay outlet.

Continued retreat of the ice front allowed the expansion of Lake Barlow-Ojibway in northern Ontario. Lake Houghton, a relatively low-level lake, was established in the Superior basin (Farrand, 1960), draining through the St. Mary's River (Figure 3d). About 8,275 years ago (Hughes, 1965) a readvance of ice, the Cochrane (Figure 3e), covered the greater part of the former bed of Lake Barlow-Ojibway (Boissonneau, 1966). Rapid melting of the ice followed and all glacial ice disappeared from the region about 7,800 years ago.

Differential uplift was still continuing as the earth's mantle adjusted to the removal of the ice burden. Uplift gradually tilted the Great Lakes basin to the south and the Nipissing Great Lakes were established about 6,000 years ago as water drained through the Chicago and St. Clair River outlets, as well as through the North Bay outlet (Figure 3f). The uplift continued and the North Bay outlet was

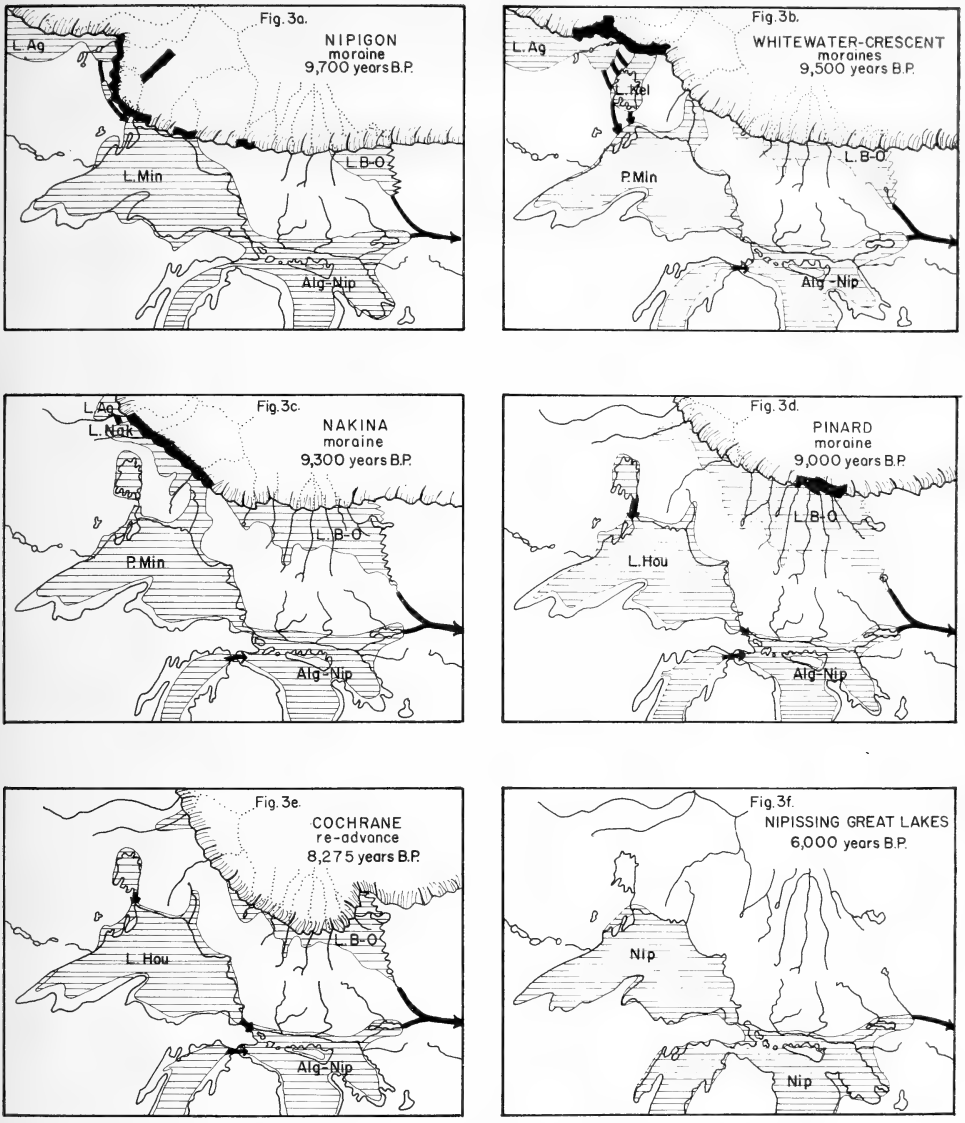

FIGURE 3. Various stages of deglaciation and the glacial Great Lakes.

finally abandoned. The St. Clair channel was deepened by erosion and became the only outlet (Hough, 1963). This terminated the Nipissing stage about 4,000 years ago. The succeeding stage, Lake Algoma, still covered the three upper lakes, but it terminated some 3,200 years ago as its outlet at St. Clair River was further eroded. The modern Great Lakes emerged from this complex series of glacial and postglacial lakes only about 3,000 years ago.

Glacier ice offered a very inhospitable environment to all life forms, destroying the existing flora and fauna. The biota later had to invade the areas which became free of ice, as no part of the area escaped glaciation. The glacial lakes formed barriers to migration as some areas which are now dry land were under water and

others which are now under water were dry land. These barriers were not insurmountable for most plants or animals, as many of the lakes existed for a short time and their outline changed frequently. The northern sections of the Great Lakes were studded with islands which offered migration routes. Lakes may have been barriers to some plants or animals, but for other organisms they provided a means of dispersion. The direct connection with Lake Agassiz in the west probably facilitated the mixing of hardy aquatic life forms.

The history of deglaciation depicts a situation of great fluidity. Ice sheets came and went, lakes flooded areas only to disappear later, great rivers drained these lakes and then dwindled to mere trickles. A great variety of environment was available to colonizing plants and their animal suite: rubble fields, sand flats, former lake beds. Pioneer plants and highly mobile animals were favored in the initial invasion of these areas, but they suffered setbacks by flooding or readvances of ice. This delayed the establishment of organisms that require a stable community for best development. Relative stability returned to the Great Lakes area some 7,000 years ago, permitting the unhampered establishment of an ecologically suitable biota.

The readjustment of the biota to the postglacial environment is not complete. Some remnants of arctic flora are still found in suitable environments far south of their normal range (Soper and Maycock, 1963). It is possible that slowly migrating organisms have not yet occupied their potential range and the native biota is still adjusting to the environment left by the departing ice.

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SOME NOTES ON THE CLIMATIC HISTORY OF THE GREAT LAKES REGION

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Introduction

Scientists and the general public are much more aware of climatic change than they used to be. Until about three decades ago even most meteorologists were not too interested in the subject. They accepted the geologists' word that there had been ice ages, periods of hot wet weather, and periods of hot dry weather over the earth, but most meteorologists did not even consider that there might be any recognizable trend to our contemporary climate. By the 1940's, however, some scientists realized that parts of the globe were experiencing warmer conditions than those that had existed in the 19th century. As a result, many physical and biological scientists began studying aspects of climatic change, along with historians, economists, archaeologists, anthropologists, etc. So many scientists are now interested that the study of climatic change probably cuts across more subject borders than do most interdisciplinary studies.

The concept of climatic change is not an easy one to grasp, especially for those of us living in the middle latitudes where the day-to-day weather changes are often quite drastic. Besides these aperiodic weather changes we do have rather marked diurnal and annual variations of temperature — two periodic changes which we accept without much thought. To study climatic change it is necessary to filter out these day-to-day variations to which we are accustomed. We effectively do this when we speak of the climate of a country or of an area, and for most purposes we do consider our climate as stable. Using long period climatic data, we are able to construct maps of mean January temperature, maps of mean annual precipitation, etc, and we expect that, over the next few decades, the meteorological elements will average much the same as they have in the past. But while normal maps are meaningful, there are series of cool summers, dry years, etc. Can we identify any significant climatic change, or has there been only a succession of minor erratic fluctuations?

Evidence

Most physical scientists can produce some evidence of climatic change. Entomologists tell of the migration of insects, ornithologists describe the changing bird migration over decades and centuries, botanists refer to vegetation changes, and physiographers point out features in our landscape that have been caused by climates different from those which we have today. Varying widths of tree rings, thicknesses of lake bottom varves, and kinds and amounts of pollen at different levels in bogs are other indications that climates have changed. The presence of oil and coal deposits in Canada is evidence that the climate of this country was once much warmer and drier than our present one. Striations on rocks are evidence of a glacial period, while in recent years geophysicists, using radiocarbon analysis, have been able to date organic material and marine deposits laid down over the past 30,000 years.

Causes

The possible causes of climatic change may be classed as astronomical, atmospheric or geophysical (1). All scientists are aware of the existence of sunspots, and of the apparent 11-year cycle in their number. Many scientists and

laymen have tried to identify cycles in climate and weather with the relative number of sunspots. There are some interesting correlations—severe storms in our latitudes are more numerous at times of maximum sunspot activity, while in the tropics temperatures are about half a degree Celsius warmer at times of minimum sunspot activity. It is not, however, possible to forecast the exact duration of each sunspot cycle, nor its relative intensity, and thus it is not possible to base a climatic forecast on sunspots. The sunspot cycle is, of course, only one cause of variation in solar output and there are other theories of climatic change that have been put forward, including variations of solar distance, varying tilts of the earth's axis, the precession of equinoxes, etc.

Other meteorologists believe that the most important causes of climatic change are atmospheric. The atmosphere shields us from solar radiation, but there are variations in transmissivity due to the relative presence or absence of dust, carbon dioxide, water vapor, ozone and clouds in the atmosphere. The Krakatoa volcanic eruption of 1883 charged the high atmosphere with volcanic dust and was blamed for the generally cooler conditions in the 1880's. Another interesting theory concerns carbon dioxide and is based on the fact that its presence in the atmosphere prevents the loss of terrestrial radiation to space, or in other words, causes a "greenhouse effect". Through the increasing combustion of fossil fuels the amount of carbon dioxide in the atmosphere has increased about 10 percent during the past 50 years, which is a possible reason for an increase in the temperature of the earth's atmosphere.

It is quite logical to believe that the relative positions of the continents on the globe have not always been as they are at present, and in recent years there has been a revival of the continental drift theory. If the continents have moved we could expect different climates to have prevailed because of the relative influences of land and water. There is also evidence that the poles have migrated and this, of course, would cause great variations in climate in any particular area. Even with non-migrating poles and anchored continents, mountain building and erosion can cause great variations in the general circulation of the atmosphere. The distinct patterns in the circumpolar circulation of the atmosphere are caused not only by the presence of continents and oceans, but also by the existence of such barriers as the cordillera stretching from Alaska to Magellan Strait on the west side of the Americas.

There are, in short, many theories of climatic change. Variations in the amount of energy arriving at the earth's surface, variations in the amount of heat allowed to escape from the earth's atmosphere, and variations in the geography of the surface of the earth — all must affect the heat budget of the earth and its atmosphere. This will cause changes in the general circulation of the atmosphere, and this of course will produce climatic changes. Most scientists are now agreed that there is no one main theory of climatic change, but that there are many causative factors at work, all of them operating simultaneously.

Orders of Climatic Change

Before describing the climatic changes that have occurred, it might be well to examine the different orders of climatic variation (2). In everyday life most of us are interested primarily in the minor fluctuations that occur over our lifetime, i.e. fluctuations that occur over a few decades. These present day variations are of course being precisely measured. Through a combination of observed, instrumental, historical and geophysical data, we also know a good deal about the postglacial and historic climatic changes that have operated over intervals of the order of 250 to 1,000 years. The next larger order may be called "glacial", i.e. the duration of phases within an ice age that lasted perhaps 10 to 30 thousand years. A higher order, still, is the minor geological order with periods of a million years — that is

the duration of an ice age as a whole, and finally, there are major geological periods which cover the occurrence of ice ages at intervals of a quarter of a billion years.

Climatic History

Pre-Pleistocene (From the earth's beginning until one million years ago) — The earth is probably between 5,000 and 6,000 million years old, while the solid mantle formed perhaps 4,500 million years ago. There have been several severe glaciations of the earth's surface, perhaps some of them complete. Each one apparently lasted about one million years, and they occurred at intervals of about 250 million years. Since the formation of the solid earth mantle it has been calculated that the earth has enjoyed a warmer, more genial climate than now exists about nine tenths of the time (3).

Pleistocene — The Pleistocene Era began about one million years ago. During this era there have been at least four ice ages, or advances of the ice cover, with retreats or interglacial ages occurring between the advances. Because the last ice age, the Wisconsin, obliterated evidence of the earlier ones, we know much more about it than its predecessors. In some respects we are still in the Pleistocene Era, and some scientists claim that there will be at least one more ice advance or glaciation before world climates become warmer. The most remarkable climatic threshold was reached about 17,000 years ago when a sudden warming of the Atlantic Ocean occurred which signalled the beginning of the end of the Wisconsin ice age. This date has been determined by using radiocarbon techniques with organic material from human occupation sites, and by analyzing the radioactive isotopes of deep sea cores from the Gulf of Mexico.

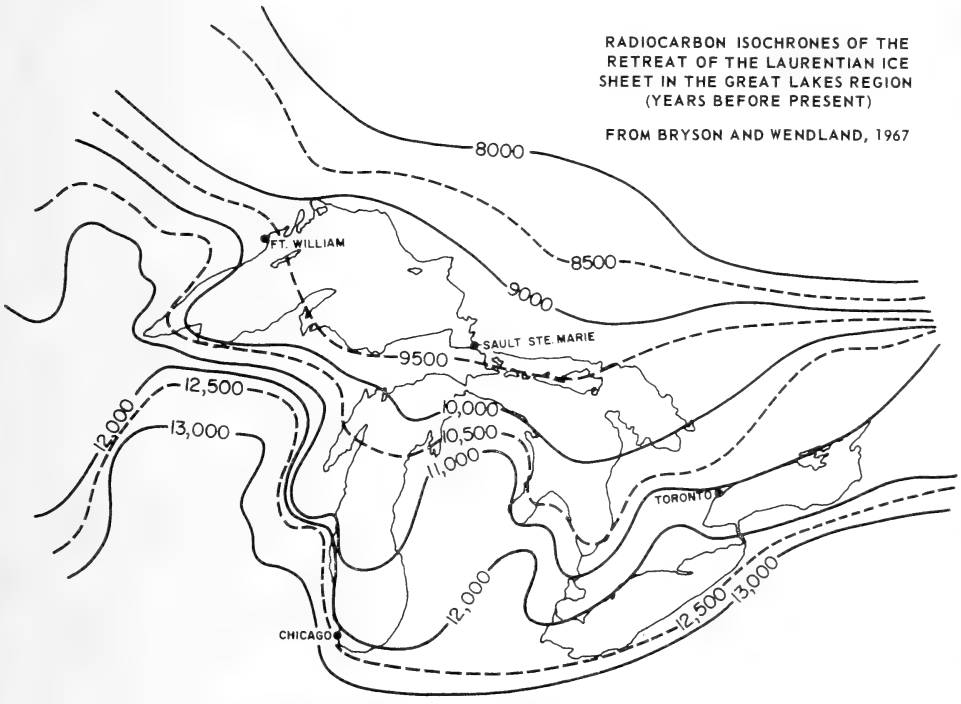


FIGURE 1 Radiocarbon isochrones of the retreat of the Laurentian ice sheet in the Great Lakes region.

Postglacial and Historical — Figure 1, showing radiocarbon isochrones of the retreat of the Laurentian ice sheet in the Great Lakes region, has been adapted from Bryson and Wendland (4). From this it can be seen that the ice retreated from the Great Lakes area between 13,000 and 8,000 years ago. The period between 5600 and 2500 B.C. is known as the Climatic Optimum, when over many centuries temperatures in this part of the country averaged about four degrees warmer than they do now. Studies of this period reveal the first evidence of farming in Europe. After 2500 B.C. generally warm and dry conditions prevailed and, finally, by 1000 B.C., Asiatic droughts were such that great migrations took place into Europe. For 500 years before the Christian era there was a general deterioration of climate with cool moist conditions aiding in the downfall of the civilization of the day.

As might be expected we have a much better knowledge of climatic details over the past 2,000 years than for earlier periods. In general, conditions improved up to A.D. 1200. The period from A.D. 900 to 1200, which might be called the Viking period, was relatively warm; at this time the coasts of Iceland and Greenland were free of ice and agriculture was carried on in Greenland. After A.D. 1200 there were generally worsening temperature conditions culminating in what is known as the Little Ice Age from 1650 to 1750. The year 1680 was known as the year of the Great Frost in England, and Iceland's climate deteriorated to the extent that authorities considered whether or not the island should be evacuated. Agricultural conditions in the early 18th century were very poor in Scotland and Scandinavia. It is always in such agriculturally marginal climates that economic difficulties appear first during times of deteriorating climate.

Secular or Modern — A study of more than 200 years of data from several European cities reveals that the warming trend which ended the Little Ice Age began early in the 19th century. The availability of instrumental data certainly facilitates the study of climatic change, but several difficulties are commonly encountered (5). The use of faulty and erroneous data can lead only to faulty and erroneous results. In general, it can be stated that continuous, homogeneous data are required — data free from faults or breaks due to instrumental difficulties, changes in exposure, or changes in methods of observation, each of which may give rise to errors of the same order as the changes being sought. Since climatologists cannot always be sure of the continuity and homogeneity of data, regional averages are frequently used combining data from several stations, rather than using data from a single station. In this way the effect of possible inhomogeneous data is minimized. Some of the longest temperature series are Manley's in central England, dating back to 1698, and Labrin's in Holland, from 1706. In America, a New Haven record dates back to 1780, while Toronto's record, which began in 1840, is the oldest fairly homogeneous one in this country. The Toronto series must be called "fairly homogeneous" because, although the observing site has been moved only three times in 130 years, and no more than a mile or so in distance, the population of the surrounding area has increased from a few thousand to two million people. With such a change in environment the data cannot be completely homogeneous.

There are now sufficient data to allow a study of the secular temperature change on a world-wide basis over the past 100 years or so. Mitchell (16) has shown that world temperatures increased by about eight tenths of a degree from 1880 to 1940, but have subsequently decreased a little. Over the same period there was a decrease and then an increase in tropical rainfall.

Toronto Data

Annual values of temperature and precipitation in Toronto for each year from 1840 to 1967 are shown in Figure 2. (7). The scatter of annual values in both

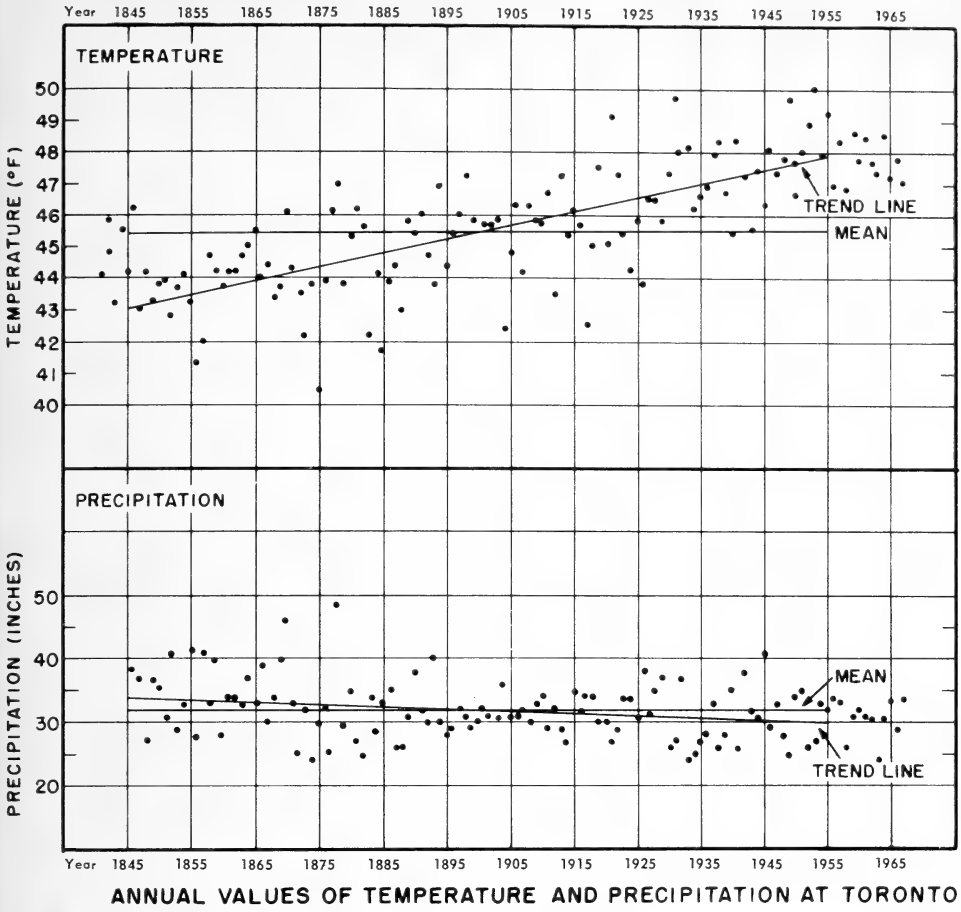
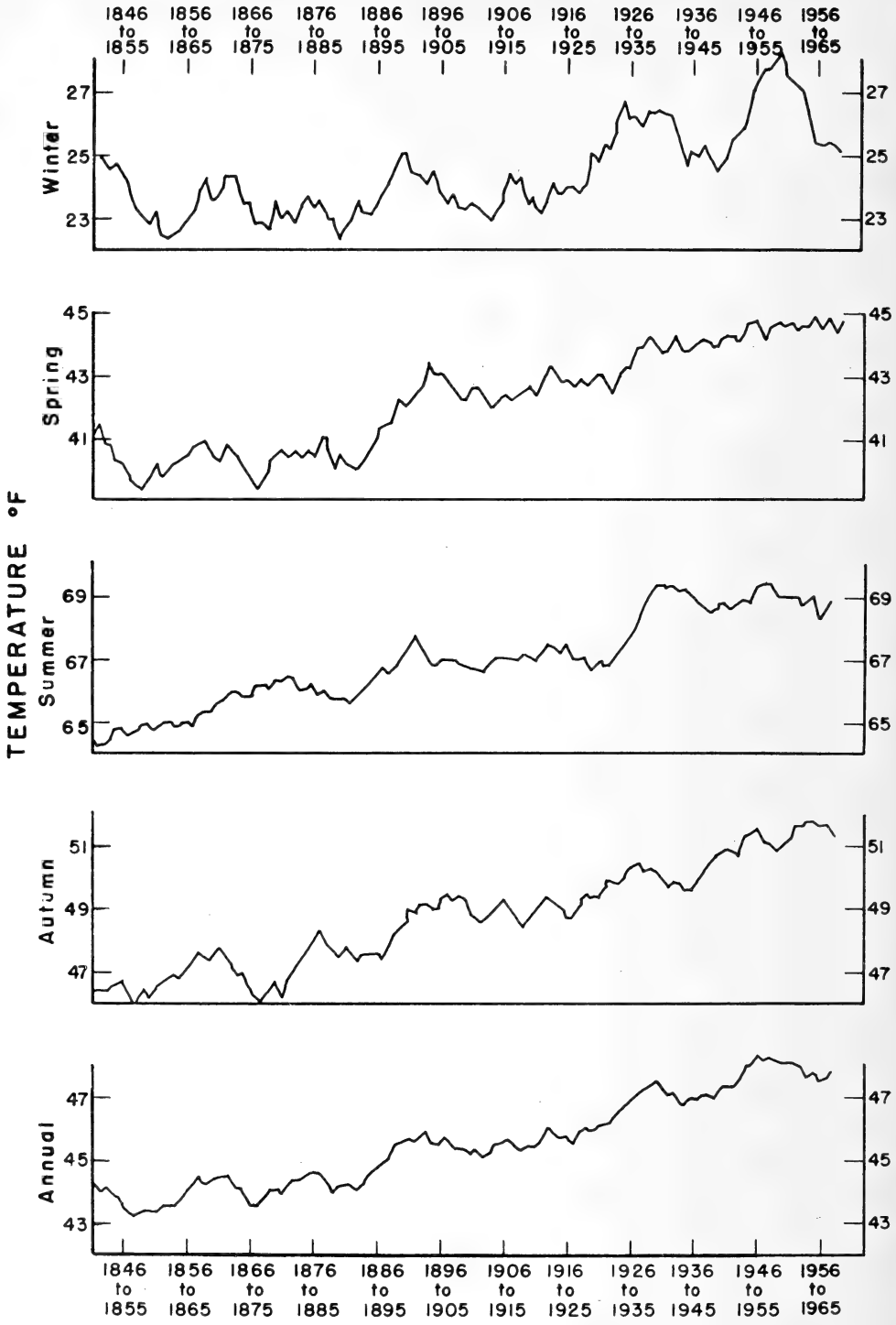


