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CARABIDAE (COLEOPTERA) AND ASSOCIATED ACARI IN NORTHWESTERN ONTARIO

by

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ABSTRACT

Carabids in Northwestern Ontario were found to follow one or another of three basic annual population curves reflecting both activity and actual population levels. Additional research is needed to ascertain whether or not other carabid species follow those three phenology patterns.

The carabid species *Scaphinotus bilobus* Say , *Sphaeroderus nitidicollis* Chevrolat, *Pterostichus coracinus* Newman and *Agonum decentis* Say were found to be primary associates of the mites (hypopi) *Acotyledon, Sancassania, Kuzinia* and *Schwiebea*. Those mites and *Poecilochirus* deutonymphs were common associates of the carabids studied. Other mites were infrequently associated with the carabids. The mites did not appear to associate selectively with either sex of carabid, particular species of carabid or particular sites on the carabids. The mites were found most commonly on ventral surfaces and rarely under elytra, and did not appear to be associated with the carabid eggs, pupae or overwintering adults. The mites appeared to be phoretic on the carabids, using them as a means of transport to environments more suitable to further development.

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1.0 INTRODUCTION

1.1 Carabid Systematics and Biology

The carabid (Carabidae: Coleoptera) fauna of North America north of Mexico is well known, Ball (1960) and Lindroth (1961-69) having revised and added to earlier work by North American coleopterists such as T.L. Casey, P. F. M. A. Dejean, H. C. Fall, W. Kirby and J. L. Leconte. Lindroth's *The Ground Beetles of Canada and Alaska* (1961-69) provides identification keys, descriptions and some biology of carabids of Northwestern Ontario.

Notable ecological studies of Carabidae in Canada have been made by Rivard (1964*a*, *b*; 1965), Barlow (1970), Frank (1971) and Goulet (1974). Rivard (1964*a*, *b*; 1965) studied breeding periods and dispersal patterns of some ground beetles in eastern Canada. Barlow (1970) examined phenology and distribution of some species of *Pterostichus* in eastern Canada. Frank (1971) and Goulet (1974) worked in Alberta, the former on biology of field carabids, the latter on biology and relationships of *Pterostichus adstrictus* Eschscholtz and *P. pensylvanicus* Leconte.

Research on some aspects of carabid ecology has been conducted in Northwestern Ontario. Freitag *et al* (1969) and Freitag and Poulter (1970) studied effects of two pesticides on populations of carabids and spiders. Mercer (1970), Ostaff (1971) and Ostaff and Freitag

(1973) conducted preliminary research on carabids and associated mite populations. Benson (1972) studied the phenology of some carabid species. Freitag and Hastings (1973) and Freitag *et al* (1973) studied ground beetle populations near a kraft mill.

1.2 Acarine Systematics and Biology

Life history data is meagre or absent for most mite groups. While approximately 30,000 species of Acari have been described, an estimated additional 500,000 species have yet to be described (Krantz 1975). Baker and Wharton (1952), Baker *et al* (1958), Hughes (1959), Evans *et al* (1961) and Krantz (1975) have written general texts on Acari which are used in North America.

1.3 Mites and Insects

Sellnick (1939), Vitzthum (1940-43), Trägårdh (1943), Cooreman (1961) and MacNulty (1971) have conducted general surveys of mite-insect relationships.

Taxonomic papers on insecticolous mites have been written by Turk (1948), Ryke and Meyer (1957, 1958), Ryke (1959), Samšinák (1957, 1960, 1962), Womersley (1958, 1959, 1960), Evans and Hyatt (1963), Hyatt (1964), Hunter and Moser (1968), Hunter and Yeh (1969), Costa (1969*a*, 1971) and Fain (1970).

Surveys of the mite fauna associated with particular insect species or groups of species have been conducted by Berlese (1903), Vitzthum (1926, 1930), Hyatt (1959), Krombein (1962), Costa (1963), Hunter and Davis (1963) and Hurlbutt (1967).

The biology of insect hosts and their associated mites have been studied by Neumann (1943), Skaife (1952), Rapp (1959), Mollin and Hunter (1964), Krantz and Mellot (1968), Springett (1968) and Smith and Oliver (1976).

1.4 Mites and Beetles

MacNulty (1971) stated that mites are found more often on Coleoptera than on insects of any other order but that investigations of such associations are rare. He listed 100 references for mite-beetle studies and stated that many of the relationships were probably more complex than phoresy.

Evans and Hyatt (1963) and Costa (1966, 1969*b*) have studied mites on manure and coprid beetles. Bark beetles and associated mite populations have been studied by Hunter and Davis (1963), Krantz (1965), Hurlbutt (1967), Lindquist (1967, 1969*a, b*), Hunter and Moser (1968), Moser and Roton (1971), Kinn (1971) and Moser (1975, 1976*a, b*). Other mite-beetle associations have been studied by Trägårdh (1946), Hunter and Davis (1965) and Hunter and Yeh (1969). These studies have generally been surveys or ecological works.