FIGURE 2

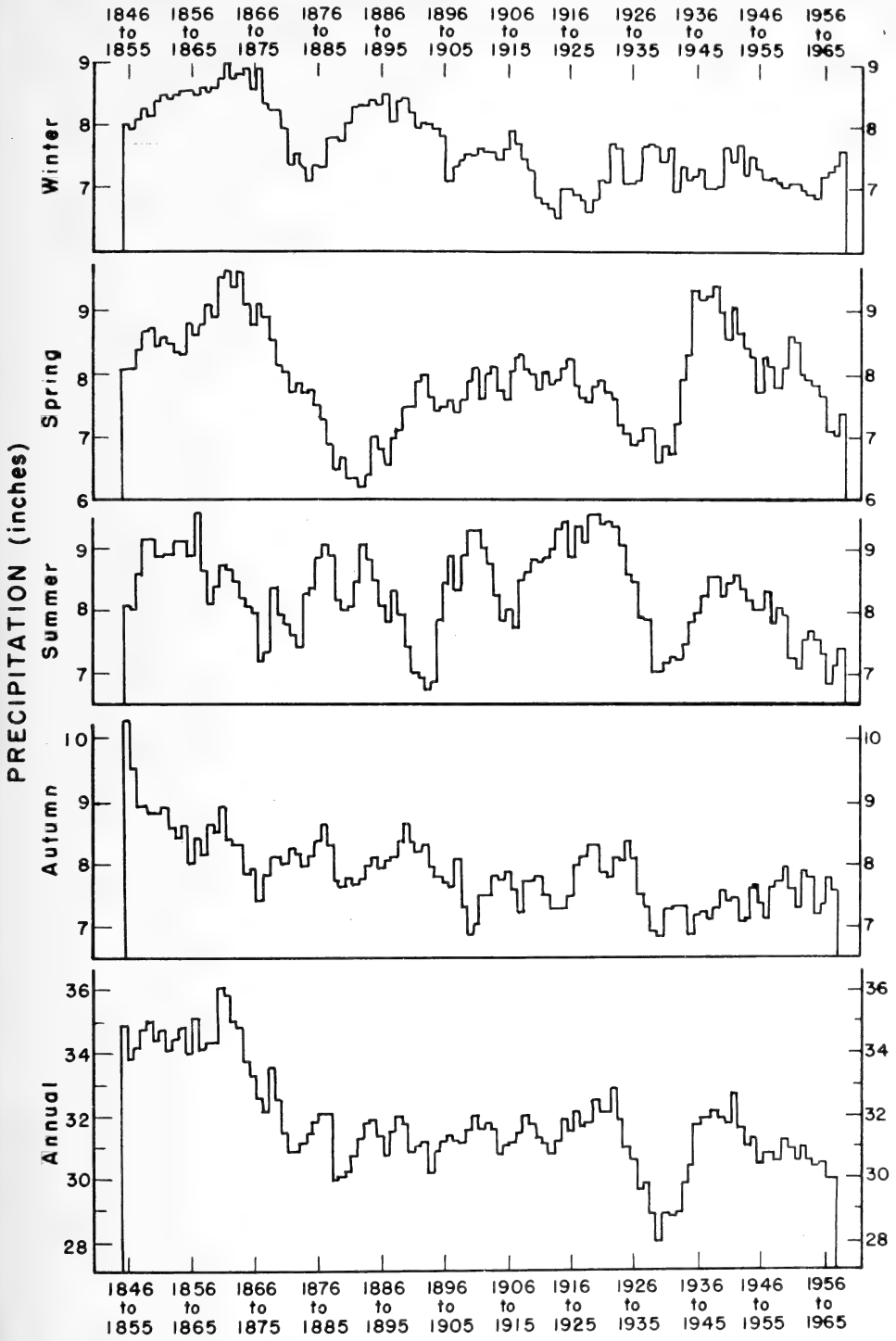
diagrams is fairly significant; although a mean trend line from 1845 to 1955 is shown, any thoughts that the climate has been progressively deteriorating or ameliorating should be dispelled by this figure. There has been a significant change, however, in the past hundred years — annual temperatures from 1955 to 1965 were generally in the 47° to 49° range, while a hundred years ago they were in the 43° to 45° range. The highest value in the series occurred in 1953, and the lowest in 1875. There is even less trend in annual precipitation, and any value in the series from the 1960's would not look out of place in the 1840's.

With the availability of a century-long time series of homogeneous climatic data, there are several ways to examine for trends, persistence, periodic or aperiodic fluctuations, etc. A popular and easy method has been to use moving means. Statisticians point out however, that with this method it is possible to introduce false cycles and other generally erroneous impressions (5). Another method that statisticians advise against is the use of residual mass curves. An efficient reliable method coming into use is power spectrum analysis. Some preliminary investigations on Toronto data have been undertaken and the computer results agree with those from earlier clerical studies (8).



TEN YEAR MOVING MEANS OF TEMPERATURE AT TORONTO

FIGURE 3



TEN YEAR MOVING MEANS OF PRECIPITATION AT TORONTO

FIGURE 4

Realizing both the shortcomings of the data and the method of analysis, the 10-year moving means of temperature and precipitation in Toronto over the period 1840 through 1967 are shown in Figures 3 and 4. The means are credited in each instance to the final year of each decade. It can easily be seen that the trend in temperature is towards warmer conditions in each season of the year — an increase of about 4 to 5 degrees per century. Since the late 1950's however, there have been colder winter temperatures. The annual temperature curve reached its maximum during the 1946-55 decade and has decreased half a degree in the decade ending in 1965. When considering Toronto temperature data, however, the urban effect must be kept in mind. This effect now averages about 2 degrees (7), so that annual temperatures in Ontario outside of the Toronto urban area now probably average only about 2 degrees higher than they did in the 1850's, and in winter, recent temperatures have been very little higher than they were 100 years ago.

From day to day and from year to year there is much more variation in precipitation than in temperature, but there does not appear to be much trend in precipitation over the past century at Toronto. There was higher precipitation from the beginning of observations until about 1880, but for the past 80 years, except for a very dry spell during the 1930's, precipitation has averaged in the 31- to 32-inch range. Spring and summer precipitation has been lighter in the past decade, however, so that the annual totals are averaging less than at any previous time, except in the 1930's, and briefly in the 1880's. It has been calculated that the mean annual precipitation over eight counties of Ontario decreased by about one inch from a 20- to 30-year period just before 1900 to the recent 1921 to 1950 period (7). The year-to-year fluctuations in precipitation are, however, so great that long-term trends in Ontario values are difficult to identify.

Great Lakes Region Data

Some interesting studies dealing with climatic change in the general area of the Great Lakes have been published recently in the United States. Landsberg (9) compared temperatures over a 25-year period from 1906 to 1930 against those from 1931 to 1955 and found that temperatures in the general Great Lakes area have increased by about one and a half degrees, an anomaly not exceeded anywhere else in the United States. In both winter and summer the increase was about 2 degrees, with smaller increases in the spring and fall. A similar study of precipitation data revealed that there was slightly more precipitation during the second period, but the variation was not statistically significant. Wahl (10) has published a comparison of the climate of eastern United States during the 1830's, with current normals. He concluded that the climate at that time was somewhat more severe than that which was normal in the first half of this century. He also pointed out that an increase in mean monthly averages of about 4 degrees is equivalent to a displacement northward of the isotherms by about 4 degrees latitude or by 250 to 300 miles. These are significant facts to consider when thinking of the effect of climatic change on plants, animals, insects and human beings.

Decadal means of annual temperatures for stations on the Canadian side of the Great Lakes from Winnipeg to Toronto are shown in Figure 5. Each decadal mean is credited to the midpoint of its decade. In the Lake Superior area temperatures during the past decade averaged about the same as they did at the turn of the century, although averages were higher during the intervening 40 or so years. Northern Ontario, as represented by data from the Lakehead and White River, was relatively colder from 1907 to 1927 than regions further west or further south. At both Beatrice (Muskoka) and Toronto, the relatively warm decade from 1948 to 1957 stands out. The increasing urban effect in Toronto is noticeable since the turn of the century, and in the current decade the temperature has fallen less

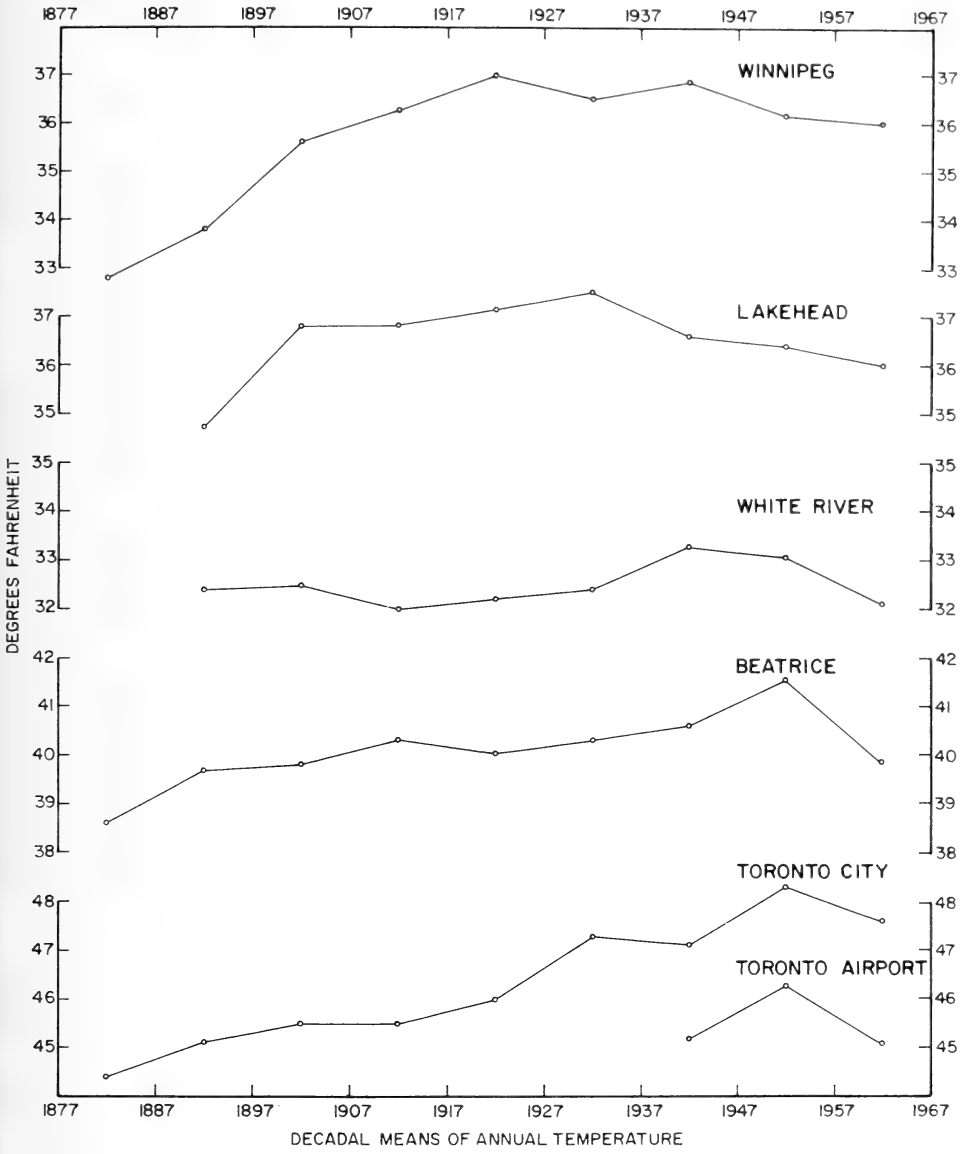


FIGURE 5 Decadal means of annual temperature at Canadian stations in the Great Lakes region.

than one degree from the previous decade, compared to more than one degree at Toronto Airport, just outside of the urban area. Inspection of these curves supports the conclusion that the warm period which peaked in the 1940's in the west, and in the early 1950's in the east, is over.

Possible Periodicities

By using a 12-month moving mean of monthly temperature or precipitation data, compensation is made for the annual variation. If such data are plotted and analyzed, a fairly smooth curve might be expected to result, but in using this type

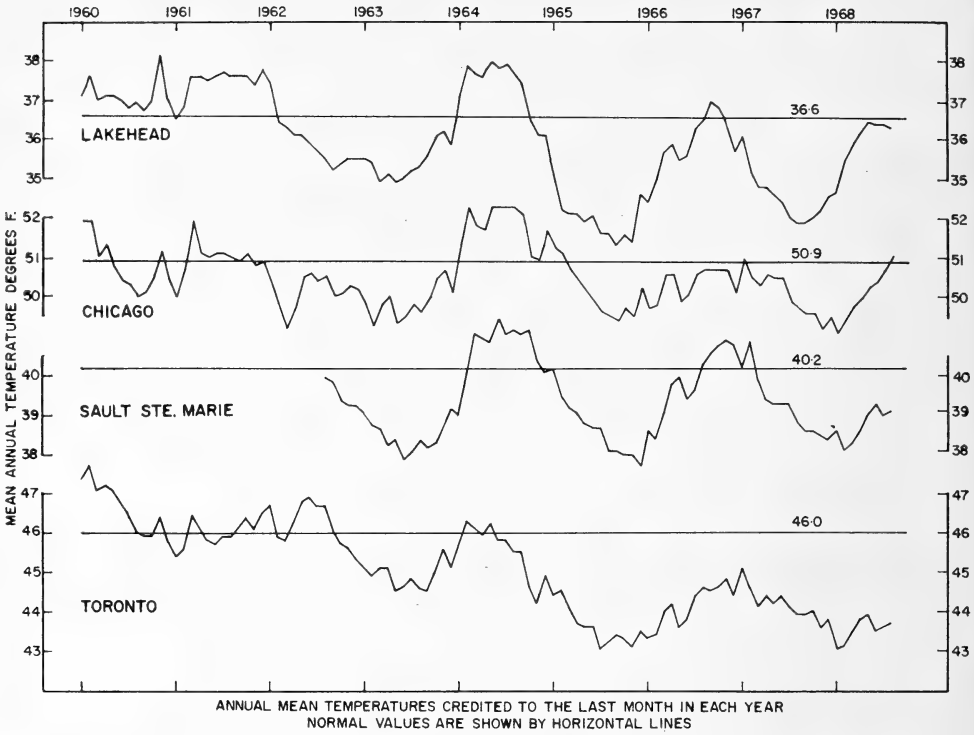


FIGURE 6 Twelve-month moving mean temperatures at stations in the Great Lakes region.

of 12-month mean it is surprising to note that a cyclical variation persists. Figure 6 shows the annual mean temperature at four Great Lakes stations credited to the last month in each year. At all stations the crests of recent cycles were reached in the spring of 1964, and again in the fall of 1966, while troughs occurred throughout the Great Lakes region in the fall of 1965, and again in the fall of 1967. From an analysis of 140 years of Toronto temperature and precipitation data it has been found that cycles persist in both temperature and precipitation data. Spectral analyses reveal an apparent mean 26-month oscillation in the temperature series, which is almost statistically significant (8), and the suggestion of a 32-month oscillation in the precipitation series (8). These relationships are not, however, good enough to allow quantitative forecasts of climatic fluctuations and change.

Summary

Scientists in many disciplines are now actively interested in climatic change. It can be easily shown that changes have occurred and there are many rival theories regarding the prime and supplementary causes. The Laurentian ice sheet retreated from the Great Lakes area between 13,000 and 8,000 years ago, and a Climatic Optimum, when temperatures were slightly higher than today, existed about 3000 B.C. A minor Climatic Optimum period existed for four centuries prior to A.D. 1200, followed by a setback in the 17th and 18th centuries. The 19th century warming trend seems to have peaked late in the first half of the 20th century. Weak periodicities may exist in the temperature and precipitation data series from Great Lakes stations.

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A DISCUSSION OF DEGLACIATION AND THE BOREAL FOREST HISTORY IN THE NORTHERN GREAT LAKES REGION

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Introduction

The region considered in this study lies generally north of the Great Lakes, and includes most of southern Ontario bordered by Lakes Ontario, Erie and Huron.

The postglacial history of boreal forest in this region has a convenient and finite starting point, the last glaciation, when the continental ice sheet covered all of the Great Lakes area. Available evidence indicates that boreal forest species survived the glaciation south of the continental ice sheet and thence followed the retreating ice margin northward during deglaciation and subsequently occupied the present limits of the boreal forest region.

The objective of this report is to present evidence for and discuss the postglacial migration and history of boreal forest in the northern Great Lakes region on the basis of palynological and paleobotanical studies made, and in relation to glacial history of the same region.

In the past 15 years palynological studies have been made by the writer at nearly 100 different sites scattered throughout Ontario. Most of these studies were made in support of geochronological investigations and because of this emphasis some of the completeness of pollen diagrams and botanical detail had to be given second priority in cases where a regional pollen sequence had been already established. For example, the early phase of palynological studies in any particular new area consisted of compiling a standard pollen sequence for that area from several pollen diagrams which contained sufficient detail. The standard diagrams were then subdivided into pollenstratigraphic zones on the basis of regionally consistent and identifiable changes in one or more pollen graphs, such as a sharp decline in the abundance of spruce pollen or an increase in pine pollen, or a well-defined maximum in the hemlock graph. In subsequent studies the sediments most closely associated with a certain geological feature (e.g. an end moraine, a drainage channel or a former shoreline scarp) were studied, and the partial pollen sequences so obtained were correlated with the standard diagram for estimating the relative age of the feature, or for placing a certain event in the regional chronological sequence. The palynological studies have been supported frequently by radiocarbon dates and thus absolute ages have been obtained for palynological marker horizons, such as the pollen zone boundaries.

The radiocarbon control in effect allows the subsequent use of pollen diagrams in actual dating of geological features or postglacial events in terms of absolute age and hence, changes in climate and vegetation as inferred from palynological evidence can be correlated both as biostratigraphic and as time-stratigraphic units.

The Multidisciplinary Approach

A study concerned with the history of vegetation, such as the boreal forest, involves a reconstruction of past environments comprising two main components — the biological and the physical. In the former category paleobotanical evidence (including palynology) is of primary importance, but supporting evidence from studies of vertebrate fossils and insect and molluscan faunas, for example, provide additional and helpful information. Glacial and postglacial history, including the geochronology, stratigraphy, areal extent and texture of surficial deposits as well as physiography, make up the physical component of environment together with climatology and hydrology.

The important point to realize is that the environment collectively is an integrated system in which the biological and physical components form a balanced whole, the ecosystem. However, this is not a rigidly fixed system but rather one which is capable of change and adjustment in accordance with the relative importance of its component parts. In this way a change in climate is compensated for by corresponding changes in the composition of vegetation, or a shift of the limits and ranges of vegetation regions, or certain species.

Because of the interdependence of the different environmental components it is apparent that an adequate knowledge of the whole system is difficult to obtain without a satisfactory understanding of the individual parts. On the basis of this reasoning the writer feels that the multidisciplinary approach in paleoecology and reconstruction of postglacial environments will be substantially more successful than inferences made from studies in any single discipline.

The integration of geological and botanical information in this report attempts to illustrate the usefulness and necessity of a multidisciplinary approach towards reconstructing the postglacial history of boreal forest in the northern Great Lakes region.

It is both necessary and commendable that multidisciplinary symposia be held from time to time in order to evaluate existing knowledge and integrate information from different sources bearing on a common problem, such as the history and characteristics of the boreal forest. The exchange of experience and data will benefit all participants and will provide a starting point for the planning and coordination of further studies required for clarifying special problems.

The Episode of Deglaciation

The waning of the Laurentide ice sheet and deglaciation of the region considered is of particular interest because it was during this time that boreal forest species migrated into the areas uncovered by ice and became established for a period of time. Further improvement of climate allowed other, more temperate species to invade the previously glaciated areas and gradually the new invaders crowded out and replaced the boreal forest which had become established. The sequence of these botanical events was intimately related to and at least in part dependent on the progress of deglaciation. For example, the complex succession of ice-dammed lakes acted both as a barrier to migration of some species and at the same time aided the dispersal of others adapted to lake shore habitats and alluvial environment. It is important to realize that during deglaciation the levels, limits and outlets of glacial lakes changed rapidly and were similarly affected by the isostatic and differential crustal uplift following melting of the continental ice sheet.

Several reports have been published on the subject of deglaciation and the successions of glacial lakes in the different basins of the Great Lakes (Boissoneau, 1966 and 1968; Chapman and Putnam, 1966; Hough, 1958 and 1963; Karrow, 1963; Lewis *et al.*, 1966; Prest, 1957 and 1963; Zoltai, 1965). Recently a considerably more detailed and more comprehensive compilation of glacial and postglacial history of the Great Lakes region has been made by V. K. Prest of the Geological Survey of Canada. This report (in press) incorporates new evidence from geological studies and radiocarbon dating and includes several revisions of the earlier accepted chronologies.

This new geological information has indicated, for example, that boreal forest species which had occupied southwestern Ontario in late-glacial time could migrate northward on Bruce Peninsula and to Manitoulin Island without crossing any water barriers because for a period of time the drainage from Lake Huron to Georgian Bay flowed eastward along a channel north of Manitoulin Island as indicated by recent studies made by C. F. M. Lewis of the Geological Survey of Canada (personal communication). At a somewhat later date this drainage shifted to the area between Manitoulin and Bruce Peninsula and species which had reached Manitoulin could migrate north again without crossing any significant water barriers. Similar sequences of geological events in other parts of the region discussed may help to explain certain present distribution patterns of plant and animal species, as well as the dispersal of biota in the past, such as the boreal forest.

The Problem of Identification

Contributions presented at recent symposia, and other published reports (Baldwin, 1958; Rowe, 1959), have adequately described the present composition and subdivisions of the boreal forest. These descriptions clearly identify and distinguish the boreal forest from other phytogeographic entities such as the Great Lakes — St. Lawrence forest region. The problem of identification becomes increasingly difficult, however, when the characteristics of a particular type of vegetation have to be assembled from palynological and limited paleobotanical data for late-glacial and postglacial time. It is quite impossible to compile a complete list

of species on the basis of fossil evidence, because a relatively large number of species will not be found in any of the fossil-bearing deposits. The jig-saw puzzle of reconstructing past types of vegetation will have always some pieces missing. It is even more difficult to attempt an estimate for the relative abundance of individual species in the composition of, for example, late-glacial vegetation. This problem was amply illustrated by Martin (1959) in his discussion related to the existence of probable tundra vegetation in the southern Great Lakes region during the Wisconsin glaciation.

In view of the numerous difficulties and uncertainties it might be questioned whether a valid reconstruction of past vegetation is possible at all with any assurance. However, palynologists have been remarkably and singularly brave for years and have described postglacial forests in astonishing detail. At the same time they have had, nevertheless, second thoughts about their enthusiasm and intuitional powers. Support for interpretation of fossil pollen and spore assemblages has been sought in studies of atmospheric pollen dispersal and recent pollen deposition in surface sediment samples. Results from these studies have helped to sharpen the focus on the relationship between local and regional vegetation and the pollen spectra produced by them. In the last few years many more studies have been made in this field of palynology and it has been confirmed that different vegetation regions can be identified, indeed, on the basis of their respective pollen assemblages (Davis, 1967). It has been also demonstrated that a more precise interpretation can be made when palynological evidence is coupled with identification of plant macrofossils (Watts and Winter, 1966). Modern data processing methods make it possible to compare and correlate any fossil assemblage with some possible modern equivalent obtained from surface samples. The available surface sample coverage, however, is still rather inadequate and most areas in Canada have yet to be covered by surface sample investigations.

It can be concluded from the available evidence that reconstruction of past types of vegetation is possible on the basis of palynological studies, provided that the limitations involved are clearly understood and properly considered.

The Late-glacial Boreal Forest

Parts of southwestern Ontario became free of ice cover more than 12,000 years ago as indicated by radiocarbon dating. There is little evidence as yet of the initial tundra vegetation assumed to have followed the retreating ice margin and in advance of the subsequent invasion by the boreal forest (Terasmae, 1967). It is quite possible, however, that further studies will turn up evidence bearing on the problem of this early pioneer vegetation.

As the deglaciation proceeded northward, southern Ontario was invaded by boreal forest in which spruce, jack pine, birch, balsam fir, alder and willows were prominent components, together with a variety of non-arboreal (NAP) species. It is quite certain that *Populus* (aspen) species and *Larix* (tamarack) were also well represented, but because of poor preservation of their pollen little palynological evidence of them has remained in the sedimentary record.

Pollen diagrams from the Harrowsmith bog (Figure 1), the Victoria Road bog (Figure 2) and the Grieff Kettle bog (*in* Karrow, 1963) have been used as examples of pollen sequences for southern Ontario. The Harrowsmith bog is about 20 miles northwest of Kingston (44°25′ N Lat, 76°42′ W Long) and a sample of basal organic sediment was dated at 10,390± 160 years B.P., before present (GSC-270). The Victoria Road bog is about 3.6 miles northeast of Kirkfield (44°37′ N Lat, 78°57′ W Long) and basal organic sediment was dated at 9,600± 190 years B.P. (GSC-132). The Grieff Kettle bog is 8 miles northeast of Galt (43°25′ N Lat, 80°11′ W Long) and basal organic sediment was dated at 11,950± 350 years B.P. (1/GSC/-29).

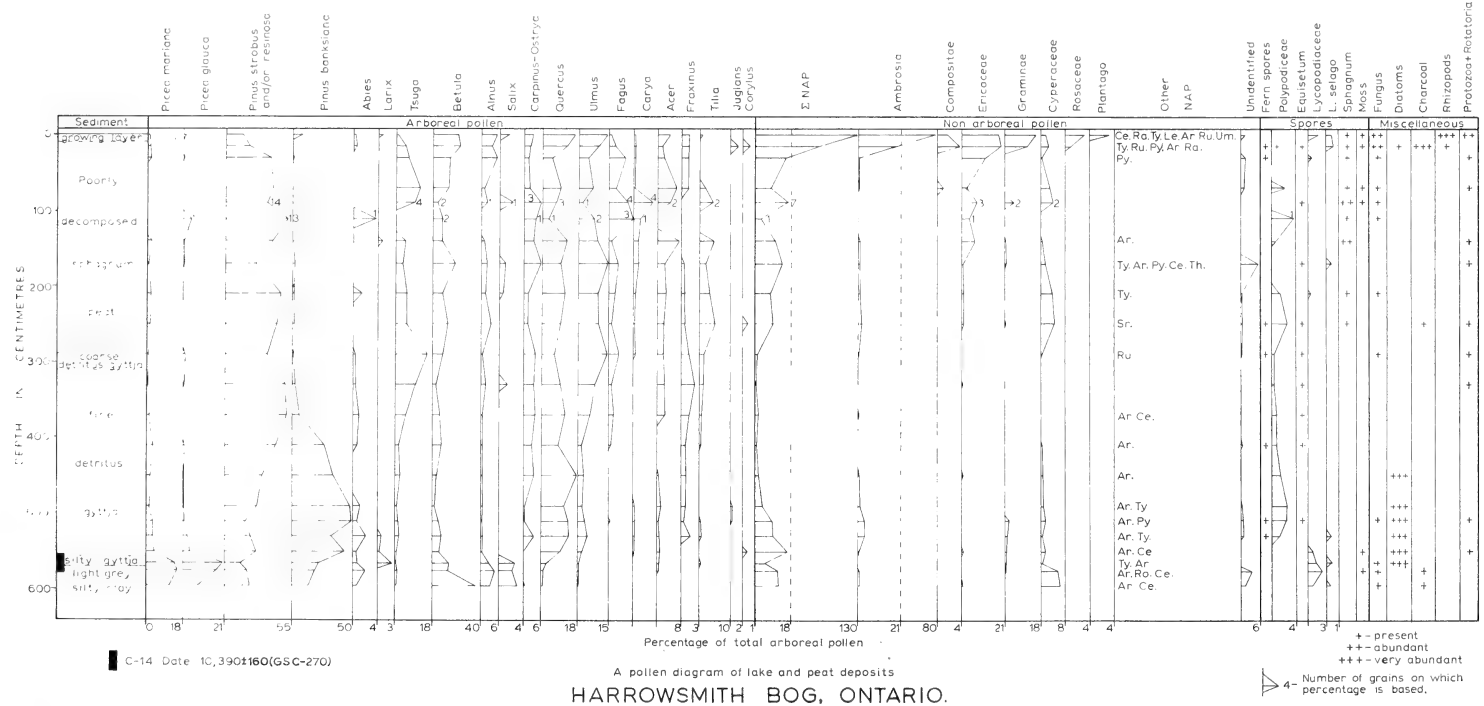
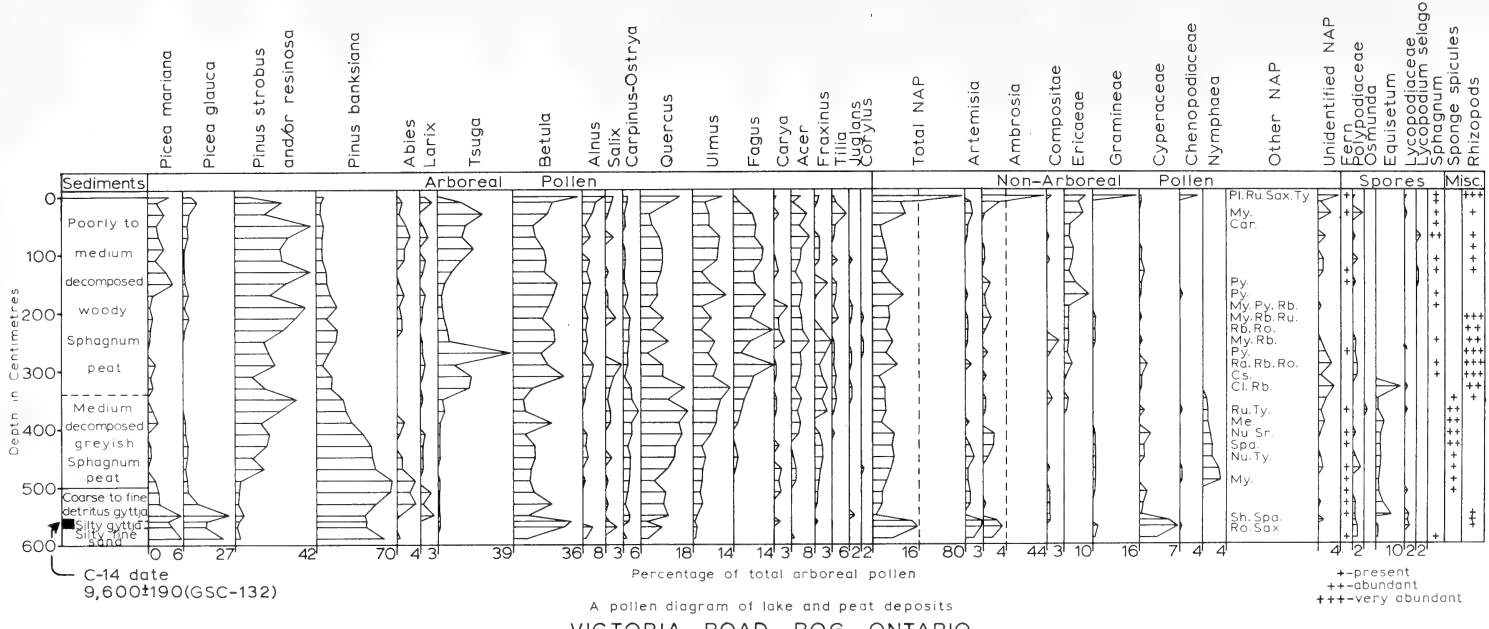


FIGURE 1. Pollen diagram of Harrowsmith bog, Ontario



A pollen diagram of lake and peat deposits

VICTORIA ROAD BOG, ONTARIO

FIGURE 2. Pollen diagram of Victoria Road bog, Ontario

The information on non-arboreal vegetation is rather insufficient, but a comparison with pollen assemblages from surface samples in the modern boreal forest indicates that the late-glacial forest was probably more open because of the greater abundance of non-arboreal pollen in the late-glacial assemblages. The extent of muskeg, now a characteristic feature of the boreal forest, in the late-glacial landscape is not known with sufficient certainty. Also little known is the extent, or even the presence, of permafrost in the same episode in southern Ontario.

In view of the several unknown factors it is difficult to visualize what the late-glacial boreal forest really looked like. The present knowledge of processes relating to the dynamics and development of boreal forest suggest that ample time was available, under suitable climatic conditions, for the establishment of a muskeg cover in poorly-drained areas such as former glacial lake bottoms. Palynological studies coupled with radiocarbon dating indicate that the boreal forest prevailed in southern Ontario for about 3,000 years; until about 9,000 years ago it was gradually replaced by a different forest cover in which the pine species gained prominence.

In the northern Great Lakes region the boreal forest became established sometime between 10,000 and 9,000 years ago, as these areas were deglaciated. It is apparent that the late-glacial episode began earlier and hence, lasted longer, in southern Ontario than in the region north of Lake Huron and Superior. For example, at sites in the North Bay area and north of Lake Huron the oldest postglacial organic sediments have yielded radiocarbon ages as follows:

The North Bay bog; at ca. 8 miles north of North Bay (46°27′ N Lat, 79° 28′ W Long) — 9,570 ± 150 years B.P. (S-100).

Wood Lake; at 3.5 miles south of Espanola (46°12.9′ — N Lat, 8°44.1′ W Long) — 9,620 ± 250 years B.P. (GSC-606).

Blind River bog; at 2 miles north of Blind River (46°12.8′ N Lat, 82°56.3′ W Long) — 8,760 ± 250 years B.P. (GSC-514).

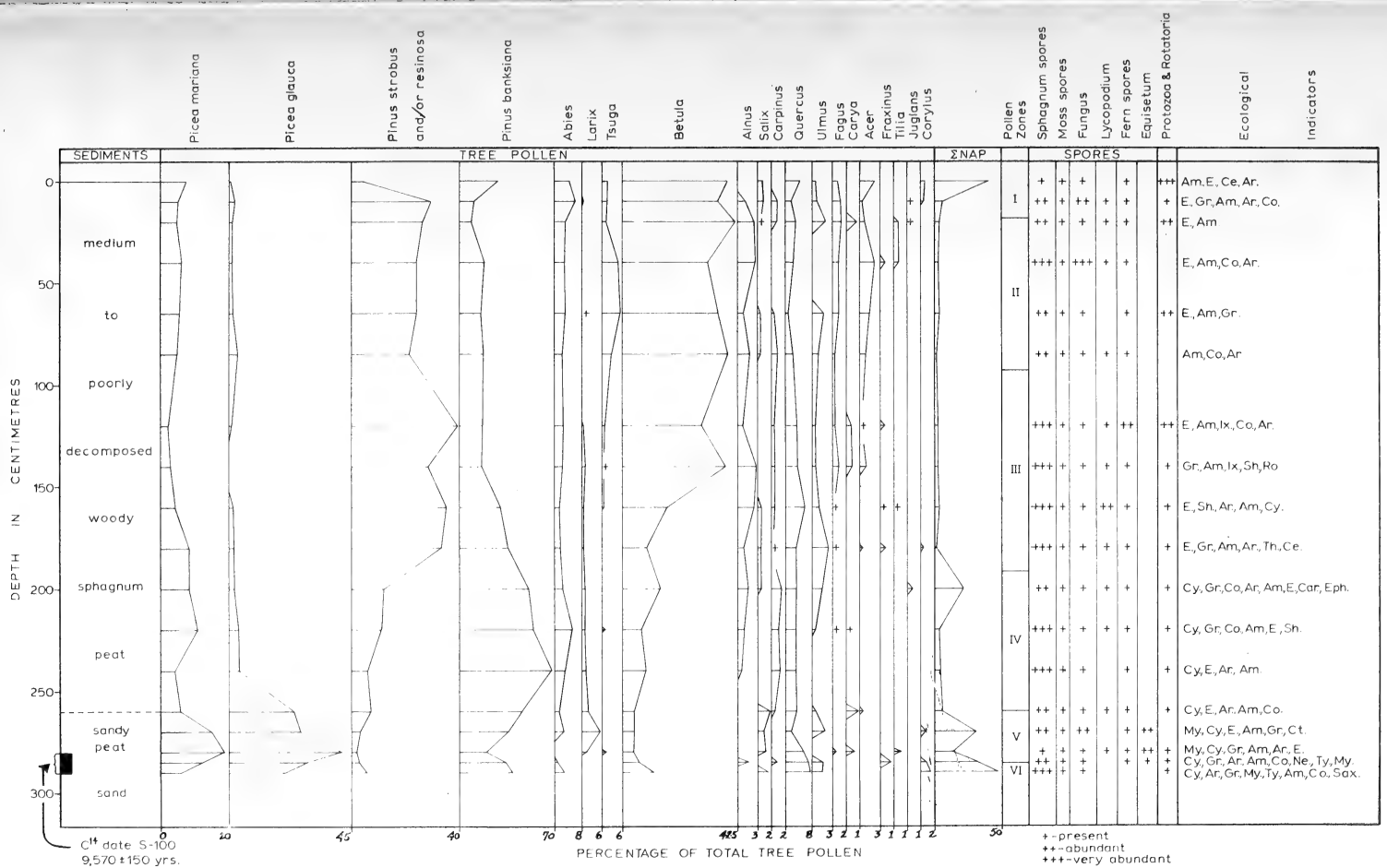
It must be pointed out that all these radiocarbon dates are minimum ages for the beginning of deposition of organic deposits in lakes and bogs. By this time boreal forest had already become well established in the area.

The end of the late-glacial boreal forest episode in southern Ontario very nearly coincided with a similar change in the area north of Lake Huron about 9,000 to 8,500 years ago when the Great Lakes-St. Lawrence forest became established there (Terasmae, 1967).

The Postglacial Boreal Forest

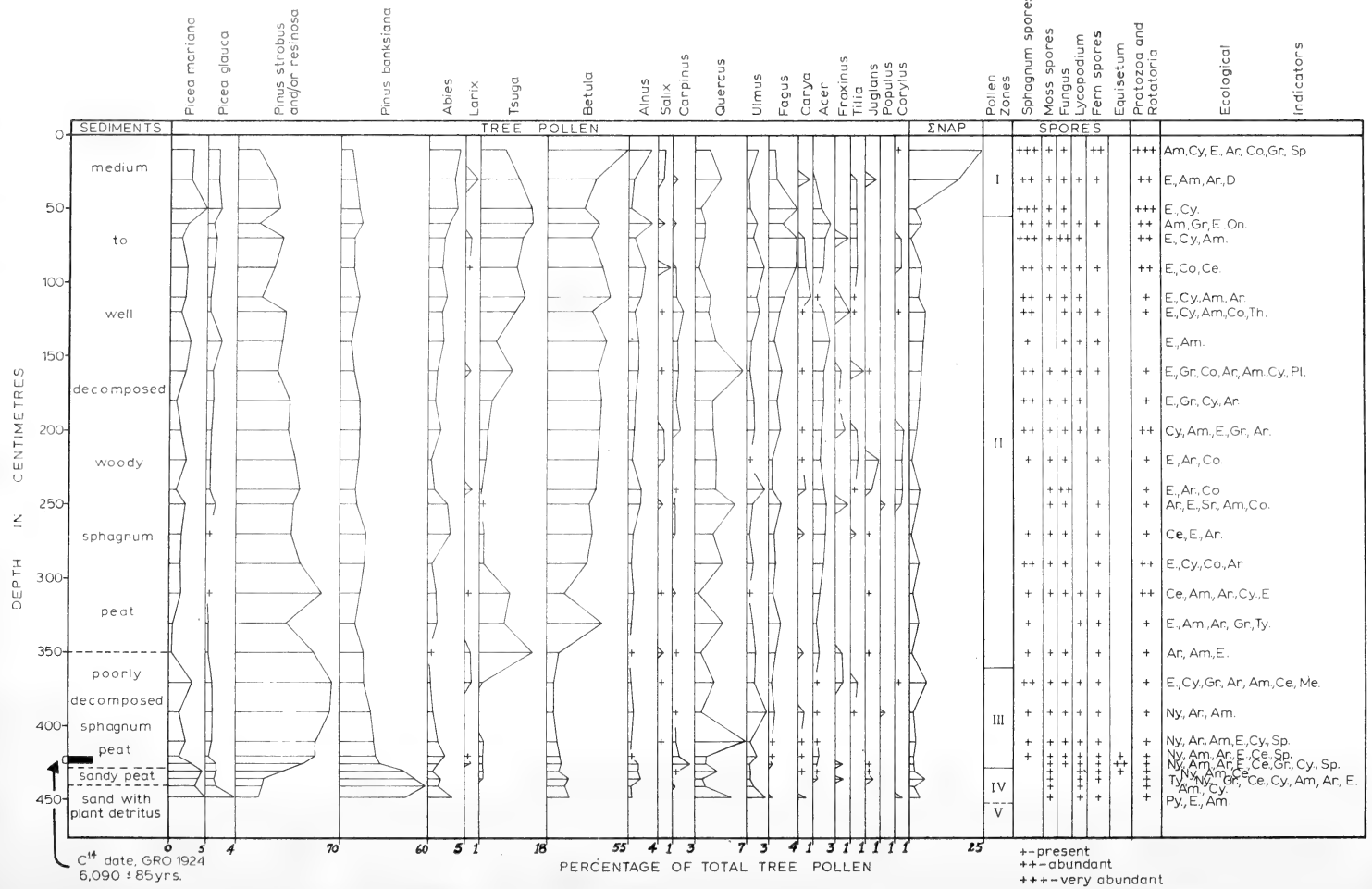
By the time of deglaciation in northern Ontario, perhaps shortly before 8,000 years ago, the boreal forest episode in southern Ontario had already ended and hence, there is little justification for speaking of postglacial boreal forest in this southern region.

In the area north of Lake Huron and east of Lake Superior the early postglacial boreal forest was invaded and replaced by the Great Lakes-St. Lawrence forest which has occupied that region ever since. Pollen diagrams from the North Bay area (Figures 3 and 4), and from the Gatineau Valley (Potzger and Courtemanche, 1956), illustrate this change. The Alderdale bog (Figure 4) is southeast of North Bay and about 4.5 miles southwest of Fossmill (46°3′ N Lat, 79°12′ W Long). A radiocarbon date on basal peat from that bog, 6,090 ± 85 years B.P. (GRO-1924), appears to be too young on the basis of palynological correlation which on the strength of many other studies supported by isotope dating has proved to be quite reliable and accurate.



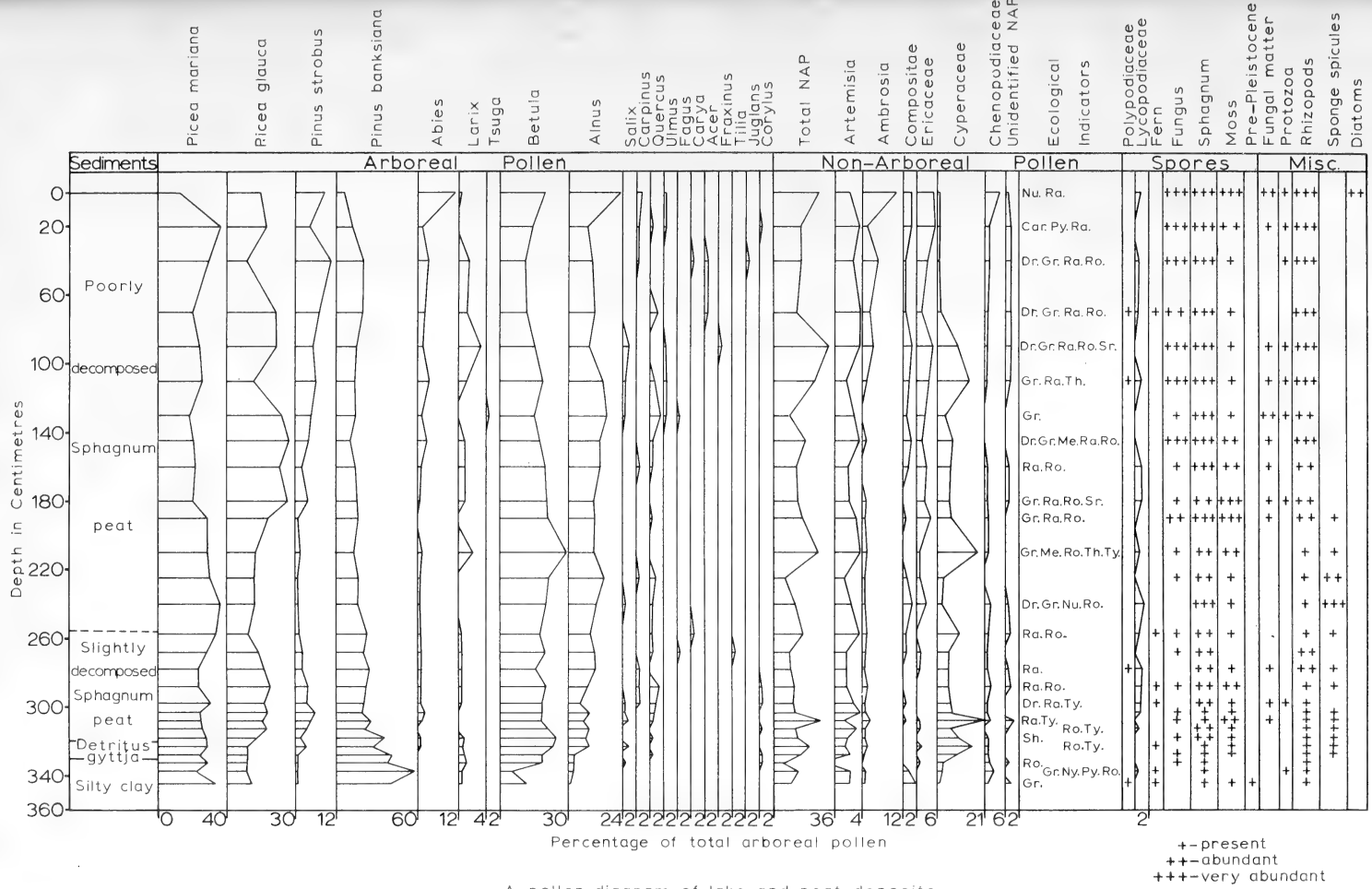
NORTH BAY BOG
NORTH BAY, ONTARIO

FIGURE 3. Pollen diagram of North Bay bog, Ontario



ALDERDALE BOG
ALDERDALE, ONTARIO

Figure 4. Pollen diagram of Alderdale bog, Ontario



A pollen diagram of lake and peat deposits

ATTAWAPISKAT LAKE, ONTARIO

FIGURE 5. Pollen diagram of Attawapiskat Lake, Ontario

North of Lake Superior and throughout northern Ontario the boreal forest, once established, has remained relatively unchanged in its overall characteristics (Terasmae, 1967). The pollen diagram from Attawapiskat Lake (Figure 5), some 200 miles north of Lake Superior, shows the general postglacial pollen sequence for that region.