Little work has been done on carabid beetles and their associated mite populations. Soper and Olson (1963) and Nickel and Elzinga (1969) have studied some aspects of carabid-mite associations. Lindquist (1970) stated that carabids serve as hosts for various mites including external parasites, tracheal parasites, commensals and phoretic commensals. He also noted that carabids may prey on large predaceous mites. Mercer (1970), Ostaff (1971) and Ostaff and Freitag (1971) studied some aspects of the ecology of carabids and their associated mite populations in Northwestern Ontario.

1.5 Objectives

The main purpose of the present research was to study various aspects of carabid and associated mite populations in leaf litter habitats in Northwestern Ontario, details of which are summarized as follows: phenology of commonly collected carabids, effects of pitfall trapping on carabid populations in the trapping sites, numbers of male and female carabids in relation to time, effects of some components of weather on pitfall collections, the species composition of mite populations found externally on carabids and beneath their elytra, mite density and frequency of occurrence on carabids in relation to time and to carabid sex, degree of host and site specificity of mites on beetles, interdependence of life cycles or absence thereof, and nature of mite-carabid relationships.

2.0 MATERIALS AND METHODS

2.1 Collecting Sites

Two sites for collecting carabids were chosen, site A beside highway 11 0.8 km west of the junction of highways 11 and 17 at Shabaqua 65 km northwest of Thunder Bay, and site B beside Gilbride Road near One Island Lake 32 km northwest of Thunder Bay.

Both research sites consisted of stands of mature, mixed boreal forest with 3 to 10 cm of leaf litter and humus. Balsam fir, white and black spruce and trembling aspen were the most common tree species in both sites. On 20 June, 1977, a list of plants evident in reasonable abundance at that time was compiled with the assistance of D. R. Lindsay for both sites.

Site A was a more mature stand with a greater predominance of deciduous trees and a deeper leaf litter layer. The soil was primarily clay (as opposed to sand in B) and retained soil moisture longer than in site B. Plant growth appeared to be somewhat more dense in site A and two more plant species were found in A than B (Table 1).

2.2 Specimens Examined

Between 26 May, 1976 and 23 December, 1977, 1863 adult carabid beetles (Tables 2, 4, 5) representing 12 genera and 15 species were collected. Ostaff (1971) collected 16 species, Benson (1972) 19.

A total of 4826 mites was identified from 554 carabids (11 species) collected in 1976. Twelve adult mites representing six families and seven genera, one tritonymph, 64 deutonymphs representing two families and two genera and 4749 hypopi representing two families and four genera were identified for a total of 13 genera of mites found on the carabids. No additional mite genera were found on carabids collected in 1977.

2.3 Pitfall Traps

In each site pitfall traps were placed in four parallel rows 10 m apart. Rows contained 25 traps 4 m apart. Pitfall traps were white plastic containers 7 cm deep and 11.5 cm in diameter at the top. They were buried in the soil with the top edge level with the soil surface. A 15 cm square of 1.5 cm mesh chicken-wire over each trap prevented the entrance of larger animals. An aluminum pie plate over each trap reduced the entrance of precipitation and debris. Pie plates were perched on twigs or natural ground contours to allow easy entrance to the traps. Area around trap edges was disturbed minimally.

2.4 Pitfall Trapping

No collecting liquid or bait was used. Southwood (1966) stated that artificial (Stammer 1949) or natural (Barber 1931; Walsh 1933) baits can introduce a further source of error into pitfall trapping.

Some hypopi and all other mite stages found externally on the carabids were dislodged in the vials of 70% ethanol in which the beetles were preserved. Collecting fluid in the pitfall traps would have similarly dislodged mites prior to collection of the carabids. Free-living mites which fell into the pitfall traps would also have been found in the collecting fluid.

Esau (1968) thoroughly reviewed pitfall trapping. He concluded that pitfall traps can be used to effectively study short-term and annual activity periods, presence (or absence) of species, distribution of species over a range, seasonal incidence, some aspects of behaviour and population dispersal, or habitats of certain fauna.

Tretzel (1955), Grüm (1959), Briggs (1961), Mitchell (1963), Greenslade (1964) and Southwood (1966) have critically studied pitfall trapping. They concluded that data from pitfall trap studies reflects both population and activity levels and must be interpreted accordingly. A better overall method for collecting carabids was not proposed.