The early postglacial boreal forest in northern Ontario differed from that which occupied the same region during the rest of postglacial time, because of both geological and climatological factors. For example, in the Hudson Bay and James Bay lowland the general slope of the land to the east and northeast was greater than now, because the isostatic rebound from glacial loading which had depressed the crust in the Hudson Bay region was just beginning. This condition provided for better drainage at that time. In addition, there is evidence to indicate that climatic conditions were probably both warmer and maybe drier at the same time, between 7,000 and 5,000 years ago. The subsequent trend towards increased moisture regime and later a change to cooler climatic conditions some 3,000 or 2,500 years ago certainly favored expansion of muskeg. This climatic trend was, furthermore, accompanied by isostatic uplift which caused a decrease of slope towards Hudson Bay and a corresponding deterioration of drainage.

Evidence for a warmer episode (the hypsithermal) is provided by paleobotanical studies which have indicated that, for example, the white pine range extended north of its present limit by some 60 miles or more just prior to 5,000 years ago, according to radiocarbon dates on buried white pine fossils at Val St. Gilles, Quebec. Both peat stratigraphic studies and radiocarbon dating have indicated that considerable expansion of muskeg occurred in the northern Ontario Clay Belt in late postglacial time.

The 'Wet Blanket' Effect

Some ten years ago the writer had the opportunity of gaining firsthand knowledge from outstanding experts in matters concerning many aspects of the northern Ontario boreal forest. These discussions were held in the appropriate environment in the field, complete with blackflies and mosquitoes. The masters of boreal forest whom I consulted were W. K. W. Baldwin, G. A. Hills, V. van Vlymen, D. W. MacLean, A. B. Vincent, and several others who had long-time experience gained from studies of the boreal forest. Further enlightenment on the boreal forest problems was provided by the international expertise at the time of a two-week field excursion in connection with the International Botanical Congress, held at Montreal in 1959.

The term 'wet blanket' was suggested by Baldwin in a discussion on the extensive black spruce muskeg for which the term seemed singularly fitting and descriptive. Everyone who has traversed the northern Ontario Clay Belt, or the Hudson Bay lowland, will agree that in these regions muskeg and water are in evidence everywhere. This wet blanket seems to be a self-perpetuating system and can exist on both clay, and sand and gravel substrates. When fires destroy the blanket it is regenerated in a few tens of years. The blanket is commonly acid although the substrate may be strongly calcareous. It is difficult to explain the existence of this wet blanket without accepting the climatic control hypothesis. Under somewhat warmer and drier conditions this wet blanket would literally dry up, and consequently would be easily destroyed by fires or an increased rate of decomposition, and most likely the self-regenerating power of the system will diminish.

The reason for discussing the wet blanket effect in this paper is the pertinence that such condition may have had in the late-glacial boreal forest. In southern Ontario, for example, it is quite conceivable that such a wet blanket may

have developed during the late-glacial episode — there was certainly sufficient time available; in northern Ontario such a blanket can develop in less than 200 years. The extensive, flat glacial lake plains and clay-till plains may have been the best substrates for such a development. If in fact a wet blanket of muskeg did develop, it would have been a serious barrier for invasion and migration of species not tolerant of acid, waterlogged surface conditions. A climatic change to a warmer and drier region would have destroyed the wet blanket and relatively suddenly the whole region would have become available for more demanding species. Perhaps the rapid decrease of spruce and increase of pine in the pollen record signify such a change. One might venture a further speculation related to studies of the late-glacial extinction of mastodon in southern Ontario (Dreimanis, 1967). He suggested that mastodon was adapted and restricted to the spruce-dominated boreal forest on glacial lake plains and became extinct at a time when this forest type rather suddenly disappeared from southern Ontario and gave way to a mixed deciduous-coniferous forest between 9,000 and 10,000 years ago. It is interesting to note that all fossil mastodon remains in southern Ontario date in the 10,000- to 12,000-year range.

In conclusion it can be stated that although the studies made have outlined and clarified some of the aspects in the postglacial history of the boreal forest, many inferences in this paper are based on assumptions which are in need of further confirmation. Detailed palynological and paleobotanical studies at selected sites are required and will undoubtedly provide the necessary data for bringing the history of the boreal forest in Ontario into sharper focus.

Available knowledge, furthermore, indicates that a sufficiently accurate and detailed record of the past development of the boreal forest will make it possible to forecast future developments in the boreal forest environment and will enable us to evaluate the present forestry management practices against the natural processes active in this forest region.

Acknowledgments

The writer is indebted to the Geological Survey of Canada for support during a comprehensive investigation of which this study is a part, and particularly to his colleagues in the Division of Quaternary Research. The helpful criticism of many other colleagues offered through inspiring discussions is gratefully acknowledged and has been invaluable for the writing of this report.

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Abbreviations Used in Pollen Diagrams

Ar	*Artemisia*	Ne	*Nemopanthus*
Am	*Ambrosia*	Nu	*Nuphar*
Car	Caryophyllaceae	Ny	*Nymphaea*
Ce	Chenopodiaceae	On	Onagraceae
Cl	Campanulaceae	Pl	*Plantago*
Co	Compositae	Py	Polygonaceae
Cs	*Cornus*	Ra	Ranunculaceae
Ct	*Comptonia*	Rb	Rubiaceae
Cy	Cyperaceae	Ro	Rosaceae
D	Diatoms	Ru	*Rumex*
Dr	*Drosera*	Sax	Saxifragaceae
E	Ericaceae	Sh	*Shepherdia*
Eph	*Ephedra*	Sp	Sponge spicules
Gr	Gramineae	Spa	*Sparganium*
Ix	*Ilex*	Sr	*Sarracenia*
Le	Leguminosae	Th	*Thalictrum*
Me	*Menyanthes*	Ty	*Typha*
My	*Myriophyllum*	Um	Umbelliferae

INSECTS OF ONTARIO: GEOGRAPHICAL DISTRIBUTION AND POSTGLACIAL ORIGIN

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Introduction

Biogeography studies the patterns of geographical distribution of organisms, and tries to find the causes that have determined these patterns and to reconstruct the course of their evolution over time. It views present distributions as determined

partly by the constraints of the existing environment and partly by the persisting effects of past conditions and processes. Its subject matter therefore tends to be varied and complex, and may require consideration of earth history back to the earliest times.

In Ontario the problems of biogeography have been greatly simplified by the Wisconsin glaciation. So far as known this covered the whole area, extinguishing all life. The present biogeographic patterns of Ontario, therefore, have developed within the last 10,000 years or so. There has been little evolutionary change at the species level or higher taxonomic levels during this time. It is true that preglacial Ontario must have had a rich biota, with a long and interesting evolutionary history. Unfortunately, our direct knowledge of the insect component of this biota is infinitesimal, and such indirect deductions as we might make would be highly speculative and would shed little light on the composition of the present fauna. The questions of immediate interest therefore concern the main environmental zonations, their changes since the Pleistocene, the geographical sources of recolonization, and the movements, interactions and adaptations of species as they responded to the postglacial recovery of the environment and the accompanying changes in position and configuration of environmental zones. The problems are further simplified by the relatively simple and uniform physiography of the province, which has presented few major barriers to dispersal. The biota has consequently tended to develop in a unified way as the climate has changed.

This relative simplicity of problems should not be taken to mean that we have a full array of solutions, or even anything like the data required for more than the barest of outlines. A law which I ascribe to Dr. Jerry Powell of the University of California states that no systematic entomologist voluntarily works on insects that occur within 1,000 miles of his home laboratory. In spite of the concentration of entomologists in Ontario, we have a regrettably fragmentary knowledge of the distribution and variation of most species of insects in the province. Even in such a well-known group as Lepidoptera, both planned surveys over wide areas and intensive studies in supposedly well-investigated localities have revealed new and often unsuspected distributional information (Lafontaine, 1968; McGugan *et al.,* 1958; Prentice *et al.,* 1962, 1963, 1965; Riotte, 1959, 1961, 1962, 1967, 1967a). To be fair, we must admit that the incompleteness of our knowledge is the result not only of Powell's Law, but also of the large extent of the area, the absence of roads over large parts of it, and the fact that many of the species that occur in Ontario are widespread ones that show more interesting features of variation and distribution in other parts of their ranges. Then, too, the total of information that would be needed to characterize adequately the general and local occurrence and the spectrum of variability of a significant number of Ontario insects would certainly be beyond the assembled resources of the Canadian taxonomic community in the foreseeable future. Such information has not yet been compiled in an adequate way even for the much smaller, more densely populated and longer and more intensively studied area of the British Isles. If we add the dimensions of genetic and ecological analysis and of paleontological and paleoecological investigation that would be needed for an adequate understanding of the detailed biogeography, it is obvious that we can only scratch the surface of the subject with our present knowledge. Even so, there is little doubt that more systematic compilation of existing records, better definition of problems, and wider dissemination of information and of questions that need answering would make it possible to enlist a larger and more active group of both professional and amateur entomologists and naturalists to fill the lacunae. The initiative of the group centered at the Royal Ontario Museum is to be commended, and it should be followed at other centers.

In the present paper we shall briefly consider the existing ecological zones, various kinds of ranges of species within them and across them, and the sources

from which species appear to have entered them as they progressed from their late-glacial to their present positions. We shall be able to identify fast- and slow-moving species, narrowly specialized and broadly tolerant ones, and to discern distributional anomalies that seem to reflect that postglacial dispersal history. We shall seek examples of the minor sort of evolutionary development that can be expected from the change and mixing of populations in post-Wisconsin time. We shall look for evidence of rates of change and of its continuance into modern times. The last phase of course has been profoundly influenced by the activities of man. This aspect will be considered by another speaker and is not discussed in detail here.

Life Zones

The dominant zonation in Ontario is that determined by temperature. The zonation is roughly latitudinal, but is strongly influenced by proximity to the Great Lakes and to Hudson Bay. There is a secondary precipitation gradient, and there is a soil zonation, determined partly by bedrock and till composition and partly by different biotic influences.

Temperature-controlled zonation is described in a general way by the traditional classification of life zones (Munroe, 1956). Ontario has a wider range of life zones than any other part of Canada except British Columbia and the adjacent part of Alberta. A narrow strip of Arctic habitat extends along the coast of Hudson Bay from the Manitoba border to Cape Henrietta Maria. South of this is a poorly-developed and poorly-known band of Hudsonian habitat. Then comes the very extensive band of Canadian coniferous forest. This is continuous and remarkably uniform right across the province from Manitoba to Quebec, and of course extends with relatively minor variation to Alaska in the west and Newfoundland in the east. The middle part of the Canadian zone in Ontario borders broadly on the north shore of Lake Superior, but to the east and west the Canadian passes gradually into the Transition zone, which is widely bipartite in this province. Finally, the Upper Austral zone is represented by a rather narrow strip along the north shore of Lake Erie, extending from Windsor in the west to the Niagara Peninsula in the east.

Speaking generally, the Arctic zone is characterized by treeless tundra vegetation and by the presence of permafrost in the ground. The fauna is poor in species but a number of the species are abundant in individuals. There is a high proportion of circumpolar species. In Ontario this zone is restricted and poorly investigated. The adjacent part of the zone in Manitoba has been much more thoroughly studied, especially in the neighborhood of Churchill, and many of the same species can be expected to occur in Ontario. Striking features of the Churchill environment are the narrowness of the zone, which is restricted to a few miles fronting on Hudson Bay, and the very sharp line of division from the Hudsonian zone at a well-marked tree line. Only a small proportion of butterfly species are common to the two zones, and these often show a marked subspecific differentiation across the Arctic-Hudsonian boundary (Freeman, 1958). Scattered records from northern Ontario indicate the extension of a Churchill-like butterfly fauna as far as Cape Henrietta Maria, where such species as *Oeneis melissa semplei* Holland, *Oeneis polixenes* (Fabricius) and *Boloria eunomia triclaris* (Hübner) have been collected (Riotte, 1959, 1967).

The Hudsonian zone has discontinuous tree cover and lacks the specialized forest floor vegetation of the Canadian zone. It is populated predominantly by the more tolerant species of the Canadian zone, such as the butterfly *Erebia discoidalis* Kirby or of even wider range, such as the butterfly *Oeneis jutta* (Hübner) or the mosquito *Aedes punctor* (Kirby) (Jenkins, 1958). It also yields strays and relict

colonies of mainly Arctic forms, such as *Erebia rossii* Curtis (Ehrlich, 1958). In addition to these more widely ranging elements there is a small but definite component of species and subspecies endemic to the Hudsonian zone. As an example we may cite the transcontinental butterfly *Pyrgus centaureae freija* Warren. Hudson Bay, however, is an important barrier for the Hudsonian endemics, a number of which are restricted to the regions to the east or to the west. Several species of the noctuid genus *Pachnobia* appear to fall in the former group, and it is interesting that these and other species of similar distribution frequently appear as relicts on the mountains of New England and the Gaspé. *Erebia theano canadensis* Warren is a butterfly that appears to exemplify the western group. An excellent example of this disjunction is found in the geometrid genus *Aspilates,* where *A. taylorae* (Butler) is found in the Hudsonian zone to the west of Hudson Bay, extending to Alaska, with a subspecies in Siberia, whereas the related *A. conspersarius* Staudinger is restricted to the Hudsonian zone of the Quebec-Labrador peninsula (Munroe, 1963).

The Canadian zone has a full cover of coniferous forest, with a specific though depauperate forest floor vegetation. The region contains a rich assemblage of insects. Many of them are associated with coniferous trees, others with successional trees such as aspen or birch, still others with understory vegetation, and of course there is a full complement of predators, parasites and scavengers. There are many aquatics in the exceptionally large number of lakes and streams in the region, and other special habitats have their own insects. Among the most interesting of the latter habitats are the cold, acid, ericaceous bogs, which harbour relict populations of Hudsonian and even Arctic species south into the Canadian, Transition and Austral zones.

The Canadian zone contains a very large proportion of transcontinental or nearly transcontinental species. Their dispersal has been made easy by the continuous extent of the zone from the Atlantic far into Alaska; many extend further by following the climatically analogous cordilleran forests southward along the western mountains. For this reason the fauna of Eastern Canada has a surprisingly western aspect to entomologists brought up in the middle eastern U.S.A. Such species as *Plebeius saepiolus* (Boisduval) and *Coenonympha tullia* (Müller) are characteristic of the Cordillera in the U.S.A., but extend eastward transcontinentally in Canada. Although the Canadian zone has a very characteristic assembly of dominant species, it has relatively few that are confined to it. We have already seen that some are shared with the Hudsonian zone; many others are shared with the Transition or with the Transition and Austral zones. A considerable number extend southward to Florida and some even farther. Canadian portions of the ranges of many transcontinental species are shown in the *Forest Lepidoptera of Canada* (McGugan, Prentice, *et al., op. cit.).* Some more specialized range types will be noted below.

Beginning with the Transition zone, the role of transcontinental species becomes much less important. In my paper on the distribution of North American Lepidoptera (Munroe, 1963a) I distinguished an Eastern Temperate Forest faunistic province extending across the complete range of temperate climatic zones, south of the Canadian. This emphasizes the association of a cohesive biota in the broad-leaved forest of eastern North America, with many relationships to those of the similar forests of Europe and temperate Asia. Very many species have wide ranges, either limited to this province, as in the sphinx moths *Sphecodina abbottii* (Swainson) and *Deidamia inscripta* (Harris), or in others, such as *Papilio troilus* (Linnaeus), the spice bush swallowtail, extending this kind of range over the Great Plains as far as the foothills of the Rockies. However, from the Canadian standpoint, the boundary between the poorer Transition biota and the richer Upper Austral biota is so striking that we can hardly ignore it. Although both zones have

a number of species of characteristic eastern distribution, the number of these that reach their northern limit at the boundary of the Upper Austral is very significant. Of the two sphinx moths mentioned above, *Sphecodina abbottii* is limited to the Upper Austral, whereas *Deidamia inscripta* extends into the Transition as far north as Ottawa and Montreal, though the range appears to have extended this far only in recent years (Munroe, 1957). *Automeris io* (Fabricius), a saturniid moth, is another species which extends about to the northern edge of the Transition zone, but is an example of one that reappears west of the Great Lakes in Manitoba and western Ontario. The cecropia moth, *Hyalophora cecropia* (Linnaeus), has a similar range in Ontario, but extends far onto the Great Plains in the mid-western U.S.A. and Canada.

We have so far discussed rather generalized ranges. The ranges of many species, however, are restricted. A number of Austral species are known only from very small areas or from single localities in Canada. *Heteropacha rileyana* Harvey is known in Ontario only from Chatham, *Hyalophora angulifera* (Walker) only from Rondeau and *Hyparpax aurora* (J. E. Smith) from Grand Bend and Rondeau. *Dasylophia anguina* (J. E. Smith) enters Ontario only in the west, extending from the Manitoba border to the Nipigon River (Riotte, 1967). The western Canadian zone butterfly, *Oeneis macounii* (Edwards), extends farther east, having been taken at Lake Traverse in Algonquin Park. The Upper St. Lawrence River region has some species, such as *Apatelodes angelica* (Grote), which are otherwise nearly limited to the Austral zone. *Euchloe olympia* (Edwards) is known from Manitoulin Island, which it probably entered from Michigan.

Intraspecific Variation

In so large an area as Ontario it is not surprising that many species show appreciable geographic variation. Some species show latitudinally correlated trends, either clinal, as in *Argynnis aphrodite* (Fabricius), which gets smaller and somewhat less heavily marked as it approaches the northern limit of its range. Other, perhaps more interesting, cases show rather sharp interfaces between populations that occupy relatively wide latitudinal zones. Often the interfaces seem to correlate rather well with the boundaries between major ecological formations. We have already touched on some examples in passing. A particularly effective boundary seems to be that between the Arctic and Hudsonian zones. Freeman (1968) cites a number of examples of butterflies with sharply distinct subspecies on the two sides of this boundary: the Arctic *Boloria frigga gibsoni* (Barnes & Benjamin) vs the Subarctic *B. frigga saga* (Staudinger), etc. Freeman considers it an open question whether most of these pairs do not in fact represent sibling species rather than subspecies of the same species. A number of comparable differentiations exist at the Transition-Upper Austral ecotone, though the proportion of species is much smaller in relation to the total in the area. Examples are the Transition and Canadian *Papilio glaucus canadensis* Rothschild and Jordan vs the Austral *P. glaucus glaucus* Linnaeus and the Transition and Canadian *Limenitis arthemis arthemis* (Drury) vs the Austral *L. arthemis astyanax* (Fabricius), with, in the latter case, a high proportion of intermediates in the blend zone around Guelph and Goderich. At least some such subspecies differences are correlated with biological differences, as between the pine-feeding *Eacles imperialis pini* Michener of the Transition zone and the polyphagous *E. imperialis imperialis* of the Austral zone (Michener, 1950). Similar differences in host preference probably occur in many species without accompanying morphological differentiation, at least that has been observed so far. *Besma quercivoraria* (Guenée) is, according to Rupert's observations, primarily an oak feeder in central New York State, but it feeds mainly on birch in Ontario (Prentice *et al.*, 1963). A three-tiered latitudinal subspecies pattern is found in *Plagodis phlogosaria* Guenée,

with one series of subspecies in the Canadian zone, a second in the Transition and a third in the Austral. The picture is complicated by east-west differentiation in each zonal complex. There do not seem to be food-preference differences in this assemblage (Munroe, 1959).

East-west differentiation is not uncommon in the more widely ranging species. Often it is gradual and clinal, especially in the species of the Canadian zone. In the more southerly zones, where the ranges are interrupted by the Great Lakes, the differentiation may be more conspicuous and abrupt. An example of the former type is seen in *Limenitis arthemis arthemis,* which gives over gradually to the Manitoba subspecies *L. arthemis rubrofasciata* (Barnes & McDunnough) in western Ontario. An example of the latter is the notodontid moth, *Macrurocampa marthesia* (Cramer), with its strikingly different subspecies *manitobensis* (McDunnough) in the Lake of the Woods district (Riotte, 1967).

Finally we should mention the somewhat randomized differentiation of certain species that live in small discrete colonies, such as those surviving as relict populations in acid bogs. A particularly striking example is the complex that includes *Crambus labradoriensis* Christoph and *C. dissectus* Grote. The population of *C. labradoriensis* across the wet northern muskegs is extremely uniform, and consists of dull greyish insects with obscure wing markings. In southern bogs, however, there are all intergradations to blackish forms with well-defined silvery white markings. These variants are distributed in an irregular pattern in different individual bogs. Only a few bogs have been adequately sampled. Similar patterns of variation probably exist in other bog species, but they have not been systematically studied in Ontario. Such a study would be highly rewarding because it should be possible to date the origin of many bogs with some degree of accuracy, and thus to get some measure of the rate of evolution of populations in postglacial time.

Sources and Movements of Fauna

The potential sources of the existing biota vary with the environmental requirements of the species and with the life zone and part of the province with which we are concerned. Arctic species may have come from an eastern Arctic refugium, postulated by many authors, or, more probably, from Beringian or Cordilleran refugia or from a cold zone to the south of the main ice sheet. Ross, Rotramel, Martin and McAlpine (1967) have proposed the last type of origin for winter stoneflies of the genus *Allocapnia.* A species such as *Aspilates forbesi* Munroe, which occurs neither in the Cordillera nor east of Hudson Bay, and which lacks relict populations south of the main tundra area, but which ranges from Churchill and probably northern Ontario west to Nome, Alaska, may well have spread east from a Beringian source. Such was almost certainly the history of the Hudsonian *A. taylorae*, already mentioned above. Such Hudsonian species as *Boloria freija* (Thunberg) may have received at least a component from a Cordilleran refuge. On the whole the evidence seems to be against the incursion into Ontario of many Arctic or Hudsonian forms from the southeast. The virtual absence in the Hudsonian zone of Ontario of the special Labradorian Hudsonian fauna, of which so many relicts are preserved on Mt. Washington, Mt. Katahdin and the Shickshock Mountains would argue against such an origin. Origin from south of the central lobe of the ice sheet would, however, be much more plausible, and would be supported by the significant number of Arctic and Hudsonian relict species known to exist in the Nipigon area.

For the relatively rich faunas of the more southerly zones we can postulate several sources, though the details must have varied considerably from species to species. The Canadian-zone forest, at least for most of Ontario, seems most likely to have been of eastern origin, and to have been relatively uncontaminated by

Beringian or Cordilleran elements. Once it became established as a transcontinental corridor, however, it was traversed by a large number of species from both these sources, and no doubt there was a return flow from the east. The pattern of distribution of such species as *Papilio machaon hudsonianus* Clark, *Plebeius saepiolus* Boisduval and *Erebia discoidalis* Kirby suggests strongly that such movements are continuing at the present time. Hardier species from the south are no doubt also continuing to penetrate the Canadian-zone forest. The presence of relict populations of many familiar boreal species in the southern Appalachians at high altitudes indicates that this has likely been an important source of colonists, though only the more vagile species have been able to come so far in the short time that has been available. Like the Hudsonian zone, the Canadian zone of Ontario shows little evidence of penetration by strains of Atlantic origin. Such species as *Papilio brevicauda* Saunders and *Incisalia lanoraiensis* Sheppard do not come much west of Quebec City, and most other Atlantic forms are even more circumscribed. A possible exception is *Metarranthis warneri warneri* (Harvey), which extends from the Maritimes into eastern Ontario, but it is probably mainly a Transition-zone species.

The main sources of the Transition and Upper Austral faunas of Ontario have certainly been the Appalachian forests on the one hand and the Great Plains on the other. The fauna is obviously still being actively recruited from these sources. The Plains species have tended to come mainly into the southern part of the province via the Prairie Peninsula. The pyralid moth *Microtheoris ophionalis lacustris* Munroe is an example of such a species. Appalachian species are so numerous that examples are unnecessary. It is likely that there is a substantial component of Great Plains species in the Rainy River and Lake of the Woods regions, but there are few definitely established examples. *Platytes vobisne* Dyar is possibly one.

We cannot close without mentioning the large, though not very well-known, migratory and casual element in the Ontario fauna. These species fall into several groups. Of two-way migrants, with a definite northward flight in early summer, followed by a breeding period and return flight in the autumn, the monarch butterfly, *Danaus plexippus* (Linnaeus), is certainly the best example. Another group migrates north in the spring and in favorable years builds up large populations, which may move in substantial numbers into the subarctic or Arctic regions. The *Vanessa* species belong to this type. A return flight is not authenticated, though it may occur. Then there are the one-way autumn migrants, such as the cotton moth, *Anomis argillacea* (Hübner), which fly north in vast numbers, only to be destroyed by the first cold weather. Finally there is a large group of strays, including many magnificent tropical and subtropical species. Such fine species as the giant sulphurs, *Phoebis sennae* (Linnaeus) and *P. philea* (Johansson) have been collected in Ontario in recent years. Our understanding of the abundance, movements, dynamics and limits of spread of both the regular migrants and the casual visitors to our province leaves much to be desired. This is one area in which individual observations and investigations can be of great value.

Though this is only a very brief and incomplete conspectus of problems of insect biogeography in Ontario, and though I have illustrated it mainly with the examples from Lepidoptera that were most familiar to me, I hope enough has been said to reveal some of the complexity as well as the interest of our biogeographical problems. The incompleteness of our knowledge is the thing I want most to emphasize. We need detailed information on occurrence, on variation, on abundance, on movements, on host relationships, on limiting environmental factors and indeed on every aspect of biology. We need a much more determined effort to correlate the existing patterns with what is known of the past. We need systematic search for and identification of the wealth of insect fragments preserved in our peat and other deposits, for only by means of fossil samples can we test the validity of

our speculations and deductions. There is a plentiful field for those who wish, in defiance of Powell's Law, to do challenging work close to home.

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EFFECTS OF MAN ON THE ONTARIO INSECT FAUNA

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Shortly after agreeing to discuss the effects of man on the Ontario insect fauna, I reached the conclusion that any adequate coverage of the topic was impossible. Not only was the time assigned for the paper all too short but, in addition, adequate data were lacking in important areas. I also concluded that nearly every entomologist knows more about some aspects of the problem than I do — a most uncomfortable state of affairs from the speaker's point of view.

In order to partly negate these difficulties, I merely outline the ways man may have affected insect faunas, leaving the citation of particular cases to others working with the problems mentioned. I will then attempt to explain why it is impossible to deduce how much effect man has had.

The obvious effect of man has been his disruption of the community *status quo*. In Ontario this *status quo* was first disrupted by glaciers (Howden, 1969) before man's arrival. In some ways man's depredations are not unlike some of the glacial effects. Those of man fall into five major categories.

I. Disruption of the forest habitats by:

(a) Lumbering. This has many effects, one of the primary ones being the increase of wood-boring insects, etc. Some of the more subtle ones are: changes in the bird fauna with the possible resultant changes in predation pressure on certain insects; erosion with its effect on the litter and soil fauna.

(b) Planting. Plantations of single species not only have many of the effects listed under (a) but encourage the population buildup of a few species. Planting of introduced species has, in the past, led to the introduction of associated insects, thus establishing not only new pests but insect-transmitted diseases.

II. Clearing of forests. This has, in general, created an entirely new community for:

(a) Grassland species, many of which have moved in either from the south or as imported species that normally could not have survived in our forest habitats.

(b) Pests on agricultural crops such as corn, tobacco, potatoes, etc. These were not native to Ontario and in many cases the associated insect pest has few natural predators.

(c) Weeds, both native and imported. Weeds have followed man and, in turn, have been followed by their insect associates.

(d) Insects closely associated with habitations of man. In general, urbanization has affected local climates as already mentioned by M. K. Thomas. Houses and their environs, greenhouses, etc, present sheltered areas in which many insects can survive our winters, when, under natural circumstances, they would probably be eliminated.

III. Changes in aquatic habitats by:

(a) Drainage of swamps which eventually eliminate the habitat.

(b) Damming of rivers. This creates new and sometimes somewhat atypical aquatic habitats. Stocking of fish not native to the area, release by

fishermen of unused bait (often crickets or grasshoppers), etc, can make the biological picture seem like some modern paintings, i.e. confusing! At the same time many terrestrial habitats may be destroyed by flooding. Since many species often extend their ranges along major river systems, surviving adverse conditions in ravines or along the banks, large dams may cause considerable disruption.

(c) Pollution of various types. These include fertilizers and pollutants listed under section V. Some aspects of this are very adequately covered by A. L. Hamilton in a subsequent paper.

IV. Insect transport by:

(a) Purposeful introductions by man, usually for biological control programs.

(b) Accidental introductions through transport in ships, planes, cars, etc, and as mentioned under other headings.

(c) Early man. Insects closely associated or feeding on man often migrated with him around the world.

V. Environmental pollution by:

(a) Insecticides. These may be airborne for short periods, but have a much greater effect in the soil and in water. I see no need to expand on the numerous effects; we will leave this to the followers of Rachel Carson.

(b) Industrial pollutants. These are numerous and have varied effects. One has only to look at the denuded countryside around Sudbury to see an extreme example. Cases of water pollution are also well known. The effect of atmospheric pollution on insect populations, however, has some interesting, less considered aspects and I will return to this subject subsequently.

(c) Human wastes. In Ontario this problem has largely affected aquatic environments and I will leave the discussion of this to A. L. Hamilton.

(d) Radiation. In the future this factor may come under industrial pollutants, but for the present I consider it a special problem. Practically every area of the earth has been exposed to some degree to radioactive fallout from atomic explosions. Since the effects from this are probably subtle and unmeasurable over the few years they have been with us, I cannot guess as to the effects on insects. A short-term study on insect populations in an area polluted by reactor wastes showed no noticeable changes that might have been caused by radiation. (Crossley and Howden, 1961.) At present it would seem that man, as a species, may be affected well before insect species are.

The above, I believe, outlines the major possible ways that man is affecting insect populations in Ontario. In the introduction I implied that the question of how much he has affected them is seemingly impossible to answer. In order to do so, it would be necessary to find some community not now affected by man in order to establish a base line for comparison. In considering this it seemed desirable to establish the approximate date that man's disruptive influence began in Ontario. The answer may surprise some people. Man apparently moved into southern Ontario shortly after the glacial recession began, perhaps 8,000 years ago. In a recent paper (Martin, 1967) the theory is presented that early man may well have been responsible for the extinction of many species of large mammals in North America and elsewhere. The case for man versus mastodons is well documented for Michigan (Martin, 1967) and, while there is some question as to the dating of Ontario finds, man undoubtedly has been in the area for thousands of years. If Martin's theories are correct, disturbance by man has been going on for a

long time. What effect his early depredations had on insects, one cannot guess, but man's presence in the area for so long a time seems to rule out the establishment of the unaffected community base line.

One other complicating aspect is man's effect upon the atmosphere. In the preceding papers we have seen how climatic changes can drastically alter the various communities. If man changes atmospheric conditions, then all communities including the insects can be affected, upsetting further any possibility of establishing a workable base line except for short-term studies. The subject of climatic changes caused by man is speculative. Mitchell (1965) discusses the theories involving CO^2 in the atmopshere which supposedly increases temperature as its concentration increases. If all other factors were constant (which they are not) the increase of free CO^2 in the atmosphere would increase the mean temperature. Mitchell does point out that with the burning of fossil fuels, man has increased the atmospheric concentration of CO^2 by about 10 percent since 1880. In recent years there also has been a slight warming trend. If the increased CO^2 is causing this warming, then, as Mitchell states, we can expect cooler times when the utilization of fossil fuels declines. A second factor possibly causing climatic change, and which is at this time pure speculation, is the effect of vapor trails from airplanes. If these alter cloud patterns, there could well be climatic changes, since cloud cover reduces radiation at ground level. On the less speculative side we do know that the mean temperature is affected in large cities such as Toronto and that smog can be a problem. However, insects that can survive the other aspects of urbanization can survive, I expect, the smog as well.

It is unfortunate that I cannot make any definite statements concerning man's effects on insect populations nor reach any real conclusions. I can only say that man is disrupting the natural (?) communities at such a rate that it is essentially impossible to sort out all of the factors involved. Drainage is being changed, land cleared, new organisms introduced, and even the climate may be affected. In the glacial sequence we had a relatively orderly procession of events and effects; with man's activities we have many similar effects, but no orderly sequence. From the way I have viewed the problem it would seem that man has certainly affected insect populations, but the question of how much can only be judged on a short-term basis.

As an afterthought, has man's effect on insects been more than insects' effect on man?

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ON SOME CONCEPTS IN THE POPULATION BIOLOGY OF THE SPRUCE BUDWORM[1]

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The modern term "population biology" will be used in this short talk instead of the more classical terms *population ecology, population genetics,* and *evolution,* because it has recently, or finally, been realized that the simpler term, population biology, is fully inclusive, or implicative, of the fields of ecology as well as those of genetics and evolution. Indeed, today one cannot, or must not, speak of "populations" without thinking of genetics as providing the morphology and internal anatomy of populations, and of ecology as giving the physiology and external relations, and of evolution as showing development and history at work in populations along the arrow of time.

One of the basic concepts in population biology is obviously the concept of population itself. The term population often evokes a numerical, merely quantitative, image. Too many ecologists still use the term "population" as if it would refer to a smaller or larger number of similar individuals, the key words being "number" and "similar". But this is false and the opposite is true. Population is a functional and structural term referring to an integrated grouping of dissimilar and, therefore, mutually dependent individuals.

Naturally, the size of a population must be measured in terms of numbers of individuals. But it is characteristic that population size is the total of a specified set of subgroups, be these sexes, age classes, castes, morphs, or any other classes. The proper measure of population size is the integral of a frequency distribution, not a ratio of individuals to units of space, substrate, or host trees. The latter is density. This difference between population size and population density cannot be overemphasized. What should be realized (by many more ecologists) is this: it is possible that two populations of the same size occur at different densities, say in two subsequent years, and it is also possible that two populations of the same densities are of very different sizes. The population size refers to the operationally integrated whole, whereas expressions of population density at best describe the local or temporary relationship of populations, or frequently of only some of their components, to their substrate, which are of course, most useful parameters; at worst, however, measures of population density may conceal significant and meaningful differences in population size.

The integrated unit, measured by population size, is the effectively reproductive group of individuals. It is the group of individuals that are *de facto* the parents of the next generation. No measure of density enters into this concept here.

But what do enter into this concept are the effects of selection, and density *per se* can obviously be an important selection factor. Now, by admitting that the parents of the next generation are subject to natural selection, there can be no question that these parents are not a random sample drawn by chance from their own population. On the contrary, they are a selected and thoroughly biased sample, a selected elite, smaller in number than the total of individuals in their generation.

This selected nature of the actually reproducing population imparts with logical inevitability certain characteristics to the effective population. First of all, it

[1]Contribution No. 121, Insect Pathology Research Institute, Department of Fisheries and Forestry, Sault Ste. Marie, Ontario.

gives it qualitatively distinctive properties, and these are transferred immediately to the next generation. If natural selection were not qualitative it would be not selection, but only decimation. Also, were there no qualitative differences within the population, no sets of natural mortality factors could bring about selection. They then bring about merely random reduction in numbers, which again is only decimation.

Decimation leaves the quality of populations unaffected, except for the random shuffling of genes; natural selection does not. Should there not be a lesson here in terms of population control measures? Could not one develop artificial controls that have the characteristics of natural selection, namely selectivity and, therefore, the capacity to control qualities — presumably the noxious qualities — of insect populations of the future? It seems entirely possible. But this requires a far more comprehensive knowledge of the structure, the qualitative differences, the divisions of labor and function which constitute the polymorphic anatomy of field populations.

In the case of the spruce budworm, some progress has been made over the years. It is now recognized that the level of polymorphism is as high in populations of this species as in any other. The hereditary mechanics of some of the polymorphisms are known. We even had an opportunity recently to make the first estimate of a spontaneous mutation rate in this species. The red-eye locus seems to mutate once every 6,000 to 7,000 gametes. This rate is well in accord with other estimates of spontaneous mutation rates.

The natural inbreeding coefficient is an unknown parameter of population structure, but we may be able to estimate it with the help of the red-eye locus in the near future. In the populations where the red-eye gene occurred a very rough estimate of its frequency is about .01. With this the natural inbreeding coefficient could be estimated if ever a homozygous red-eyed individual were recovered from the field. This has not been the case so far. The significance of an estimate for the inbreeding coefficient is very great, because it is a basic datum for a description of the population mating system. The occurrence and the degree of assortative mating, and the size of such population isolates that may practice assortative mating are other essential population characteristics.

All these parameters of population structure are unknown for the spruce budworm, yet they may lead to a better understanding of the forces behind population outbreaks.

Many other concepts are only partially understood. For example, I may mention that of "epicenters". Epicenters are the initial locations of insect outbreaks. However, there are two possible interpretations of "the initial location of an outbreak". Either the insect population that grows up in such a location will begin to spread physically into the surrounding territory, thereby constituting a colonizing population; or there is no such actual spread but the epicenter is merely the spot at which a general and already widespread population surfaces first, the surface being some recognizable density level. We actually do not know today which of these radically different structures applies to the epicenters of the spruce budworm. The colonizing interpretation is assumed, of course, either explicitly or implicitly, when the appearing epicenters are made the target of a "nip-in-the-bud" control action. Today, such control action is only a large-scale field experiment which may settle whether epicenters are of that kind. The hoped-for outcome would be the prevention of any outward spread of increased population density. Should it prove that epicenters are indeed the places at which colonizing populations are created, obviously by natural selection, it might then become more worthwhile to attempt to control the natural selection factors at such spots with a view to preventing the creation of colonizers.

If, on the other hand, epicenters are not colonizing centers but only surfacing peaks, the suppression of the first peak will not prevent the outward spreading rise of the surrounding population to the given density surface. All past experience points to this latter interpretation of epicenters. Prevention might then not be a geographically localized problem but involve wider regions, the environmental structure of which would have to be altered.

May I conclude with a quote from a paper by J. J. de Gryse written in 1944:

" . . . the idea of prevention has played only a minor part in applied entomology, control was the need of the hour and it took precedence over everything else. Until the emphasis is shifted from control to prevention, we shall accomplish little or nothing in forest entomology . . ."

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III. SUBMITTED PAPERS

REDUCTIONS IN FECUNDITY ASSOCIATED WITH INCLUSIONS IN NEODIPRION SERTIFER (GEOFF.)

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The presence of irregularly-shaped, hard, dark objects has been observed in adults of several sawfly species. These inclusions have variously been called tumors, cysts, capsules, and inclusions. They have been associated with sublethal polyhedroses in *Gilpinia hercyniae* Htg., by Bird (1949) and in *Neodiprion swainei* Middleton, by Smirnoff (1967). Smirnoff has suggested their usefulness in detecting viral infections in populations of *N. swainei* and Nuorteva (1964) has proposed a similar scheme for *N. sertifer* (Geoff.). It has been found, however, that the presence of inclusions does not necessarily indicate sublethal polyhedrosis. In fact, in *N. sertifer*, Bird and Whalen (1949) reported finding inclusions in Canadian populations before the virus was introduced into Canada. In our work at the Forest Research Laboratory, Sault Ste. Marie, Ontario, we have shown that the presence of non-virogenic inclusions is related to temperature experienced by the sawfly larvae during the feeding stages. The exact nature and mechanism of formation of the inclusions have not been satisfactorily determined, but recent work by Smirnoff (1968) suggests that their formation results from a haemocytic reaction to food and gut remnants displaced into the haemocoel at the time of replacement of the mid-gut epithelium early in prepupal life. He has also hypothesized that the gut remnants result from incomplete histolysis because of some derangement of the normal enzyme systems.

In this paper we are concerned only with the effect of non-virogenic inclusions on the fecundity of the affected females. Nielson and Elgie (1968), working with *Diprion hercyniae* Htg., found the presence of "tumors" in non-diseased insects to be associated with a smaller average cocoon size but they could not show a significant reduction in fecundity. Our results, as described herein, demonstrate that *N. sertifer* females containing inclusions are significantly less fecund than normal females.

N. sertifer egg clusters originating near Chatsworth, Ontario (Lat. 44°30′ N), were placed at 20° C and 17-hour photophase shortly before hatch and the eclosing larvae were reared to maturity on foliage of *Pinus resinosa* Ait., under the same conditions. At the end of the feeding period the cocoons were collected daily, assigned an identification number, and weighed within 24 hours of spinning. Separate, equally-sized lots of these cocoons were incubated at 12°, 16°, 20°, 22°, and 24° C in darkness. Suitable precautions were taken to eliminate family bias or variations due to larval developmental rate in the distribution of the cocoon samples. There was no evidence of polyhedrosis in the larval rearings and about 90 percent of the cocoons produced adults. The conditions in the experiment led to a course of diapause development with mean adult emergence occurring between 56 and 89 days after cocoon spinning, depending on the incubation temperature. Upon

emergence each female adult was weighed, the mass of eggs weighed, the number of immature and mature eggs counted, and the presence of inclusions and amount of residual fat body recorded. The prepupal and pupal exuviae were removed from the open cocoon and the empty cocoon including the cap were weighed. From these data the prepupal weight at the time of cocoon spinning was calculated.

Abdominal inclusions were found in 58.4 percent of the adult females. Table I compares the mean number of mature eggs in normal individuals with the same values for females containing inclusions. Two points are immediately evident, (1) the females with inclusions had fewer eggs on the average than the normal females, and (2) the variation in egg production was much greater in the affected females at all five cocoon-rearing temperatures. These differences, in spite of the large variation among "tumored" individuals, are all significant at least at the 1 percent level. Three of the differences are significant at the 0.1 percent level.

The reductions in mean fecundity just described represent losses of 20 to 32 percent of the fecundity of normal females. Because we had recorded the weights of the prepupal larvae and the adults, we have been able to apportion the reductions to two primary causes. In the first instance, we have found that the average initial prepupal weight for females later shown to contain inclusions is significantly lower than that for normal females. The mean weight for normal

TABLE I. Comparison of the mean number of mature eggs by dissection in *N. sertifer* females with and without inclusions. Larvae reared at 20°C, 17-hour photophase, on red pine, and cocoons reared in darkness.

Cocoon rearing temp °C	Condition of female	Statistic				
		$\bar{X}$	$\bar{Sx}$	$\bar{sx}$	n	P
12	without inclusions	98.5	3.11	1.554	4	
	with inclusions	75.9	14.42	4.809	9	<0.001***
16	without inclusions	99.7	7.36	2.784	7	
	with inclusions	72.4	22.13	7.377	9	<0.01**
20	without inclusions	96.0	7.84	2.363	11	
	with inclusions	76.3	18.79	6.264	9	<0.01**
22	without inclusions	99.3	5.94	2.244	7	
	with inclusions	68.9	12.58	3.978	10	<0.001***
24	without inclusions	85.1	7.86	2.622	9	
	with inclusions	60.0	14.63	4.876	9	<0.001***

prepupal larvae was 65.2 mg, and for larvae developing into females with inclusions, 58.6 mg. The difference is significant at the 0.1 percent level. This reduction in size attained by the end of larval feeding necessarily dictates fewer eggs in the abnormal females because of the high correlation we observe between fecundity and prepupal weight. We have also found that a useful measure of the efficiency with which an individual utilizes the stored reserves of the prepupa for egg production may be obtained by calculating the number of mature eggs produced per milligram of initial prepupal weight. We have termed this measure of efficiency the Reproductive Index.

With these data on hand, we are now in a position to calculate the proportions of the loss in fecundity associated with inclusions that may be attributed to smaller prepupal size and with less efficient use of reserves to produce eggs, respectively. Table II demonstrates this division for samples held at the five cocoon-rearing temperatures. We see that the total reduction, as already stated, ranges between 20 and 32 percent. Of this total reduction the more constant proportion is that attributable to reduced efficiency with values ranging from 13 to 20 percent. The reduction assignable to the small size attained by the prepupae ranged from 3 to 16 percent. We have observed also that females with inclusions have a higher number of immature eggs at emergence than normal females and we have no evidence that a significant number of additional eggs mature after adult emergence. In addition, in normal females only traces of residual fat body are present at adult emergence while in tumored females, large amounts are readily detectable. Our data on egg weights suggest that there is no difference in the mean weight of mature eggs in the two classes. Finally, the presence of inclusions does not affect the rate of development of the stages within the cocoon.

TABLE II. Loss in fecundity of *N. sertifer* associated with inclusions attributed to smaller prepupal size and with less efficient use of reserves to produce eggs. Larvae reared at 20°C, 17-hour photophase, on red pine, and cocoons incubated in darkness.

Cocoon-rearing temp. °C	Reduction in fecundity %		
	from smaller size	from lowered efficiency	total
12	8.8	14.1	22.9
16	13.9	13.4	27.3
20	3.4	17.1	20.5
22	15.5	15.1	30.6
24	11.5	20.3	31.8

The magnitude of the loss in fecundity suggests that the relationship of the condition we have described with trends in natural populations is a most fertile area for investigation since any single factor causing a loss in reproductive potential of up to 30 percent cannot be ignored. We know nothing about the vigor of the affected adults, their ability to disperse, to mate, and to oviposit. We also know nothing about the quality of the offspring resulting from the eggs of tumored females. There are, however, instances when field populations deteriorate from unknown causes and we wonder about the role of the tumor-like inclusions as a factor contributing to population vitality and decline. Studies are currently underway to examine this point.

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CONTROL OF GLISCHROCHILUS QUADRISIGNATUS (SAY) (COLEOPTERA: NITIDULIDAE), A PEST OF FRUIT AND VEGETABLES IN SOUTHWESTERN ONTARIO

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Introduction

Glischrochilus quadrisignatus (Say) the picnic, sap or raspberry beetle attacks corn, raspberries, tomatoes, peaches and many other crops when they become overripe in the field or in roadside fruit stands. Corn is attacked and kernels are hollowed out from the silk stage to early dent. Goble (1967) described this species as the most serious contaminant of tomatoes, corn, and raspberries in Ontario. Eliminating these insects from processed fruit and vegetables is difficult. Chemical control is discouraged to avoid pesticide residues in the crop. Contact insecticides do not kill beetles burrowed into fruit or under husks.

The biology of *Glischrochilus quadrisignatus* in Ontario appears similar to that described by Luckmann (1963) in Illinois. Adult *G. quadrisignatus* overwinter and have one generation per year. No insect parasites were seen, but many dead beetles infested with the fungus *Beauveria bassiana* (Balsamo) Vuillemin were found in the field. Preliminary investigations and Luckmann's (1963) observations showed that beetles were attracted, seemingly by smell, to bait materials. This study, considered necessary because of inadequate control, reports on the potential of baits for control of this species.

Materials and Methods

Baits consisted of 100 gram samples of various materials (see Table I) mixed in a Waring Blender with 1 gram (active) of insecticide. Mixtures were placed in separate 6-inch aluminum pie plates and covered by another plate perforated to

permit beetle entrance (Figure 1). Plates containing test materials were placed 50 feet apart along a corn field. Preliminary tests involved one plate of the various bait combinations. Results were recorded by counts of dead or moribund beetles.

To test the effectiveness of baits in controlling beetles around fruit stands, two plates of banana — 1 percent endosulfan bait, were maintained 50 feet downwind (east) of exposed fruit from June 8 to September 5, 1967. Fruit on display was examined once each week by the author and daily by the owners. Fresh baits were supplied weekly and dead beetles counted and removed.

In corn, 8 plates of banana-endosulfan bait were placed at the south end of a 10-acre field (400 feet long, 1,000 feet wide) from July 1 to August 20, 1967. These baits were replaced each week and dead beetles counted. The effectiveness of baits in controlling beetles in large areas was tested by counting beetles on bird-damaged ears at varying distances from the bait. Ten ears were examined at each sample site.