2.5 Collections of Carabids

In 1976, pitfall traps were put in site A on 19 May and in site

B on 26 May. Weekly collections were made from each site until 26 October. A last pre-winter collection was made on 9 November. Early in each of the months January through April 1977, 25 traps in each site were checked. Examining 25 traps in each site for each collection eliminated disturbance of the subnivean environment prior to collection. All of the traps were examined on 6 and again on 26 April. Weekly collections were then made from the traps in both sites until 24 May. Three hand collections of hibernating adult carabids were made in 1977, on 19 November and on 3 and 23 of December. Mounds of earth, rotten logs and stumps and surrounding areas on, in and under the leaf litter layer were examined for adult carabids, as outlined by Larochelle (1972*b*, 1974, 1975).

All carabid beetles collected were placed individually into vials of 70% ethanol with a label bearing date of collection and site and trap designation.

2.6 Carabid Identification and Examination

Adult carabids were identified to species using keys by Ball (1960) and Lindroth (1961-69).

Every second carabid collected between 1 June and 26 October for which two or more specimens of the species were collected was examined for mites. Each beetle was removed from its vial of ethanol and all of its external surfaces examined under a Wild M5 dissecting microscope. Elytra were either removed or lifted to permit inspection of elytral undersides and areas normally concealed beneath elytra. This procedure was followed with about half of the beetles examined externally.

2.7 Mite Specimens

One or more specimens of each species of mite found on the carabids was prepared for identification. Oribatid mites were merely placed in microvials containing 70% ethanol. Other representative mite specimens were mounted on plain microscope slides in Hoyer's Solution under round coverslips (number 2 thickness, 18 mm diameter). Where necessary, mites were cleared in warm lactic acid prior to mounting. Mounted specimens were placed in an oven at 43°C for five to seven days and then left at room temperature for a week or more before the coverslips were ringed with euparal.

Mites were sent to either E. E. Lindquist or R. A. Norton for identification.

3.0 RESULTS AND DISCUSSION

3.1 Record of Carabid Collections

Table 2 contains a record of weekly collections of carabids from sites A and B from June to October in 1976. Table 3 contains a breakdown of those collection records on a tri-weekly basis per site for purposes of comparison of the sites. Table 4 lists miscellaneous collections of carabids made in 1976 and 1977 in pitfall traps and by hand. Table 5 contains records of May 1977 collections from each site. Table 6 contains the data from the present study and from previous pitfall collections from Northwestern Ontario on weekly carabid collections for periods of various lengths. Dates given in Table 6 are from the present study and are only approximately accurate for previous studies listed. Data is given for 100 traps in all instances although Freitag and Poulter (1970) used 20 traps and Mercer (1970) and Ostaff (1971) used 25 traps in each of their sites.

3.2 Comparison of Collecting Sites

Table 3 illustrates that sites A and B are essentially similar although A is noticeably richer. Consistently larger collections of carabids were made at site A. Only *Pterostichus adstrictus* was more common in site B. Total numbers of the most common species per tri-weekly period shows that collections rose and fell synchronously at both sites (yearly population peaks are variable (Table 6)).

Carabid species composition from each site also illustrates that the sites are similar although A is richer. Eleven carabid species were collected from site B. All 11 species were also present in site A. In addition, the species *Calosoma frigidum* Kirby, *Agonum superioris* Lindroth, *Amara laevipennis* Kirby and *Bradycellus lugubris* Leconte were collected from site A only.

3.3 Collections of Carabids

On 26 May, 1976, 129 carabids were collected from site A (Table 4). This data was included in outlining phenology of individual carabid species because data for each site was considered independently therein. Between 1 June and 26 October, 1106 (Table 2) carabids were collected from both sites. Examination of those specimens produced the major body of data for the present study. One carabid was collected on 9 November. No carabids were collected from the pitfall traps during the winter of 1976-77 (Olynyk 1977).

Between 6 April and 26 April 1977, and during May, 15 (Table 4) and 603 (Table 5) carabids respectively were collected, recording for the first time earliest spring carabid activity in Northwestern Ontario. Hand collections of hibernating adult carabids were made on 19 November and 3 and 23 December in site A (Table 4) to provide information on local carabid adults and mites in winter. Those collections yielded a total of nine carabids.

3.4 Phenology of Carabids Commonly Collected

Tables 7-9 contain collection records for five carabid species commonly collected from pitfall traps in Northwestern Ontario. Dates following collectors' names refer to the year of collection. Weekly collection dates refer to the present study and are only approximately accurate for other studies listed. Data is given for 100 pitfall traps although Freitag and Poulter (1970) used 20 traps and Mercer (1970) and Ostaff (1971) used 25 traps in each of their sites. Descriptions of life cycles in this section are based on data in Tables 7-9, and on Tables 4 and 5.

Adults of *Sphaeroderus nitidicollis* Chevrolat appeared in May (Tables 5, 7). Collected specimens were most abundant in early June. Numbers decreased rapidly and remained low until fall. A second population peak occurred in September, almost equal in magnitude to the spring peak. Teneral adults were collected in fall in the present study, suggesting imaginal overwintering.Peak numbers collected in spring were probably due to intense feeding, mating and oviposition activity and in fall due to emergence and mating.

Lindroth (1955) stated that *S. nitidicollis* adults overwinter.

Larochelle (1972*a*, 1974) collected hibernating adults.

Adults of *Pterostichus adstrictus* appeared in April (Tables 4,5,7). Numbers of specimens collected weekly peaked in early June. Few specimens are captured after June. Imaginal overwintering is indicated by early appearance of adults in spring and low numbers collected in fall suggests that mating activity occurs exclusively in spring.

These findings agree with those of Lindroth (1961-69), Frank (1971) and Goulet (1974). They all concluded that *P. adstrictus* adults overwinter and all collected immature adults in fall. Frank (1971) collected gravid females from 10 May to 17 July. Goulet (1974) observed that adults actively sought food and mates in early spring, oviposition occurred in May and June, and that larvae pupated from late August to late September. He observed some mating in fall.

Adults of *Pterostichus pensylvanicus* appeared in April (Tables 4,5 8). Numbers of specimens collected weekly peaked in early June. Numbers then decreased rapidly and remained low until October when large numbers were again collected. Teneral adults were captured in fall. Peak spring collections were probably due to intense feeding, mating and oviposition activity, peak fall collections due to emergence of adults and mating activity.

Earlier research supports these conclusions. Lindroth (1961-69) collected immature *P. pensylvanicus* adults in August and September. Larochelle (1972*a*, 1974) collected hibernating adults in winter. Goulet (1974) observed that males suffer higher winter mortality among overwintering adults and that peak feeding, mating and oviposition activity occurred in spring. He also found that adults tended to be quiescent in summer and that newly emerged and older adults (some survived two or three winters) were active in September and October with some mating activity occurring at that time.

Adult *Pterostichus coracinus* Newman appeared in late May (Tables 5 and 9). Numbers of collected specimens per week increased until early July and then gradually decreased until September. A temporary drop in weekly collections occurred about mid-June. Relatively late appearance of adults in spring and low numbers collected in fall suggest that *P. coracinus* overwinters in an immature form. Declining numbers in mid-June could be due to a brief period of inactivity following adult emergence and preceeding mating and oviposition activity. It is also possible that the mid-June decline in numbers occurred after the period of mating and oviposition activity of adults which had overwintered. Progeny of adults which mated in early July would overwinter in an immature form and mate the following July.

Previous studies do not help to clarify uncertainty in the pattern of the *P. coracinus* life cycle. Lindroth (1955, 1961-69) captured many immature adults in fall and stated that imaginal overwintering was certain. Larochelle (1972*a*, 1974) collected hibernating adults. Barlow (1970) suggested that both adults and larvae overwinter. Thiele (1973) found that newly emerged adult carabids were initially active but entered an aestivation diapause or parapause prior to mating. Thiele (1969), Greene (1975) and others have reported on similar patterns in other carabids.

Adults of *Agonum decentis* Say appeared in early May (Tables 5,9). Weekly collections were greatest in early June and decreased rapidly thereafter. Few specimens were captured after July. Early appearance of adults in spring suggests imaginal overwintering.

Previous authors provide marginal substantiation to suggest imaginal overwintering. Lindroth (1961-69) collected one adult in September and Larochelle (1972*a*, 1974) recorded collecting some hibernating adults.

3.5 Patterns of Carabid Phenology

Goulet (1974) found that adults of *Pterostichus adstrictus* and *P. pensylvanicus* were quiescent in the summer months following intense feeding, mating and oviposition activity in spring. Barlow (1970) noted that death of individuals spent from spring breeding was also a factor in smaller summer collections of those species.

Pitfall collections are governed in magnitude by both activity and population levels. Peak collections occur during periods of adult emergence and feeding and reproductive activity. Optimum collecting periods during the year vary with the species of carabid.

Carabid species in Northwestern Ontario follow one or another of three basic annual population curves. These curves are presented in a generalized form in Figure 1.

The first population curve is bimodal, peaks occurring at the beginning of June and again in fall. Adults are active in early spring. Peak spring collections result from accelerated feeding, mating and oviposition activity and fall collections to emergence and some mating activity. The species *Sphaeroderus nitidicollis* and *Pterostichus pensylvanicus* followed this pattern.

A second population pattern was exhibited by *Pterostichus adstrictus* and *Agonum decentis*. A single population peak occurs in early June. These species mate exclusively in spring, with intense feeding and reproductive activity occurring at that time. Adults emerge in fall but hibernate rather than mate at that time.