The fungus *Beauveria bassiana* was isolated from dead beetles collected in the field and was grown on potato dextrose agar. Ten healthy beetles were exposed to a culture of this fungus for 15 minutes, then removed to a sterile plate and fed on banana slices.

Results

TABLE I. Numbers of adult *Glischrochilus quadrisignatus* attracted to various bait materials, Ridgetown, Ontario, August 1-8, 1967.

Material	No. Beetles Killed
Immature sweet corn + 1% endosulfan (including cob)	5,312
Banana + 1% endosulfan	2,972
Sour cherries (overripe) + 1% endosulfan	2,104
Raspberries +1% endosulfan	1,488
Bread + 1% endosulfan	610
Peaches (ripe) + 1% endosulfan	412
Cherry pits + 1% endosulfan	97
Tomatoes (ripe) + 1% endosulfan	45
Apples (ripe) + 1% endosulfan	40
Corn stalk + leaf + 1% endosulfan	7
Silage + 1% endosulfan	0

Table I shows that unripened sweet corn, ripe bananas, sour cherries, and raspberries were most attractive to adults. These were moist and fermenting whereas tomato baits were acid and the odor was not attractive. Corn stalk and silage baits, although moistened with 30 ml of water during preparation, had dried, leaving no noticeable odor.

Tests with insecticides (Table II) showed that Baygon(R) (Figure 1) (O-isopropoxyphenyl methylcarbamate, endosulfan, aldrin and Bayer 25141 (*O, o*-diethyl *O*-p-(methylsulfinyl) phenyl phosphorothioate) gave effective kill. These baits were still attractive to beetles after one week. Most of the bait containing DDT was eaten but only 20 beetles were found dead in the plate (Figure 1). DDT was either slow acting or, as suggested by Luckmann (1963), ineffective. Carbaryl, diazinon and methoxychlor baits hardened and did not ferment, suggesting a reaction with the bait. Adding water did not improve this condition. Baits containing Imidan(R) (*O, O*-dimethyl S-phthalimidomethyl phosphorodithioate) Azinphos-methyl, 4072 (diethyl 1-(2,4-dichlorophenyl)-2-chlorovinyl phosphate) Dyfonate(R) (*O*-ethyl-S-phenyl-ethylphosphonodithioate) and malathion smelled

TABLE II. Effectiveness of various insecticides in banana baits in the control of *Glischrochilus quadrisignatus,* Ridgetown, Ontario, August 8-15, 1967.

Treatment	No. Dead Beetles
Baygon(R) 50 WP + banana	15,060
Endosulfan 50 WP + banana	14,480
Aldrin 50 WP + banana	13,312
Bayer 25141 S.C. (6 lb/U.S. gal.) + banana	11,460
Dyfonate(R) E.C. (4 lb/U.S. gal.) + banana	966
Malathion 50 WP + banana	873
Dupont 1642 90 WP + banana	540
Imidan(R) 50 WP + banana	513
Carbaryl 50 WP + banana	304
Azinphos-methyl 25 WP + banana	104
Methoxychlor 50 WP + banana	81
4072 E.C. (2 lb/Imp. gal.) + banana	41
DDT 50 WP + banana	30
Diazinon 50 WP + banana	15

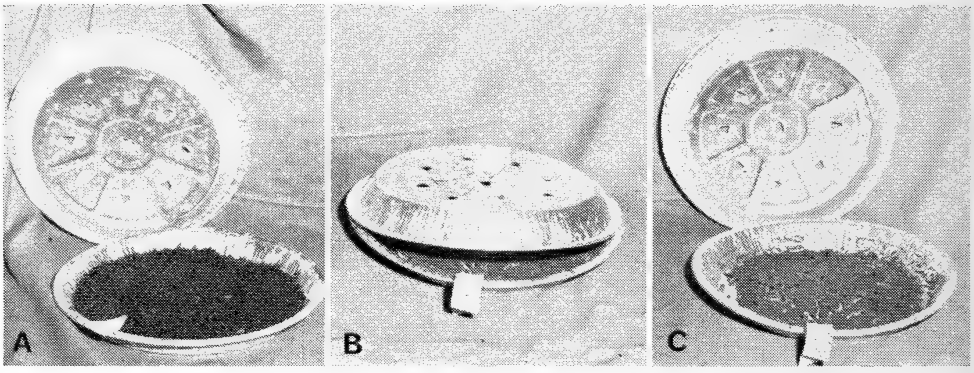

FIGURE 1. Baited Aluminum Foil Traps Used in Control of *G. quadrisignatus* Ridgetown, Ontario.

A. Bait trap containing 100 grams banana—1% Baygon mixture after 6 days in field.

B. Bait trap showing trap and covering lid.

C. Bait trap containing banana — 1% DDT mixture after 6 days in field.

of the respective insecticides and were not attractive. Bacterial and fungal growth was slowed or stopped.

Most of the insects trapped were *Glischrochilus quadrisignatus,* although the northern corn rootworm, *Diabrotica longicornis* (Say) (Coleoptera: Chrysomelidae) was present in large numbers. Dupont 1642 (S-methyl N-(carbamoyloxy thioacetimidate) attracted many species of Sarcophagidae (Diptera) in addition to picnic beetles.

Baits, after 7 to 10 days, lost moisture, odor, and attractiveness. Aldrin- or endosulfan-treated banana baits gave kills for 6 weeks when baits were moistened once a week with water. Baygon(R), and Bayer 25141 in banana baits attracted and killed beetles for 3 weeks in a corn field if kept moistened. Of the methods tested to slow dehydration, use of a perforated plastic bag covering the plate was most successful (Table III). Baits containing 1 percent corn syrup (by volume) were attractive 3 days longer than the control (banana plus 1 percent endosulfan). Although calcium chloride lengthened attractiveness to 14 days, fungus growth

TABLE III. Prevention of Bait Dehydration, Ridgetown, Ontario, August 4-18, 1967.

Material	Beetles Killed	Effective Period
Banana + 1% endosulfan	103	7 days
Banana + 1% endosulfan + plastic bag covering	243	14 days
Banana + 1% endosulfan +1% corn syrup	101	10 days
Banana + 1% endosulfan + 1% $CaCl_2$	90	14 days
Banana + 1% endosulfan + 1% captan 50 WP	4	14 days
Banana + 1% endosulfan + 1% $CaSO_4$	1	2 days

TABLE IV. Effects of adding diluents to bait materials, Ridgetown, Ontario, August 1-8, 1967.

Material	Beetles Killed
100% banana + 1% endosulfan	2,972
75% banana + 25% sawdust + 1% endosulfan	2,023
50% banana + 50% sawdust + 1% endosulfan	1,130
25% banana + 75% sawdust + 1% endosulfan	1,038
100% sawdust + 1% endosulfan	63
75% banana + 25% bread +1% endosulfan	3,365
50% banana + 50% bread + 1% endosulfan	1,918
25% banana + 75% bread + 1% endosulfan	2,540
100% bread + 1% endosulfan	610

increased and smell was changed. Captan slowed fungus growth and reduced fermentation. Copper sulfate absorbed water from the bait and caused drying.

Dilution of banana baits with less attractive, inexpensive materials (Table IV) reduced the numbers of beetles killed. Baits containing sawdust were dry when prepared; therefore, 200 cc water were added per 50 grams of sawdust. Similar results were obtained using ripened sweet corn diluted with sawdust. Aluminum plates were corroded by baits containing high percentages of moist sawdust.

Control of G. quadrisignatus With Baits

Two plates of banana-endosulfan bait controlled the beetles around a fruit stand. Bait mixtures killed 3,288 beetles and 10 beetles (total) were found on displayed fruit between June 8 and September 5, 1967.

In corn, 8 plates of banana-endosulfan bait maintained for 50 days killed approximately 125,000 beetles. Table V shows a correlation between distance from the bait and the number of beetles per ear. This is especially apparent if data from the sample site 1,000 feet from the bait on the west side is omitted. The sample site was adjacent to a dump containing rotting fruit which was attractive to beetles. Bird-feeding damage, caused by red-winged blackbirds, *Agelaius phoeniceus* (L.) and cowbirds *Molothrus ater* (Boddaert) was most extensive along the west side and north end of the field. This may explain the higher numbers of beetles per damaged ear in these areas of the field.

On August 11, 450 beetles marked with white paint were released one-half mile north of these baits. One of these beetles was found on bait August 17. Winds during this period were west to southwest. This indicates that beetles move about, but does not imply that beetles are attracted from this distance.

TABLE V. Control of *G. quadrisignatus* in corn, Ridgetown, Ontario, 1967.

Sample Site	Average Number of Beetles per Bird-Damaged Ear
Baited area (south end)	6.1
200 ft from bait (southwest corner)	1.0
300 ft from bait (southeast corner)	8.6
400 ft from bait (west side)	2.0
400 ft from bait (east side)	3.5
600 ft from bait (west side)	12.0
600 ft from bait (east side)	9.8
1,000 ft from bait (west side)*	6.3
1,000 ft from bait (east side)	13.2
1,000 ft from bait (north end)	27.7

*Sample site was near garbage dump.

Tests With Beauveria bassiana

Beetles exposed to *Beauveria bassiana* cultures were killed within two weeks. White fungus growth appeared within seven days after death. This fungus was identified as *B. bassiana.*

Discussion

Baits are an efficient means of preventing infestation in small areas like fruit stands but in larger areas, i.e. corn fields, baits are unlikely to eliminate the beetles. Whether baits in fact attract beetles into an area has not been investigated.

Mixtures of baits and *B. bassiana* have potential for biological control of *G. quadrisignatus.* Sprays of *B. bassiana* against the European corn borer, *Ostrinia nubilalis* (Hübner), proved ineffective because the disease did not become established in the field (Bartlett and Lefebvre, 1934). Mixtures of bait and *B. bassiana* may infect sufficient beetles to establish the disease, but this aspect requires further investigation.

Summary

Glischrochilus quadrisignatus (Say) the picnic, sap or raspberry beetle was attracted in large numbers to small amounts of sweet corn, bananas, cherries, and raspberries. Endosulfan, Baygon (R), aldrin, and Bayer 25141 were the most effective insecticides in the baits. Reduced percentages of attracting materials in bait-insecticide mixtures caused a reduction in numbers of beetles killed.

Two aluminum foil plates, baited with banana-insecticide mixture renewed weekly, prevented infestation of a fruit stand. Baits in a corn field reduced the beetle populations up to 1,000 feet. *Beauveria bassiana* was very effective in killing beetles when tested in the laboratory.

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STUDIES OF THE BYRON BOG IN SOUTHWESTERN ONTARIO XXXVIII. INSECTS ASSOCIATED WITH FLOWERING BONESET, Eupatorium perfoliatum L.

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Introduction

The Byron Bog has been described by Judd (1957). There are three zones in it. The central part, Zone A, is a floating mat of *Sphagnum* moss almost completely covered by bushes of leatherleaf, *Chamaedaphne calyculata.* In Zone A is Redmond's Pond. Surrounding Zone A is Zone B, a region which is damp or flooded throughout the year and which supports a considerable growth of trees and shrubs. The outer region is Zone C, consisting of relatively dry, wooded slopes. An account of the vegetation in these zones is given by Judd (1957) and a map showing the extent of the zones is included by Judd (1957).

In the northeast corner of Zone C there is a rectangular patch of ground of dimensions 90 yards by 25 yards occupied by boneset, *Eupatorium perfoliatum* L. This area, although part of the wooded portion of Zone C, is low-lying and consequently is damp through most of the year and is conducive to a luxuriant growth of boneset, with some plants growing to a height of 6 feet.

On August 16, 1967, the plants were in full bloom and collections of insects were made in the afternoon. It was a day of bright sun and scattered cumulus clouds, with a temperature of 80°F and a light breeze which moved the heads of the plants only slightly. The insects were swept from the flower heads with a net and were put in poison jars and later pinned and labeled. Most of the insects were identified by the following taxonomists (ERI refers to the Entomology Research Institute, Department of Agriculture, Ottawa): G. L. Ayre, Entomology Research Institute, Belleville, Ont. (Formicidae); D. Brown, ERI (Hemiptera, Homoptera); R. deRuette, ERI (Coleoptera); M. Ivanochko, ERI (Sphecidae, Tiphiidae); H. E. Milliron, ERI (Tenthredinidae, Colletidae, Halictidae, Apidae); O. Peck, ERI (Perilampidae); G. E. Shewell, ERI (Diptera). Moths and butterflies were identified by the writer. All specimens are deposited in the collection of the Department of Zoology, University of Western Ontario, except some denoted as "kept" in the Canadian National Collection, Ottawa.

Account of Insects Collected

Altogether 295 insects were collected from the plants during the afternoon, including 74 in Hemiptera, 11 in Homoptera, 3 in Coleoptera, 9 in Diptera, 5 in Lepidoptera and 193 in Hymenoptera.

Hemiptera
Miridae

Adelphocoris lineolatus (Goeze) — 1 bug. Bugs of this species occur abundantly on weeds (Blatchley, 1926).

Phytocoris sp. — 1 bug. Several species of *Phytocoris* occur on vegetation (Blatchley, 1926).

Platytylellus insignis (Say) — 1 bug. This bug has been reported from Ontario by Blatchley (1926) who records it as inhabiting various plants.

Plagiognathus politus Uhler — 1 bug. This species is reported as occurring commonly on various Compositae.

Lygus sp. — 63 bugs. These were among the commonest of the insects occurring on the boneset. Many species of this genus occur commonly on plants (Blatchley, 1926).

Phymatidae

Phymata wolffi Stal — 4 bugs. Blatchley (1926) records this species as occurring on various Compositae, including boneset.

Neididae

Neides muticus (Say) — 1 bug. Blatchley (1926) records this species as occurring in weedy fields and pastures.

Corizidae

Corizus crassicornis (L.) — 1 bug. Blatchley (1926) records this species as ranging from Quebec to New England.

Cydnidae

Corimelaena sp. — 1 bug. Insects of this genus occur commonly on various plants (Blatchley, 1926).

Homoptera

Membracidae

Ceresa bubalus Walker — 1 tree hopper. Britton (1923) records this species from a wide range of hosts including boneset.

Cercopidae

Lepyronia quadrangularis (Say) — 2 hoppers. Britton (1923) records this species as inhabiting various plants and occurring in Ontario.

Philaenus leucophthalmus (L.) — 8 hoppers. This species was previously recorded from the Byron Bog (Judd, 1960), where it occurred in 1956 on bushes of leatherleaf from July to September.

Coleoptera

Phalacridae

Olibrus sp. — 2 beetles. Blatchley (1910) records various species of *Olibrus* as occurring on plants.

Cantharidae

Chauliognathus pennsylvanicus DeG. — 1 beetle. Blatchley (1910) records this species as being most abundant on flowers of goldenrod and allied plants.

Diptera

Bombyliidae

Villa sp. — 1 female. Stone *et al.* (1965) record several species of this genus as parasitic on Diptera in North America.

Syrphidae

Sphaerophoria sp. — 1 female. Stone *et al.* (1965) record several species of this genus as widely distributed in North America.

Anthomyiidae

Hydrophoria implicata Huck. — 1 male (kept). Stone *et al.* (1965) record this species as widely distributed in North America.

Muscidae

Musca autumnalis Deg. — 1 male. This species has been found previously in the vicinity of London on marsh marigold (Judd, 1964) and in Dunn Township on milkweed (Judd, 1968).

Calliphoridae

Bufolucilia silvarum (Mg.) — 1 fly. This species was found commonly in the bog in 1956 by Judd (1958).

Pollenia rudis (Fab.) — 2 males. This species was found commonly in the bog in 1956 by Judd (1958, 1960).

Sarcophagidae

Sarcophaga nearctica Park — 1 male. This species is reported as widely distributed in North America by Stone *et al.* (1965).

Oxysarcodexia (*cingarus* Ald. ?) — 1 female. Several species in this genus are recorded from North America by Stone *et al.* (1965).

Lepidoptera
Euchromiidae

Cissipes fulvicollis Hbn. — 1 moth. This moth occurs commonly on flowers and has been reported on milkweed by Judd (1968).

Nymphalidae

Phyciodes tharos Drury — 3 butterflies. This species occurs commonly in eastern North America and visits a wide range of flowers (Klots, 1951).

Pieridae

Pieris rapae L. — 1 butterfly. This species has been recorded in the bog on flowering leatherleaf (Judd, 1966a) and elsewhere in London on marsh marigold (Judd, 1964).

Hymenoptera
Tenthredinidae

Tenthredo basilaris Say — 3 sawflies (1 kept). This sawfly is recorded from eastern North America by Muesebeck *et al.* (1951).

Perilampidae

Perilampus hyalinus Say (complex) — 1 wasp. *P. hyalinus* is recorded as parasitic on a wide range of insect hosts in North America.

Tiphiidae

Myzine quinquecincta (Fabr.) — 5 wasps (2 kept). This species is recorded by Muesebeck *et al.* (1951) as parasitic on *Phyllophaga* in North America.

Formicidae

Formica fusca L. — 6 ants. This species is reported as widely distributed in North America by Muesebeck *et al.* (1951) and has been found on flowers of milkweed by Judd (1968).

Sphecidae

Bicyrtes ventralis (Say) — 1 wasp. Muesebeck *et al.* (1951) record this species as generally distributed in the United States and southern Canada and predaceous on immature Hemiptera.

Prionyx atratus (Lep.) — 2 wasps (1 kept). This species is recorded as occurring over the entire United States and southern Canada (Muesebeck *et al.*, 1951).

Diodonotus sp. — 1 wasp (kept). Muesebeck *et al.* (1951) record various species of this genus from eastern North America.

Colletidae

Colletes simulans Cr. — 1 bee. This species is recorded from North America by Muesebeck *et al.* (1951).

Halictidae

Halictus ligatus Say — 1 bee. Muesebeck *et al.* (1951) record this species as widely distributed in North America.

Halictus confusus Sm. — 2 bees (1 kept). Muesebeck *et al.* (1951) record this species from eastern North America.

Lasioglossum admirandum (Sandh.) — 1 bee. This species was previously collected in the bog from flowers of leatherleaf (Judd, 1966a).

Sphecodes dichrous Sm. — 1 bee. Muesebeck *et al.* (1951) record this species from eastern North America, including Ontario.

Apidae

Melissodes rustica (Say) — 2 bees (1 kept). Muesebeck *et al.* (1951) record this species as widely distributed in North America.

Anthophora furcata terminalis Cr. — 1 bee. Muesebeck *et al.* (1951) record this species as widely distributed in North America.

Xylocopa virginica (L.) — 1 bee. Muesebeck *et al.* (1951) record this species as widely distributed in eastern North America.

Bombus affinis Cr. — 7 bees. This species was previously found in the bog by Judd (1966a, 1966b) on flowers of leatherleaf and blueberry.

Bombus impatiens Cr. — 3 bees. This species was previously found in the bog by Judd (1966a, 1966b) on flowers of leatherleaf and blueberry.

Psithyrus ashtoni (Cr.) — 1 bee. Muesebeck *et al.* (1951) record this species from northeastern North America.

Apis mellifica L. — 153 bees. This was the commonest insect collected from the boneset, accounting for about half the total collection. It was previously collected in the bog by Judd (1966a) from flowers of leatherleaf.

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MIGRATION OF THE GREEN PEACH APHID FROM PEACH IN ESSEX COUNTY

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The green peach aphid (*Myzus persicae* Sulzer) has two different life cycles varying in relative importance in different parts of its range. In parts of Europe and North America with cold winters a holocyclic life cycle occurs. In the holocyclic life cycle oviparae lay overwintering eggs on peach and related trees and colonies derived from these eggs produce alatae in spring which migrate to secondary hosts. In Australia, South Africa, some European countries and those areas of North America where the winters are relatively warm, *M. persicae* has an anholocyclic life cycle. That is, asexual forms overwinter in colonies on weeds and crops and produce migratory alatae the following spring.

Borner (1951) showed that alatae from anholocyclic colonies in Germany had longer ungues (i.e. the terminal filaments of the antennae) and a lower ratio of cornicle length to length of last joint of proboscis than alatae from holocyclic

colonies being produced at the same time. In addition the cornicles of alatae from anholocyclic colonies had fewer scales on them and were more swollen in the distal half. This latter difference was also observed by Gillette and Palmer (1908). The cornicle differences were used by Edwards (1965) to differentiate anholocyclic alatae from holocyclic ones. He showed that more spring migrant alatae came from anholocyclic colonies than from holocyclic ones in Cambridgeshire, England.

M. persicae is widely dispersed in Essex County, Ontario, by the prevailing southwest wind in spring. As winters in Essex County are milder and shorter than in other parts of Canada, the alatae of *M. persicae* which invade early potato crops may be from anholocyclic colonies overwintering on weeds either locally or in the U.S.A.

The methods used to differentiate spring alatae from primary hosts from those from secondary hosts developing at the same time of year are evaluated here. If successful, the technique would show whether the early infestations are the results of migrations from peach or secondary hosts. If they always come from peach, it might be worthwhile to eradicate colonies on peach before the flights or to predict the summer population from the number of colonies found on peach in spring.

Methods

In 1967 and 1968 alatae of *M. persicae* were taken from a suction trap and trap plants to record spring migration and to make morphological comparisons. The suction trap, similar to those described by Johnson (1950) had no catch segregation device. It had a 10-inch diameter fan and a capacity of about 700 cubic feet per minute. The trapped aphids fell into a jar of 50 percent alcohol. The trap was operated continuously near buildings of the Harrow Research Station from April to November each year and the aphids were counted each working day.

The trap plants were Brussels sprouts (variety Catskill) with about 6 large leaves. Each plant was grown in a 4-inch pot arranged in blocks with 2 feet between plants in each direction. The blocks of trap plants were located in an open area among various other experimental plots. A total of 80 or 120 plants was used in the early spring when few aphids were flying, the number being reduced to 40 when they became more numerous. The aphids were collected once each working day. Results are expressed as alatae accumulated per 40 plants since the previous count.

In the spring of 1967 and 1968 colonies of *M. persicae* derived from eggs on peach trees, were observed daily for the first appearance of alatae and those observed were collected for morphological comparison until no more winged or wingless aphids remained.

To investigate the possibility of overwintering on a common secondary host, colonies of *M. persicae* were established on plants of shepherd's purse (*Capsella bursa-pastoris* L.) in 3-inch pots surrounded by 4 inches of peat moss in saran mesh cages in an outside insectary, in the fall of 1967 and spring of 1968. In addition wild shepherd's purse plants were examined for *M. persicae* in the fall of 1966 and 1967 and in the spring of 1967 and 1968.

A one-sixth-acre plot of Irish Cobbler potatoes was searched for alatae of *M. persicae* from May 22 and counts made from May 30 to June 19, 1968.

All alatae collected were put on slides using Richards' (1964) method, examined and measured with an eyepiece micrometer. For each specimen the lengths of the unguis, last joint of the proboscis and the cornicle, the maximum and minimum width of the cornicle in the distal part, and the extent to which the cornicles were scaled were recorded. At least 29 specimens from each source were examined and measured.

Results

Measurements of the cornicle, unguis and last joint of proboscis lengths did not show the differences between alatae from caged anholocyclic colonies on shepherd's purse and alatae from holocyclic colonies on peach trees which would be expected from Borner's (1951) work. The extensive scaling of the cornicles used by Borner (1951) and Gillette and Palmer (1908) to distinguish holocyclic alatae from anholocyclic ones was observed on alatae trapped throughout the year.

The degree of cornicle swelling was found to differ between the alatae of holocyclic and anholocyclic colonies in 1968. The absolute values of the maximum and minimum width of the distal part of the cornicle varied with size of the alatae. This was overcome by calculating the maximum-minimum ratio for each specimen. Alatae from peach had the least swollen cornicles with the ratio ranging from 1.0 to 1.5 (mean = 1.2) in both years. In 89 percent of these alatae the ratio was under 1.4. In contrast the alatae from the anholocyclic shepherd's purse colony had more swollen cornicles with the ratio ranging from 1.2 to 2.0 (mean = 1.5) and in 59 percent of the alatae the ratio was over 1.4. In 1968 all spring migrants collected and measured were within the range for peach forms. In 1967, 4 out of 37 spring migrants trapped had ratios above 1.6 and therefore outside the range of peach forms.