A third pattern was exhibited by *Pterostichus coracinus* and by *Scaphinotus bilobus* Say, *Calathus ingratus* Dejean and *Agonum retractum* Leconte. Some adults are collected in spring, then there is a temporary decline in collections and peak numbers collected in early July. Some individuals are collected in fall. Part of the population overwinters in an immature stage and reproduces in early July; the other part of the population overwinter as adults and reproduce in spring. Benson (1972) provides strong supportive data for this pattern for *P. coracinus*, *C. ingratus* and *A. retractum*. A slight increase in numbers collected in fall is due to emergence of progeny of carabids which reproduced in spring.

It appears that the magnitude and temporal separation of major population peaks in curves of the first and third type in relation to one another are somewhat variable. The species of carabids involved would be expected to cause some differences and various environmental factors would also be expected to assert some effects.

Holliday and Hagley (1978) collected ground beetles in apple orchards in Ontario. Their results indicate that *Harpalus affinis* Schrank follows the first type of population curve, *Amara* spp. the second and *Pterostichus melanarius* Illiger the third.

Comprehensive analysis of earlier studies and future research are needed to determine whether or not carabids always follow the three basic annual population curves outlined herein. Timing of various segments of the life cycles will probably be found to vary to some degree.

3.6 Numbers of Male and Female Carabids

Table 10 lists the numbers of male and female carabids collected by Mercer (1970), Ostaff (1971), Benson (1972) and during the present study. The five species of carabid beetles most commonly collected in Northwestern Ontario are included in the table.

Many more female than male *Sphaeroderus nitidicollis* were collected. Mercer (1970) and Benson (1972) captured more males.

Many more female than male *Pterostichus pensylvanicus* were collected. Benson (1972) had similar results, but Ostaff (1971) captured only a few more females.

Many more male than female *P. coracinus* were collected. Benson (1972) had similar results, but Mercer (1970) captured almost equal numbers of both sexes.

Approximately equal numbers of male and female *P. adstrictus* and *Agonum decentis* were collected. Ostaff (1971) had similar results, but Benson (1972) collected many more females of both species.

Proportions of males and females of each species of carabid collected are variable between years and sites. Generally, female *Pterostichus pensylvanicus* and male *P. coracinus* are more commonly collected. Almost equal numbers of male and female *Sphaeroderus nitidicollis*, *P. adstrictus* and *Agonum decentis* are normally collected.

Table 10 also serves to illustrate that proportions of males and females were generally similar throughout the collecting season. The species *Sphaeroderus nitididcollis* was the sole exception. Many more females were captured in spring and more males in fall. Fall mating, with males actively seeking mates could explain larger collections of males in fall. Goulet (1974) found greater winter mortality among male *Pterostichus pensylvanicus*. Randolph *et al* (1976) noted that adult female carabids had stored fat bodies in fall. It is possible that female *S. nitidicollis* suffer lesser winter mortality. Males would again actively seek mates in spring but their numbers would be reduced from fall levels and females would be actively seeking oviposition sites; therefore more females would be collected in spring. Activity level differences for both sexes must be determined in a temporal framework before actual differences in numbers of males and females can be quantified from pitfall trap studies. Activity level differences may be variable among various carabid species.

3.7 Correlations of Carabid Activity with Weather

Weather data was taken from monthly meteorological summaries supplied by the Thunder Bay Airport station of the Atmospheric Environment Service of Environment Canada.

Figures 2-4 illustrate the relationships of the magnitude of carabid collections to some components of weather.

Figure 2 indicates a negative correlation between pitfall trap collections and rainfall. Low rainfall corresponded to increased carabid collections on 1 June, 6 July, 24 August, 7 September and 5 October. High rainfall corresponded to decreased carabid collections on 15 June, 20 July and 21 September.

Correlations between carabid collections and both hours of bright sunlight (Figure 3) and temperature (Figure 4) appeared to be positive but were generally ill-defined. Carabid collections and hours of bright sunlight both increased on 6 July and 5 October and similarly decreased on 15 June, 13 July and 12 October. Carabid collections and temperature both increased on 1 June, 24 August and 5 October and decreased on 31 August and 12 October.

Hours of bright sunshine and rainfall would obviously be expected to have opposite effects because bright sunshine has a drying effect.

Grüm (1959) found that temperature decreases in spring reduced carabid collections. Briggs (1961) and Greenslade (1961) found that pitfall collections and temperature were positively correlated. Thiele (1964) found that light and humidity determined carabid distribution. Krehan (1970) stated that parapause in carabids was terminated in spring by increasing day length and temperature. Total carabid activity seems to be a product of activity due to light, activity due to temperature and activity due to various other factors (Williams 1940).

Peak carabid collections in 1977 occurred two weeks earlier than in 1976 (*see* Tables 2 and 5). Spring 1977 was unusually mild. Weather conditions seem to modify both the timing and intensity of peak periods of carabid activity to some extent (Table 6).

3.8 Effects of Pitfall Trapping on Carabid Populations

Pitfall traps in both sites were designated as peripheral or central as per Table 11 and collections from both groups of traps were recorded for carabid collections in May 1977. Average number of carabids collected weekly per 10 traps of each group was used as an arbitrary basis of comparison, and was greater twice for peripheral traps, once for central traps and equal once. Differences were small and overall averages were almost equal, 7.5 for peripheral traps and 7.2 for central traps.

It is noteworthy that the openings of the pitfall traps equalled less than 0.1% of the surface area bounded by the rows of traps.

Pitfall collections in May 1977, after a full year of pitfall trapping in both sites, did not show a decline in numbers of carabids collected in relation to 1976 collections. More carabids were collected during the spring population and activity peak in 1977 than in 1976.

Esau (1968) noted that no carabid species was found with greater frequency in his outside pair of pitfall traps and concluded that major faunal elements of communities sampled were not depleted. Barlow (1970) stated that a trapping artifact may occur in carabid populations where individuals caught are not released. Individual numbers would be lower in the next generation unless replaced by immigration. Immigration of carabids into a site would be reflected by more carabid captures in peripheral traps.

Pitfall trapping did not seriously reduce the number of carabids within the areas bounded by the traps and no appreciable amount of immigration of carabids into the research sites occurred (Table 11).

3.9 Mites Collected

More than 90% of 4826 mites identified in 1976 (Table 12) were hypopi, primarily of the family Acaridae (Canadian Acaridae are relatively well known, having been revised as early as 1945 by Nesbitt). Precise numbers of each species were not determined because of their size and similar appearance. Approximate percentages of the total number of hypopi were calculated (from exact numbers of each on ten carabids) for each species as follows: *Sancassania* (=*Caloglyphus*) sp. 65, *Kuzinia* sp. 20, *Schwiebea* sp. nr. *S. nova* Oudemans 5 and *Anoetus* (=*Histiostoma*) sp. 10. The three former are in the Acaridae, the latter in the Anoetidae.

Sixty-three deutonymphs of *Poecilochirus* sp. nr. *P. carabi* Canestrini and Canestrini (family Parasitidae) were collected. Eight other mite species were collected infrequently in 1976.

The four species of hypopi collected in 1976 and *Poecilochirus* sp. deutonymphs were present on carabids collected in May 1977.

Table 12 lists mites found on carabids collected in 1976 and similar information from studies made by Mercer (1970) and Ostaff (1971).

Mercer (1970) and Ostaff (1971) also collected hypopi of

Sancassania and *Schwiebea* species. They both collected *Acotyledon* hypopi rather than *Kuzinia* hypopi as in the present study. In the family Anoetidae, Mercer (1970) collected *Spinanoetus* hypopi, Ostaff (1971) collected hypopi of an undetermined genus and in 1976, *Anoetus* hypopi were collected.

Mercer (1970) did not record collecting mites other than hypopi. Ostaff (1971) recorded collecting five mite genera in which the deutonymph or adult stage was present on the carabids. Of these genera, only *Poecilochirus* was found in the present study.

In all three studies, only the genus *Parasitus* collected by Ostaff (1971) was present on the carabids in more than one stage or sex. Deutonymphs and females were collected. Presence of only one instar cannot in itself indicate anything more than a phoretic relationship (Lindquist 1975).

3.10 Mites Found Beneath Carabid Elytra

A total of 245 carabids was examined to determine if carabids normally harboured mites beneath their elytra. The five most commonly collected carabid species (Table 2) and *Scaphinotus bilobus* Say were examined and the results summarized in Table 13. Only 1.6% of the carabids examined carried mites beneath their elytra.

Four carabids carried a total of six mites beneath their elytra. Two *Sancassania* hypopi were found on the underside of an elytron of a female *Pterostichus adstrictus*, one *Ceratoppia* sp. nr. *C. quadridentata* Haller adult was found on the body of a male *P. coracinus*, one *Scheloribates* adult was found on the body of a female *P. coracinus* and two *Antennoseius* sp, nr. *A. pannonicus* Sellnick females were found on the underside of an elytron of a female *P. pensylvanicus*.

Three hypopi were found on the underside of an elytron of a female *P. coracinus* collected in May 1977. None of the other 99 carabids collected in May 1977 and examined for mites harboured any mites subelytrally. None of the carabids collected in April or winter of 1977 carried mites under their elytra.

Neither Mercer (1970) nor Ostaff (1971) recorded examining any carabids subelytrally for mites.