Wild shepherd's purse plants examined in the fall of 1966 and 1967 had 0 to 38 *M. persicae* per plant, but the following spring plants at the same sites had no *M. persicae* on them, except for some plants growing near open greenhouse vents. Similarly out of 14 shepherd's purse plants infested with *M. persicae* in the insectary in the fall of 1967, 6 survived the winter but were free of aphids the following spring. The minimum air temperature recorded was –6°F.

In 1967 alatae were present in 8 colonies on peach from June 1 to June 20 (Table I). Alatae appeared that year on the trap plants from May 26 to June 26. No others were trapped until July 6.

In 1968 alatae first appeared in 2 of the 25 colonies on peach on May 24 and the maximum number seen at one time (29) was recorded on June 4. These colonies were empty by June 14. Alatae accumulated on potatoes and trap plants from May 30 to June 19. No other specimens appeared until July 2.

TABLE I. Number of alatae recorded on hosts and in a suction trap

	1967			1968			
Source	Peach[1] colonies	40 Trap[2,3] plants	Suction[3] trap	Peach[1] colonies	40 Trap[2,3] plants	100 Potato[1] plants	Suction[3] trap
Date							
May 26	0	0.44	1	3	0	0	0
May 29	0	0.44	0	18	0	0	0
May 30	0	0.33	0	—	0	4	0
May 31	0	0	0	27	1.5	—	0
June 3	+	1.0	1	—	6.5	37	0
June 4	+	0	4	29	6.0	—	1
June 6	+	2.0	2	5	9.0	40	4
June 12	+	9.3	8	5	1.5	12	4
June 19	+	3.33	2	0	0.4	1	1
June 23	0	1.0	2	0	0	—	0

[1]Single observations, 0 = none, + = present, — = not recorded, [2]potted Brussels sprouts, [3]accumulated since last date.

Discussion

Most of the morphometric differences recorded by Borner (1951) and Gillette and Palmer (1908) between alatae reared from holocyclic and anholocyclic colonies of *M. persicae* were not observed in populations examined here. There was some difference observed in the extent to which the cornicles were swollen.

No natural overwintering anholocyclic populations from which to collect alatae for comparative purposes were found. Anholocyclic populations placed on shepherd's purse did not survive the winter in an outside insectary, even though the host plants did. It was necessary to reestablish these populations in March to obtain alatae for comparison.

A comparison of the ratio of maximum-minimum cornicle width established that most alatae were comparable to peach forms, but the ratio ranges of holocyclic and anholocyclic forms overlap. It is possible that the 4 alatae trapped in 1967 which had a high ratio value could be anholocyclic. There might also be occasional anholocyclic individuals with low ratio values which would be undetectable in the catches.

Alatae first appeared on plants, and in the suction trap within 7 days of their first being seen in peach colonies in each year. The trap plant, suction trap and colony observations produced data which showed that the migration lasted 28, 28 and 20 days respectively in 1967. These data and the potato crop observations showed that migration lasted 17, 15, 21 and 19 days in 1968. All flight activity ceased 3 days after the colonies became empty in 1967 and 5 days in 1968. Alatae were not observed again for 13 days in both years, after which flight activity began to increase. Aphids in these new flights could be from colonies founded by the first alatae which flew from peach, since the high temperatures in June would permit several generations to develop in these colonies. Barlow (1962) recorded that this species needs only 6.3 days at 59°F to complete development and temperatures exceeded this throughout June. The agreement between the cornicle measurements and appearance times of alatae from peach and trap plants and the suction trap indicates that in 1967 and 1968 *M. persicae* alatae were mainly from holocyclic colonies. It is proposed to record spring flights and measurements for a further period to see if anything occurs to upset this conclusion: for instance, if alatae appeared in the trapping studies a long time before there were any in peach colonies, this would indicate these came from outside the area or from another host.

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PROBLEMS AND PROSPECTS IN THE USE OF PATHOGENS IN INSECT CONTROL[1]

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Introduction

Although diseases of insects have been the subject of research by numerous individuals since Pasteur made his famous study of pebrine in silkworms, it is now just about a quarter-century since Steinhaus at the University of California established insect pathology as a distinct discipline and practically simultaneously the Insect Pathology Research Institute was established in Sault Ste. Marie, Ontario. This therefore seems to be an opportune time to look briefly at how far we have come, and where we can expect to go in future in application of this science to the regulation of insect populations.

Ever since Metchnikoff in 1879 made the first significant experiments in the application of microorganisms to reduce damage caused by insects, entomologists have wondered whether this type of biological control could be developed into a practical method. The early workers were optimistic. Krassilstschick established a laboratory at the University of Odessa in 1884 for production of spores of the fungus *Metarrhizium anisopliae* to be used in controlling larvae of *Anisoplia austriaca*. Between 1910 and 1915 several attempts were made to control locusts in various parts of the world, by distributing the bacterium, *Coccobacillus acridiorum*, originally discovered in Mexico. About 1920 two fungi were distributed in orchards in the Annapolis Valley of Nova Scotia in an attempt to control two different insects. And between 1927 and 1932 a large international organization involving the United States and several countries of Europe was formed to develop methods for controlling European corn borer, *Ostrinia nubilalis*, by the use of pathogens.

During the same half-century, beginning in 1865 with the work of Pasteur to control pebrine of silkworms, much effort was devoted to control of disease in beneficial insects, especially in the silkworm and the honeybee. Then about 1940 a very serious outbreak of *Diprion hercyniae* in eastern Canada was practically eliminated by a virus disease (Balch and Bird, 1944). It was evident that diseases could indeed be potent agents in causing mortality among insects; lack of success in manipulating them was due to lack of fundamental knowledge about the pathogens that caused them.

There is no great value in once more recounting the history of the development of insect pathology as a science. The story has been told several times, and a most interesting story it is. Since planned and organized research has been initiated, and since the necessary attention has been given to understanding basic principles, progress has been relatively rapid. The results that have led to the most practical and widespread development and application have been obtained with bacteria, specifically one or other of the several strains of *Bacillus thuringiensis* as well as *Bacillus popilliae*. No figures have been compiled to indicate world usage of these materials, but it certainly amounts to tens or even hundreds of tons per year. Viruses and fungi also are used, although not to the same extent as bacteria. In spite of these promising developments, there are still problems to be solved, and

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pathogens are not yet, and probably will not be for many years, a completely satisfactory substitute for chemicals as a method of eliminating insect enemies.

The Problems

There seems always to be a tendency to think about new or unknown subjects in terms of what we already know. When the first studies of insect pathogens as control agents were undertaken, they were looked upon largely as a new kind of insecticide, and research was planned accordingly. Although their potential was recognized, the need for careful fundamental investigation was not appreciated, and many disappointments followed. Only within the past 25 years or so have some of the basic problems been recognized and studied, and progress toward their solution is being made. But there are various practical considerations as well, and it is to these that your attention is now directed.

1. *Effectiveness.*

Effectiveness is the prime consideration when any agent, chemical or biological, is being studied with a view to utilizing it in control of a pest. Regardless of any other attributes it may possess, if it is not effective in doing the job it is of little or no use. This is probably one of the greatest problems to be overcome insofar as pathogens are concerned. Because insects have been here for a long time, they have in most cases come to terms with their pathogens and other controlling influences, and the effectiveness of the latter has reached a balance. Where a particular insect increases in numbers, it is because for some reason the balance has been upset. Not necessarily the balance of the pathogens — perhaps parasites or predators have been eliminated, the food crop is more intensively cultivated, or perhaps there have been several years of particularly favorable weather. How then can the pathogen be made more effective, both for the immediate situation and to maintain a low host level in the future?

Probably more effort has been expended on solving this problem as it relates to *Bacillus thuringiensis* than to any other pathogen (Angus, 1968). One of the first points to become clearly evident was that even though by all the usual criteria the different cultures of *B. thuringiensis* used for different preparations are the same species in the usual taxonomic sense, there are distinct strains having quite different characteristics (Heimpel and Angus, 1960). Various comparisons of these strains have shown that the characteristics are measurable and can be correlated with effectiveness. The effectiveness in turn will be assessed differently depending on the test insect used, hence any statement or claim must be related to the specific insect.

It is well known that *B. thuringiensis* has two insecticidal effects, one due to a toxic proteinaceous parasporal crystal produced at the time of sporulation and causing a toxemia that, by causing tissue damage in the insect, permits the growth and multiplication of the bacteria resulting in a true septicemia. Depending on the species, insects are affected differently by these two processes. There is also evidence that the toxic proteins produced by different strains of *B. thuringiensis,* although very similar, are not identical, and some suggestion that the protein molecule can be subdivided with some of the fractions being toxic and others harmless. It is still not clear whether the actual toxic fraction is the same in all strains. Although normally there is one spore and one crystal produced from each sporangium, it is not known whether this is necessarily the optimum ratio for general applications. Moreover the crystals vary in size, and it is necessary to determine whether the spore-to-crystal ratio should be based on a count or a weight basis, and the relative importance of the spore and the crystal must be assessed in determining the effectiveness of a given preparation.

Finally, a major problem in any commercial production process is to ensure uniformity of the product regardless of the strain that may have been selected. Here it is necessary to control not only the physical conditions, as is frequently required in chemical reactions, but the biological conditions as well. As the bacteria grow and develop, changes take place in the nutrient medium — nutrients are used up, the pH changes, and the medium becomes polluted with metabolic by-products. These changes in turn affect the developing organisms, and must be counteracted so as not to interfere with optimum production or even to induce undesirable adaptations such as premature lysis, or failure to produce the parasporal inclusion bodies. Moreover, there is the ever-present problem of guarding against contamination by bacteriophage which might cause similar problems.

Generally speaking there seems to be less of a problem in assessing the effectiveness of viruses. This is because most of them are quite host-specific and the level of effectiveness seems to be more or less inherently established — some viruses are very good ones, as those of *Neodiprion sertifer* (Bird, 1953), *Trichoplusia ni* (Hall, 1957), etc, while others, even though they occur quite commonly, are less effective, such as the polyhedrosis virus of *Neodiprion banksianae* (Bird, 1955). Some evidence has been published suggesting that the effectiveness of viruses may be increased (Smirnoff, 1961), but this is generally not as easily accomplished as in the case of the bacteria. This of course may be an advantage, because if by some means it is possible to increase effectiveness, the new condition may be more stable and less subject to a possible downward change later on.

Another factor now coming to light is the possibility that multiple infection by viruses may lead to interference (Bird, *in press*). A relatively mild virus may confer some kind of protection against infection by a more virulent one. The mechanism of this protection is not yet known, but it could lead to unsatisfactory results in attempts to utilize an apparently highly effective virus for control. Since a virus once introduced probably can never be eliminated, it will be necessary to use caution in making introductions of exotic viruses and to perform extensive tests of compatibility, lest the result be the development of a situation that may be worse rather than better.

Effectiveness in the fungi is still uncontrollable and largely unpredictable. Ever since Metchnikoff's original experiments, the hope has been entertained that fungi could be manipulated in some way to suppress insect populations. There are many recorded instances where they have been naturally effective, but very few where any manipulation has increased the effectiveness. The well-known work of Telenga (1960) and Zakharchenko (1959) in which very low dosages of chemicals were combined with applications of spores, showed promising results, but this technique needs to be expanded, and studied more intensively. No one has yet explained the reason for the result — whether it is reduction of resistance to infection because the chemical is present, whether susceptibility to the chemical is increased by the fungus infection, or whether there is some kind of synergism of the one by the other. It offers a promising lead for further study.

It has been generally considered that because the resting spores of the *Entomophthora* can be kept without serious loss of viability for fairly long periods, this would be the best stage to produce in quantity. If these spores could be caused to germinate at will, this assumption would probably be correct. However, the mechanism of their germination, and the conditions necessary for successful initiation of an epizootic, are not well known, and results are frequently unpredictable. It is known that after initial infection natural epizootics build up and spread almost entirely through dissemination of the less resistant conidiospores, and it may be that emphasis should be placed on developing better methods for producing conidiospores in quantity and to protect them from the harmful

conditions of the environment until they can germinate and invade the host insects. In some cases fragmented mycelium, properly protected, might also serve as a suitable inoculum.

Effectiveness of all pathogens is governed in part by the method of formulation, and this in turn may depend on the method of application — a dust preparation, an ordinary type of spray applied by ground equipment, or a low volume spray by aircraft. Since many biological preparations are sensitive to ultraviolet radiation as well as to heat and humidity, protection against rapid deterioration following application must be devised. And in at least some cases, and on high-value crops, it may be necessary to abandon the idea of establishing an effective epizootic and to depend on repeated applications as is done with chemicals.

These are some of the problems that insect pathologists face when assessing the effectiveness of pathogens for controlling insect outbreaks.

2. *Safety*

The second class of problems that occur in connection with any attempt at insect control are those involving possible hazards and necessary safeguards, and here the insect pathogens appear to be in a very favorable position. Many of the most generally useful of the chemical insecticides carry a very high hazard rating, and some are now completely forbidden in many places, while others may be used only by specially trained experts. So far there is no indication that the pathogens that are effective against insects pose any such problems. But because of their very nature, continuing care must be observed. For instance, some taxonomists include *B. thuringiensis* in the *Bacillus cereus* group and would also assign *Bacillus anthracis*, the organism causing the disease anthrax, to this same group. Although this implies a close relationship between these two organisms, the differences are of more practical importance than the similarities. *B. cereus* does not cause anthrax in man, nor does it cause paralysis in the silkworm. The primary effect of *B. anthracis* is as an infection and not a toxemia. Although the apparent close relationship dictates that precautions against contamination must always be scrupulously observed, there is no record that anyone involved in the production or use of *B. thuringiensis* has ever suffered any kind of injury due to exposure to the organism.

One of the great advantages of *B. thuringiensis* is that it is chiefly a pathogen for Lepidoptera. A very large proportion of the insects that compete with man for food and fiber belong to this order, while it includes very few primarily beneficial insects — perhaps the silkworm, and the cactus moth *Cactoblastis cactorum* in Australia, are the two major ones. The highly beneficial insects, that is the parasites, predators and pollinators, belong mostly to the Diptera and Hymenoptera, with some predators also among the Coleoptera. Members of these orders appear to be almost completely immune to both infection and toxemia as caused by *B. thuringiensis* except that some preparations may contain a water-soluble exotoxin that is lethal to some Diptera.

Many tests have been done to determine the effects of *B. thuringiensis* on vertebrates, both warm- and cold-blooded, even to the extent of feeding some animals relatively massive doses of strains that produce the exotoxin "fly factor" as a means of rendering the feces toxic for fly larvae (Dunn, 1960). The organism was found to pass unaffected through the digestive tract of white mice and of several species of wild birds, without having any injurious effect on the animals (Smirnoff and MacLeod, 1961). In no case has any sign of infection or poisoning been reported. Human volunteers have swallowed suspensions of the material without any ill effects.

It can be said that at the present time preparations of *B. thuringiensis* are very much less hazardous than almost any of the conventional types of insecticides in use today.

Similarly with the viruses. One of the objections that has been raised occasionally against the use of virus in practical control of insects is that they are usually quite specific, frequently to a single insect species, or at least to a few very closely related forms. As more viruses, and different kinds, are discovered, it is found that this specificity is somewhat less absolute, at least in some cases, than had been thought. Nevertheless it is still a fact that the host spectrum for a particular virus is quite restricted. In fact there is very good evidence that, for instance, parasites of infected insects not only are immune to infection themselves, but actually they frequently prove to be very effective in transmitting infection to healthy host insects (Bird, 1961). Birds also may transmit virus by feeding on diseased insects and distributing infected fecal droppings, but without themselves suffering any ill effects (Bird, 1954). Again, there is no recorded evidence that an insect virus has ever caused any ill effects in any vertebrate animal.

Although there are one or two reports that spores of entomogenous fungi have been responsible for causing illness in persons working with them, the symptoms described appear to be more those of an allergy than an infection (York, 1958). Spores of a *Beauveria* species have been recovered from lesions in the flesh of some vertebrate animals, but whether the fungus was the primary cause of the lesion or a secondary invader is not clear. Nevertheless the obvious precautions should be observed in handling materials made up of or containing these organisms.

While all this is negative evidence to show that insect pathogens are relatively harmless to other animals, it can be said that no evidence has yet been put forward to indicate that they present any general hazard. In comparison with chemical insecticides in common use, the danger appears to be minimal, and as stated earlier there are no real problems in this regard — the major one appears to be to obtain approval of regulatory authorities for their general use.

3. *Cost*

Finally, the problem of economics is always a major one. There is little published information about the cost of using pathogens in insect control. A good deal of work done so far has been of the nature of experimentation and demonstration, with costs a comparatively minor consideration. In the last few years in North America, and probably over a somewhat longer period in some European countries, actual commercial use has increased, and an indication of comparative costs is now available. Although a great many factors have yet to be weighed, it appears that the costs of using bacterial pathogens, specifically *Bacillus thuringiensis,* will be reasonably competitive with most chemical insecticides especially on high-value crops. There is as yet no information on costs of viruses and fungi. When the somewhat nebulous but very real costs of pollution and residues from chemicals are considered, in many cases the use of an available and effective pathogen will be the method of choice even though the immediate expense may be somewhat greater than for chemical insecticides.

Prospects

What then are the prospects for practical use of pathogens in insect control? Considering the points discussed, it would appear that they are very promising indeed. The most important factor in their favor is the necessity to reduce environmental pollution. Because of the public concern with this problem, the widespread and indiscriminate use of chemicals must be curtailed, yet in the face of

rising demands for food and fiber the insects that compete with man for these products must be controlled. Technical developments and advanced chemical knowledge in the past quarter-century have produced weapons unequalled in history for the continuing battle against insects. But at the same time the uncontrolled use of these weapons has caused other problems to develop. It is unnecessary to describe them in detail — examples are well known; secondary pests developing into major ones because their parasites and predators have been destroyed; fish production reduced because of stream pollution; selective killing of the more susceptible individuals in a population so that average resistance to the chemical is increased and heavier dosages are required; and above all the very high hazard to man himself that is presented by careless or unskilled use of some of the chemicals.

As has been pointed out, the pathogenic organisms do not have any of these objectionable attributes. They are not, in the usual sense, pollutants but a normal element of the environment — no pathogen has been developed *de novo,* but all have been found already existing in nature. They are largely — although not completely — selective in their action so that one may be chosen to meet the requirements of the particular situation with only little prospect that it will cause an undesirable change in the natural balance. They are, so far as is known at present, completely harmless to higher animals including man, making them particularly suitable for crops that will be used directly as food.

It has already been demonstrated that *Bacillus thuringiensis* is an effective insecticide for many insects, and that in these cases it is economically competitive with conventional insecticides. The organism causing milky disease of the Japanese beetle has been produced and sold commercially in America for more than 20 years. It has been demonstrated by small-scale tests over a period of several years that viruses can be used effectively in controlling some field insects, and recently a large scale program for testing one of the viruses in the United States has been planned. As its acceptance is proved, and as satisfactory production methods for other viruses are worked out, the use of these materials too can be expected to increase. Combinations of very small amounts of chemical insecticides with fungal spores has proved to be effective in controlling some insects in Russia, and this and other methods for using fungi can be expected to be developed further.

Conclusions

Thus it has been shown conclusively that representatives of each of the three major classes of pathogens — bacteria, fungi, and viruses — can be used effectively and competitively as insecticides, at least in specific cases. Whether or not they can be developed to have as widespread use as chemicals have is yet to be determined but the difficulties appear to be largely technical and not fundamental. They will probably be most important, not as a replacement for chemicals but as a very significant part of integrated control programs that will utilize all available means including methods of cultivation, use of parasite and predators, and judicious use of selected chemicals as and when required. In this context, there is little doubt that the prospects for the development of insect pathology as an applied science, and of insect pathogens as significant weapons in insect regulation, are very bright indeed.

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IV. THE SOCIETY

PROCEEDINGS OF THE ONE HUNDRED AND FIFTH ANNUAL MEETING — ENTOMOLOGICAL SOCIETY OF ONTARIO

SAULT STE. MARIE, ONTARIO

OCTOBER 2-4, 1968

MEETING OF OUTGOING DIRECTORS

The 1967-1968 Board of Directors met on October 2, 1968, at 11:00 a.m. in the Conference Room, Forest Research Laboratory.

The meeting was called to order by President Boyce with one director unable to attend. The minutes of the last Directors' meeting were accepted as circulated to the membership on a motion by J. M. Cameron, seconded by D. G. Harcourt.

The Financial Statement for the year ending December 1, 1967, was presented and approved by the Directors on a motion by C. E. Atwood, seconded by D. C. Herne. The Interim Financial Statement for the period ending September 30, 1968, was approved also on a motion by P. E. Morrison, seconded by D. G. Harcourt.

The Reports of Standard Committees were received and discussion centered on the refereeing of papers accepted for publication and on the future of the Society Library. A recommendation was made that possible appointment of a committee to deal with the library problems be placed on the agenda for the Annual Meeting.

The President of the Society was asked to appoint a Resolutions Committee and the Secretary to compile the agenda for the Annual Meeting.

The meeting adjourned at 1:15 p.m.

ANNUAL MEETING

The 105th Annual Meeting of the Society was held in the Centennial Room of the Public Library, 50 East Street. Registration of members was conducted from 9:30 a.m. onwards, on October 2. The opening session began at 1:30 p.m. under the chairmanship of President H. R. Boyce. Addresses of welcome were given by A. C. Harry, Q.C., Mayor of the City of Sault Ste. Marie, and by R. M. Belyea, Director of the Forest Research Laboratory, Department of Forestry and Rural Development, Sault Ste. Marie. President Boyce delivered a presidential address and made various announcements about the forthcoming program. Twenty-four papers were presented during the three days of the meetings (some of these appear in the preceding sections of this volume).

Three papers, as follows, were presented at the afternoon session, beginning at 2:15 p.m. on October 2:

ZOLTAI, S. C. (Forest Research Laboratory, Winnipeg, Manitoba). The glacial history of the Great Lakes region.

THOMAS, M. K. (Climatology Division, Department of Transport, Toronto). Climatic history of the Great Lakes region.

TERASMAE, J. (Brock University). Discussion of the postglacial history and postglacial ecology of the Great Lakes region.

At 8:00 p.m. a wine and cheese party was held in the Officers Mess at the Armouries, 375 Pine Street.

On October 3, in a morning session beginning at 9:00 a.m., under the chairmanship of J. M. Cameron, the following papers were presented:

MUNROE, E. G. (Science Secretariat, Privy Council, Ottawa). Insects of Ontario: geographical distribution and postglacial origin.

HOWDEN, H. F. (Entomology Research Institute, Ottawa). Effects of man on the Ontario insect fauna.

HAMILTON, A. L. (Fisheries Research Board of Canada, Winnipeg, Manitoba). Recent changes in the insect fauna of the Great Lakes.

SMITH, S. G. (Insect Pathology Research Institute, Sault Ste. Marie). Cytogeography of North American *Pissodes* weevils.

STEHR, G. (Insect Pathology Research Institute, Sault Ste. Marie). Some concepts in the population biology of the spruce budworm.

In the afternoon session of October 3, from 2:00 to 3:55 p.m., under the chairmanship of G. W. Green, the following papers were presented:

MASON, W. R. M. (Entomology Research Institute, Ottawa). Distribution and history of introduced and native Ichneumonidae in the Great Lakes region.

FOOTT, W. H. (Research Station, Harrow). Insect problems of pepper in southwestern Ontario.

PENGELLY, D. H. (University of Guelph). Predator-prey relationships of Dermestidae (Coleoptera) and Bethylidae (Hymenoptera).