Mites were not commonly harboured beneath the elytra of carabids collected in the present study. Substantial subelytral mite populations would indicate a close relationship (Lindquist 1975).

3.11 Mite Density and Frequency of Occurrence on Carabids

Table 13 lists the density and frequency of occurrence of the mites on most of the carabid species collected. The second group of carabids in the table were not collected in large numbers.

Adults of *Scaphinotus bilobus* and *Sphaeroderus nitidicollis* carried mites most frequently, 95.5 and 79.7% respectively being carriers. High average numbers were also carried by both (42.5 and 27.2 respectively). Distribution of mites was more extreme on adults of *S. nitidicollis*, with some carrying 200 to 300 mites.

Moderate numbers of *Pterostichus adstrictus* and *P. pensylvanicus* carried mites, 48.9 and 39.0% respectively. Average mite numbers were low on beetles carrying mites, 3.5 and 4.2 respectively.

Frequency of occurrence of mites on *P. coracinus* and *Agonum decentis* was high, being 74.5% in both instances. Average mite numbers on beetles carrying mites were moderate, 9.4 and 6.6 respectively.

For other carabids examined, frequency of occurrence of mites ranged from 16.6% for *Harpalus fulvilabris* Mannerheim to 100.0% for *Patrobus longicornis* Say. Average numbers were low, ranging from 1.4 for *P. longicornis* to 4.3 for *Synuchus impunctatus* Say.

Data on mite density and frequency of occurrence was not quantified in 1977 but appeared to be similar to 1976 results.

Mercer (1970) noted average number of mites per carabid per habitat but did not calculate the frequency of occurrence of the mites on the beetles. Average density ranged from 19.9 to 139.8 for *Scaphinotus bilobus*, from 18.5 to 88.0 for *Sphaeroderus nitidicollis* and from 12.0 to 21.6 for *Pterostichus coracinus*.

Ostaff (1971) found an average of 1.8 mites per beetle for *P. adstrictus*, 1.3 for *P. coracinus* and 3.4 for *Agonum decentis* adults. He did not calculate frequency of occurrence of the mites on the beetles.

Data from the studies by Mercer (1970) and Ostaff (1971) generally confirm tendencies in magnitude of average number of mites per beetle found in the present study (Table 14).

Lindquist (1975) used the term primary associates to describe hosts of mites on which there are frequently large numbers of mites. He did not quantify magnitudes necessary to delimit primary associations.

An analysis of Table 14 suggests that *Scaphinotus bilobus*, *Sphaeroderus nitidicollis*, *Pterostichus coracinus* and *Agonum decentis* are primary associates of the mite species present as hypopi (see Table 12). Low frequency of occurrence of mites on beetles, low average mite numbers on infested beetles or insufficient data exclude other carabid species in Table 14 from being classified as primary associates of the mites.

3.12 Average Number of Mites per Beetle in Relation to Time

Average number of mites per beetle in relation to time (Table 15) increases gradually for *Agonum decentis* and decreases gradually for *Pterostichus adstrictus* adults from 1 June to 7 July.

The species *Scaphinotus bilobus* and *Sphaeroderus nitidicollis* had constantly fluctuating mite numbers per beetle over the entire collecting period. Adults of *Pterostichus pensylvanicus* were subject to less extreme variation in number of mites per beetle.

Adults of *P. coracinus* had increasing numbers of mites through June until early July, then gradually decreasing numbers.

Average number of mites per beetle was generally low in spring and fall. Peak mite numbers were found on the beetles in early July and late August in 1976. No mites were found on the carabids collected in April or in winter (hand collections) of 1977 (*see* Table 4).

Mercer (1970) did not record a pattern for mite numbers on the carabids in relation to time. Ostaff (1971) found peak mite numbers on carabids in early July and late August (same result as present study). Greene (1975), working with cychrine carabids in Washington, found acarid hypopi appearing on the beetles in late August with many hundreds of hypopi per beetle becoming common by October. He did not record examining any carabids for mites over winter.

Mite numbers were greatest in early July, a month after the population and activity peak of all of the most commonly collected carabids except *Pterostichus coracinus* and again in late August when few carabids were active. Mites seem to occur on carabids in Northwestern Ontario in cycles independent of the carabid life cycles.

Low mite numbers on carabids captured in early spring and late fall and absence of mites on carabids collected in April and winter of 1977 suggest that mites do not normally overwinter on carabids.

This is also suggested by Greene's (1975) study. He found large numbers of acarid hypopi on carabids by October, but virtually none on the beetles in spring.

Few if any mites were found on teneral *Sphaeroderus nitidicollis* or *Pterostichus pensylvanicus* in fall, suggesting that mites found in association with the adults were not also associated with pupae.