PHILLIPS, J. H. H. (Research Station, Vineland). Parasitism of a population of the Oriental fruit moth, *Grapholitha molesta* Busck, in an unsprayed peach orchard.
Eight species of insects parasitic on the Oriental fruit moth, *Grapholitha molesta* (Busck) were reared from host larvae collected in a peach orchard that was unsprayed since 1961. *Marcocentrus ancylivorus* Rohwer was the dominant species and parasitized between 40 and 50 percent of first and second generation larvae from 1964 to 1966. Despite this the parasite did not appear to be a controlling factor in these years and population fluctuation of the fruit moth resulted from other causes. In 1967 parasitism rose sharply to 61 percent in the first generation and 74 percent in the second. This increase occurred at the same time as host-larvae numbers increased and suggested that the parasite was responding positively to the increased host numbers. Low adult emergence in the second generation was related directly to the increased parasitism. To determine its total effect parasitism must be measured throughout each fruit moth generation because in most years it tended to reach a maximum early in the generation and then gradually decline.

ELLIOTT, W. M. (Research Station, Harrow). Migration of the green peach aphid from peach to early potatoes in Essex County.

In the session from 3:55 to 4:30 p.m., the following two "President's Prize" papers were presented:

WYATT, B. K. (University of Guelph). Pollen analysis of a *Bombus fervidus* (Fab.) nest (Hymenoptera: Apidae).

CHANG, P. K. (University of Guelph). Studies on the structure, ultra-structure and cytochemistry of the mycetome of the pear psylla.
The orange-colored mycetome of the pear psylla, which comprises a cellular covering membrane, a number of mycetocytes and a central syncytium, contains two kinds of inclusions (microorganisms — in the literature). As DNA could not be detected in them, their status as microorganisms is questioned. Both kinds contain protein; one kind contains RNA, and (by electron-microscopy) tubule-like peripheral maculae. In spite of their anomalous reactions, the inclusions are probably unusual, degenerate or aberrant microorganisms. The biosome theory is invoked in explanation.

Starting at 6:30 p.m. on the evening of October 3, a reception and banquet were held in the G. Verdi Hall, 455 Queen Street West, with entertainment during the banquet provided through the courtesy of the Sault Ste. Marie Folk Arts Council.

In the morning session of October 4, from 8:45 to 11:00 a.m., under the chairmanship of T. A. Angus, the following papers were presented:

SOHI, S. S. (Insect Pathology Research Institute, Sault Ste. Marie). Adaptation of *Aedes aegypti* cell to a hemolymph free medium.
Cell cultures of *Aedes aegypti* originally established by Dr. T. D. C. Grace (Australia), were obtained from Dr. J. L. Vaughn (U.S.D.A., Beltsville) in June 1967. Vaughn grew these cells in Grace's insect tissue culture medium supplemented with *Antheraea pernyi* hemolymph (5 percent) and fetal bovine serum (5 percent). The same medium was

used as the starting point for these experiments and the temperature was constant at 28°C. I gradually replaced the *A. pernyi* hemolymph in the medium with the *Bombyx mori* hemolymph, and also reduced the quantity of the hemolymph from 5 percent to 1 percent. The quantity of fetal bovine serum was increased from 5 percent to 9 percent. Thus the total animal proteins in the culture medium stayed at 10 percent. Finally *B. mori* hemolymph was completely omitted from the medium and the quantity of fetal bovine serum was increased to 10 percent. These cells are now growing in hemolymph-free medium since January 1968.

Bombyx mori hemolymph promoted growth of cultures almost as well as *A. pernyi* hemolymph did. In the beginning the growth of cells in insect hemolymph-free medium was much slower than that of cells in the medium containing as low as 1 percent hemolymph. Gradually the cells became adapted to the hemolymph-free medium. Now the growth of the adapted cells in the hemolymph-free medium is as good as that of the unadapted cells in medium supplemented with 1 percent hemolymph.

(Contribution No. 119. Insect Pathology Research Institute, Canada Department of Fisheries and Forestry, P.O. Box 490, Sault Ste. Marie, Ontario.)

SULLIVAN, C. R. and D. R. WALLACE (Forest Research Laboratory, Sault Ste. Marie). Reductions in fecundity associated with inclusions in *Neodiprion sertifer* (Geoff.).

SANDERS, C. J. (Forest Research Laboratory, Sault Ste. Marie). The extrusion of sex glands in female spruce budworm.

WEATHERSTON, I. and JEAN PERCY (Insect Pathology Research Institute, Sault Ste. Marie). Aspects of sex pheromone studies in the bumblebee wax moth, *Vitula edmandsi* Packard.

SMITH, C. and S. S. SOHI (Insect Pathology Research Institute, Sault Ste. Marie). Effect of fetal bovine serum on the growth and survival of insect cell cultures.

The effect of different quantities of fetal bovine serum (FBS) on the growth and survival of three insect cell lines, namely, *Aedes aegypti, Antheraea eucalypti,* and *Bombyx mori* was studied. The cells were originally established by Dr. T. D. C. Grace in Australia. We maintained the stock cultures at 28°C in Grace's insect tissue culture medium supplemented with *Bombyx mori* hemolymph (BMH) and fetal bovine serum (FBS) as follows: *A. aegypti* (BMH 1 percent, FBS 9 percent), *A. eucalypti* (BMH 2 percent, FBS 2 percent), and *B. mori* (BMH 3 percent, FBS 5 percent). In these experiments the quantity of BMH was kept constant for each cell line, but different quantities of FBS ranging from zero to 30 percent were used.

Cell viability was low and no growth occurred in any of the cell lines when FBS was omitted from the medium. Maximum growth of *A. aegypti* cells was obtained with 10 percent FBS. There was no further increase in this growth when FBS was increased to 20 or 30 percent and neither did the increased quantities have any adverse effect on the growth or survival of cells. *A. eucalypti* and *B. mori* cells grew best in 5 percent FBS. But the growth of these cells was significantly less in 20 or 30 percent FBS than in 5 percent FBS. Also viability of *A. eucalypti* cells was quite low in 20 or 30 percent FBS, though there was no adverse effect on the viability of *B. mori* cells at these concentrations.

(Contribution No. 118. Insect Pathology Institute, Canada Department of Fisheries and Forestry, P.O. Box 490, Sault Ste. Marie, Ontario.)

STOLTZ, D. B. and W. L. HILSENHOFF (McMaster University). A cytoplasmic virus in *Chironomus plumosus* (Diptera: Chironomidae.).

A cytoplasmic polyhedrosis virus has been found in larvae of *Chironomus plumosus.* Larvae die of a massive virus infection in the midgut epithelium. With phase-contrast microscopy, two different types of inclusion bodies can be distinguished in the cytoplasm of infected cells. These correspond in the electron microscope to areas of viral multiplication (largely free virus) and accumulations of polyhedra (occluded virus). In the course of virus maturation, free viruses are individually invested with a thick layer of polyhedral protein. Subsequent to this, the protein coats of adjacent viruses apparently fuse to form polyhedra.

The Annual Business Meeting of the Society was held at 11:00 a.m. (Report of the meeting follows.)

In the afternoon session of October 4, from 1:20 to 2:40 p.m., under the chairmanship of G. T. Harvey, the following papers were presented:

RANDALL, A. P. (Chemical Control Research Institute, Ottawa). Application of insect control methods for the protection of forest trees.

A brief account is given of the concept of ultra-low-volume (ULV) spray application of concentrate insecticides by aircraft, for the control of the spruce budworm, *Choristoneura fumiferana* (Clem.). Results of aerial spray experiments during the past four years for

the control of the spruce budworm, in New Brunswick, confirmed the original hypothesis of droplet size effectiveness at dosage deposits as low as 2 to 6 oz/acre. A comparison of ULV concentrate spray (4 to 6 fl oz/acre), with standard boom-and-nozzle sprays (64 fl oz/acre), produced similar levels of budworm mortalities at comparable ground deposits of active ingredients. Experimental evidence is presented which supports the concept of a defoliation index as a reflection of insect control rather than that of an insect mortality index, as the criterion of forest protection. The concept is based on the protection of growing foliage through the use of early spray application of systemic insecticides applied prior to the development of the deciduous forest canopy, of individual bud shoots, and the advanced exposed instar stage of the insect.

McClanahan, R. J. (presented by C. D. F. Miller) (Research Station, Harrow). Selective acaricides for integrated control of the two-spotted spider mite.
Spray tower tests were made to establish which acaricides controlled *Tetranychus urticae* Koch at doses that did not harm the predaceous mite *Phytoseiulus persimilis* (Athias-Henriot). Eggs, nymphs and adults of both species were sprayed separately. BAY 58733, Micasin, Milbex, tetradifon and tetrasul (Animert V101) were shown to be harmless to the predator at 0.2 percent. The last three materials helped eliminate prey mites and had no effect on the oviposition of *P. persimilis* when applied to a predator-prey population in a closed ecosystem. Possible application to greenhouse cucumbers was discussed.

Howse, G. M. and W. L. Sippell (Forest Research Laboratory, Sault Ste. Marie). Spruce budworm control in northwestern Ontario.

From 2:40 to 4:30 p.m. members were free to visit the Insect Pathology Research Institute and the Entomology Section, Forest Research Laboratory.

At 4:30 p.m. the new directors for 1968-1969 met in the Conference Room, Forest Research Laboratory.

Annual Business Meeting

The Annual Business Meeting was held at 11:00 a.m. on October 4 in the Centennial Room of the Public Library.

The meeting, attended by 82 persons, was opened by President H. R. Boyce.

The minutes of the last annual meeting were accepted as circulated to the membership on a motion by T. A. Angus, seconded by H. B. Wressell.

The Financial Statement for the year ended December 31, 1967, was accepted on a motion by the Secretary, seconded by W. C. Allan. Following the discussion, a motion by H. A. U. Monro, seconded by S. G. Smith, recommended that the Directors consider investing society funds that are in excess of a "working minimum" of one thousand dollars.

The Interim Financial Report for the period ending September 30, 1968 was approved on a motion by S. E. Dixon, seconded by A. H. Rose. In the discussion that followed J. M. Cameron outlined possible changes in the fee structure of the Canadian Society.

Of the 267 ballots mailed to the membership 160 were returned. The Directors for 1968-69 are J. M. Cameron, S. E. Dixon, H. W. Goble, D. G. Harcourt, D. C. Herne, M. G. Maw and G. E. Shewell.

In a second ballot the membership approved the election of George Francis Manson as a Fellow of the Entomological Society of Ontario.

Editor's Report

Volume 98 of the Proceedings is being prepared and includes five reviews of infestations of insect and nematode pests in Ontario, eight submitted papers and the proceedings of the 104th Annual Meeting held at Kingston, November, 1967.

Members of the Society and other entomologists are encouraged to submit papers on all branches of entomology for Volume 99, in particular reviews of infestations and studies of insects in Ontario. Please prepare papers according to the guide on the back cover of Volume 97 and submit them by January 15, 1969.

W. W. Judd, Editor

It was moved by the Secretary-Treasurer and seconded by S. E. Dixon that the Report be accepted. Carried.

J. M. Cameron reminded the members that next year we will be publishing the 100th volume of our Proceedings and suggested that every effort be made to make this an outstanding issue. The secretary will circulate this request to the membership.

Librarian's Report

During 1967 the Library has handled mostly requests for library loan material. Many requests through this service have been for photocopy and were non-returnable. Libraries using our services most frequently were: C.D.A., Ottawa, MacDonald College, Forestry Research, Fisheries Research Board, and Royal Ontario Museum. Most requests were for articles in older journals. Very seldom did we receive a request for an article appearing in a current publication.

We have maintained 70 exchange agreements involving the Canadian Entomologist plus Proceedings of the Entomological Society of Ontario. These are handled through the Treasurer's Office of the Entomological Society of Canada.

Our own Society also maintains a mailing list of approximately 90 addresses to which we send the "Proceedings". Some of these organizations send us publications in exchange but many have no publication available and merely wish to have our journal in their library or reference collection.

We have not altered the exchange list involving the "Canadian Entomologist" since 1964 but the list with the "Proceedings" only has had quite a few addresses added during the past few years.

The McLaughlin Library of the University of Guelph has agreed to take over and operate our library. This Committee therefore requests that a specific take-over group be named by the Board of Directors of the Society to enquire into and decide upon the actual mechanics and detail of the take-over.

W. C. Allan, Librarian

It was moved by W. C. Allan and seconded by W. Y. Watson that this report be accepted. Carried.

Considerable discussion followed on the future of the Society Library and the proposed incorporation of it into the McLaughlin Library at the University of Guelph. Opinions were expressed against splitting the library holdings and on increasing, rather than decreasing, exchanges. On a motion by C. D. F. Miller, seconded by T. A. Angus, it was recommended that the incoming Directors appoint a special committee to work with the librarian to make a complete study on the agreement with the Canadian Society and exchanges. This motion was carried.

R. M. Belyea asked if putting the library holdings on microfiche had been considered. Suggestions and questions on appraising library holdings, insurance and restricting of circulation of rarer journals were discussed.

New Business

It is with profound regret that the passing of C. C. Steward, former Secretary-Treasurer of the Society, is herein recorded.

A. L. West, President of the Entomological Society of Canada, spoke briefly on topics under consideration in the national society.

E. J. LeRoux, in a letter to the president, asked that members submit names of persons they deem worthy of consideration for the Gold Medal Award. These suggestions are to be made by individuals and are to be received by December 15, 1968.

W. E. Baldwin opened a discussion on the honorarium given to the Secretary-Treasurer and moved that this be increased to $150.00. This was seconded by H. A. U. Monro. The motion was carried.

W. E. Heming extended an invitation to the Society, on behalf of the University of Guelph, to meet there next year. Acceptance of this was unanimous.

Report of Resolutions Committee

H. A. U. Monro, Chairman; P. D. Syme, H. B. Wressell.

1. WHEREAS the City of Sault Ste. Marie has afforded assistance and contributed greatly to the success of the 105th Annual Meeting BE IT RESOLVED that our Society through the Secretary extend to Mayor A. C. Harry, Q.C., the Library Board and the Chief Librarian, our sincere thanks.
2. WHEREAS the Program and Local Committees under Chairman C. R. Sullivan have done an outstanding job in preparing for the meeting BE IT RESOLVED that our Society through the Secretary express our appreciation for their efforts.
3. WHEREAS the Department of Forestry and Rural Development has contributed in many ways to the arrangements for and success of the meeting BE IT RESOLVED that our

Society through the Secretary express our gratitude to Dr. R. M. Belyea, Regional Director for that Department.

4. WHEREAS the competition for the President's Prize continues to be an important and valuable feature of our program BE IT RESOLVED that our Society express our appreciation to Dr. F. W. Fletcher, Dr. W. F. Baldwin and Dr. W. L. Sippell for their contribution by serving as judges.
5. WHEREAS the various social functions contributed greatly to the success of the meeting BE IT RESOLVED that the special thanks of the Society be extended to the Sault Ste. Marie Folk Arts Council and to the Commanding Officer 49th Field Regiment, R.C.A.
6. WHEREAS the standard of the illustrations accompanying the papers presented at this meeting has varied from excellent to mediocre BE IT RESOLVED that the Directors of the Society undertake measures to bring about improvements in the visual presentation of scientific data at future meetings.

The Meeting was adjourned at 12:45 on a motion by W. E. Heming, seconded by C. D. F. Miller.

Meeting of Incoming Directors

The meeting of incoming Directors was held in the Centennial Room of the Public Library on October 4 at 4:30 p.m.

The meeting of the Directors was called to order by President H. R. Boyce who asked for nominations for the position of President. On a motion by D. C. Herne, seconded by M. Maw, J. McB. Cameron was elected on a unanimous vote and he accepted the chair from Past-President Boyce.

H. W. Goble was elected Vice-President on a motion by H. R. Boyce, seconded by D. G. Harcourt.

The Secretary-Treasurer was re-appointed on a motion by D. C. Herne, seconded by G. E. Shewell.

W. C. Allan was re-appointed as Librarian on a motion by H. R. Boyce, seconded by M. Maw.

The Nominating Committee was formed in part, by the appointing of H. R. Boyce and D. H. Pengelly. The Chairman is to be found and appointed by the President.

W. C. Allan and W. H. A. Wilde were named scrutineers for the balloting of the Society.

As directed by the membership at the Annual Meeting, a committee was formed to study the Exchanges within the Society Library and to investigate all aspects of the proposed incorporation of the Society's holdings into the University Library at Guelph. On a motion by D. G. Harcourt, seconded by H. R. Boyce the committee was established: W. C. Allan (chairman), S. E. Dixon, W. E. Heming and D. C. Herne.

The previous Nominating Committee, chaired by Joan F. Bronskill, had been asked to bring forth names of entomologists to be considered for election as Fellows of the Society. Eight names were placed with the Secretary and before these were presented, discussion centered on the numbers of Fellows the Society would have at any one time. D. G. Harcourt made the following motion "The maximum numbers of Fellows in the Society be limited to 4 percent of the membership *or* 10 persons, whichever is greater, and that not more than 1 percent be elected in any one year". H. R. Boyce seconded the motion, and it was accepted unanimously.

A secret ballot by the Directors selected names of those who will be considered for Fellowship. These will appear on a ballot in May 1969.

For the meetings of the Society, to be held in Guelph, in 1969, P. E. Morrison (Waterloo) was named Program Chairman, and S. E. Dixon Chairman of the Local Committee.

APPENDIX I

FINANCIAL STATEMENT FOR 1968

RECEIPTS		EXPENSES	
Dues Received	$2,256.90	Dues to Ottawa	1,759.00
Exchange Included	12.50	Exchange paid	22.55
Sale of Reprints	1,032.00	Library	200.00
Sale of Proceedings	30.81	Printing	673.64
Premium U.S. Funds	26.76	Stationery	47.06
Bank Interest	107.74	Postage	375.35
Bond Interest	18.00	Annual Meeting	
Grant Prov. Gov't	300.00	Advance	100.00
Library Fee	1.00	Banquet	360.00
Refund from Printing	10.00	Pres. Prize	50.00
Receipts Annual Meeting	491.47	Programmes ('67)	10.50
	4,287.08	Programmes ('68)	72.73
Bank Balance Jan. 1/68	2,200.94	Auditors ('66, '67)	10.00
	6,488.02	Secretarial Assist.	25.00
Bonds	400.00	Cheque Returned	10.00
Investment Certificate	643.51	Honorarium to Sec.	75.00
	7,531.53		3,790.83
		Bank Bal. Dec. 31/68	2,697,19
			6,488.02
		Bonds	400.00
		Investment Certificate	643.51
			7,531.53

Signed:
B. E. Saunders
D. W. Wright
January 24, 1969

APPENDIX II

Two papers were presented by university students at the 105th Annual Meeting in the eighth annual competition for the President's Prize (see students, titles and abstracts above). The judges were F. W. Fletcher, W. F. Baldwin and W. L. Sippell. The prize was awarded to P. K. Chang, University of Guelph.

Kwang-poo Chang was born in Peking, China in 1942. He received the B.Sc. degree in Entomology and Plant Pathology in 1965 from the National Taiwan University. In 1968 he earned the degree M.Sc. from the University of Guelph in the Department of Zoology. His thesis dealt with the mycetome of *Psylla*. He is at present registered for the Ph.D. degree in the Department of Zoology, University of Guelph, where he is interested in invertebrate pathology.

V. IN MEMORIAM

CHARLES COWLEY STEWARD

July 29, 1907 — September 22, 1968

(obituary by W. O. Haufe, Canadian Entomologist, 101 (2): 186, 1969)

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AUTHOR'S GUIDE

1. Two copies of a manuscript are required by the Editor (including second copy of each figure by print or photostat).

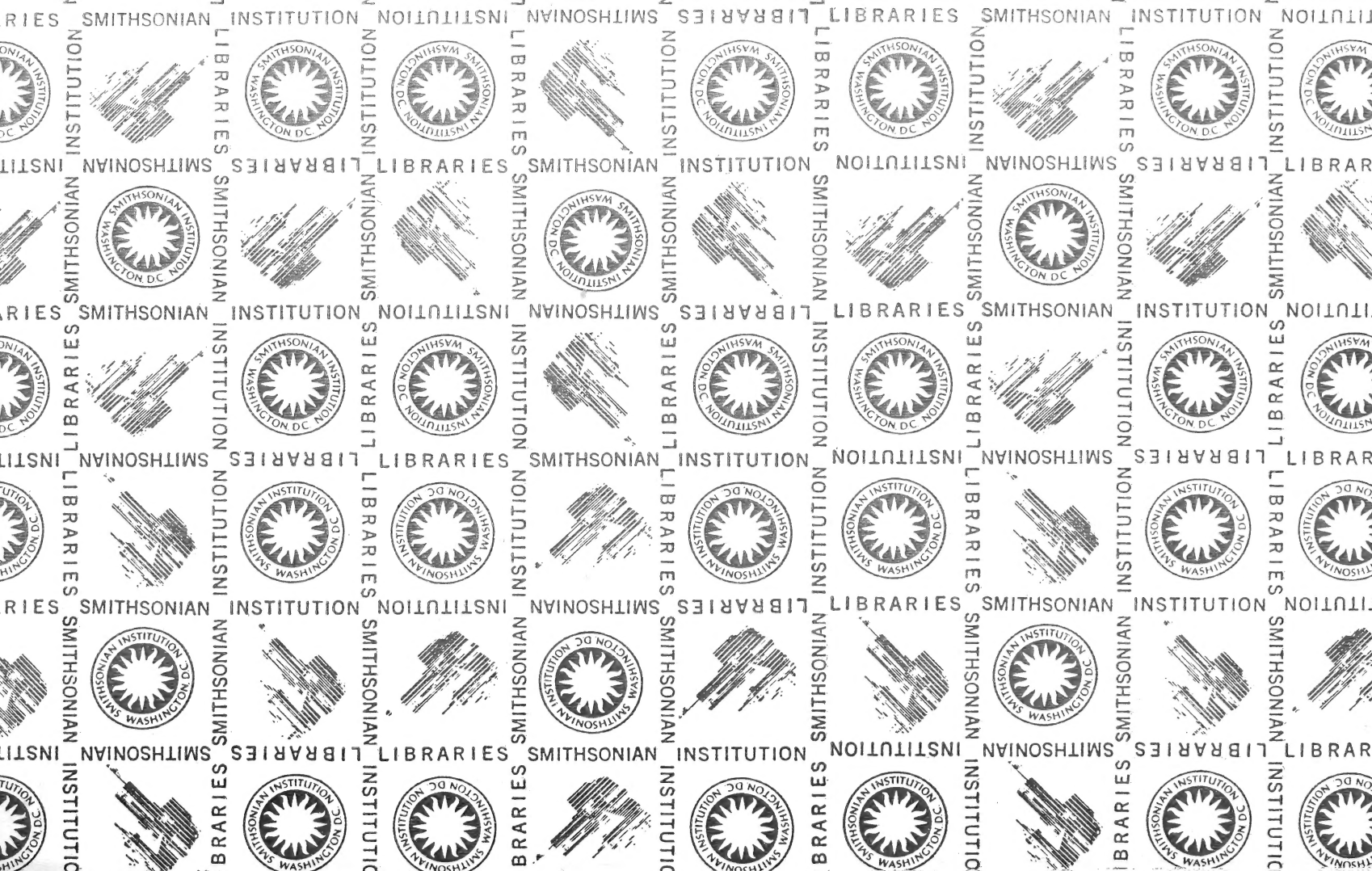
2. Manuscripts should be prepared in the manner described in the "Style Manual for Biological Journals", published by the American Institute for Biological Sciences, 2000 P. Street, N.W., Washington 6, D.C. 20036, U.S.A., 2nd ed. ($3.00).

   (a) Citations in text to bibliographic references should be made by use of the "name-and-year" system.

   (b) Refer to this Volume of the Proceedings for examples of type and style of titles, headings, etc.

3. Starting with Volume 99, arrangements have been made with the staff of Biological Abstracts for them to take abstracts directly from the volumes of the Proceedings. Each author is thus requested to insert an "ABSTRACT" of his article in the manuscript between the author's name (including his address) and the main body of the text.

4. Correspondence concerning, and orders for, reprints should be addressed to the Editor.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