3.13 Carabid Sex in Relation to Mite Density

Average mite numbers on the most commonly captured carabid species (Table 2) are listed in relation to time in Table 16.

More mites were found on male *P. adstrictus* than on females, but differences in numbers were slight and based on only two sets of data. Among the other carabid species listed, mite numbers fluctuated in a seemingly random pattern. Neither sex had consistently higher densities of mites during any part of the time period surveyed.

Mercer (1970) captured more female than male carabids but did not sex all of the beetles. He found 3,434 mites on female carabids and 7,772 mites on male carabids in his study. Ostaff (1971) took 111 mites from 124 male carabids (average:0.9 mites per male carabid) and 228 mites from 168 female carabids (average:1.4 mites per female carabid). It seems that mites generally distribute themselves randomly on carabids of either sex.

Krombein (1962) studied acarid hypopi associated with adult bees and wasps. Hypopi were found to attach themselves to teneral adult bees and wasps. Some hypopi dropped off during oviposition to feed on eggs, young or provisions stored for larvae. Mite numbers on female carabids would decrease following oviposition if mites were transferred to carabid eggs during oviposition. Table 16 illustrates that few, if any mites are transferred to carabid eggs during oviposition.

Mites were found associated with adult carabids in Northwestern Ontario in a discontinuous relationship. It appeared that the mites were not associated with the carabid eggs or pupae and did not overwinter on the beetles.

3.14 Host Specificity

None of the mite species present as hypopi nor *Poecilochirus* deutonymphs were species-specific (Table 12). Low numbers of mites of other species collected from carabids in 1976 suggest that those mite species are not normal associates of carabid beetles.

Regenfuss (1968, 1972) and Samšinák (1971) found many species of mites in the families Podapolipidae and Canestriniidae to be highly host specific, all instars occurring under the elytra of their carabid hosts. Costa (1969*a*) and Lindquist (1975) stated that a high degree of host specificity indicates a close relationship.

None of the mite species present as hypopi on the carabids or *Poecilochirus* deutonymphs were host specific on the carabids, indicating that their relationship with the carabids is not close.

3.15 Site Specificity

None of the mite species present as hypopi on the carabids or *Poecilochirus* deutonymphs were found on specific areas of the carabids. They were found most commonly on ventral surfaces, but were also found on all of the external surfaces of the carabids.

Treat (1966, 1968) and Regenfuss (1972) found definite instances of site selectivity of mites on various insect hosts, while Greene (1975) recorded that only the elytral discs of the carabids he studied were substantially free of acarid hypopi.

Site selection specificity of mites on hosts reflects closeness of association (Lindquist 1975). This suggests that the relationship between the carabid and mite populations in the present study was not a close one.

3.16 Phoresy

Phoresy is a form of commensalism common throughout the Arthropoda but found in other phyla such as Nematoda (Poinar 1964) and Mollusca (Buttner 1953) also. Lesne (1896) first defined phoresy as follows:

> We will call phoresy all phenomena of transport in the strict sense, that is, those cases in which the transport host serves its passengers only as a vehicle.

Farish (1965) proposed a more rigid definition and Farish and Axtell (1971) modified that definition to read:

> Phoresy is a phenomenon in which one animal actively seeks out and attaches to the outer surface of another animal for a limited time during which the attached animal (termed the phoretic) ceases both feeding and ontogenesis, such attachment presumably resulting in dispersal from areas unsuited for further development, either of the individual or its progeny.

Linnaeus (1785) first mentioned phoretic attachment of Acari on insect hosts. Mégnin (1874) determined the true status of the hypopus, which was previously considered to be a separate genus.

There are four main types of phoresy in the Acarina. First the unspecialized type as in Macrochelidae, in which adult females are the only phoretics and attachment is by chelicera. Second in Parasitidae in which deutonymphs are phoretic and attachment is with claws. Thirdly, in Uropodidae deutonymphs are phoretic by means of an anal pedicel. Fourth, there are specialized deutonymphs, exemplified in the Acaridae, which have sucker-like discs and are resistant to dessication (Farish and Axtell 1971).

Soper and Olson (1963) found only phoretic mites on the carabids they studied. Chmielewski and Lipa (1967) stated that there are no typical parasites in the Acaridae associated with insects.

3.17 Hypopi

Heteromorphic deutonymphs (hypopi) occur in the life cycles of many mites of the suborder Astigmata. Appearance of this deutonymph is facultative as is apolysis to the tritonymph. Both processes are regulated by environmental factors. Adverse conditions can slow protonymphal development and deutonymphs form rather than the tritonymphs which would otherwise have formed.Hypopi are heavily sclerotized, lack functional mouthparts and bear adhesive organs such as suckers. They can survive long periods on stored energy and are as a rule more active than other stages. Occurrence of hypopi in a life cycle provides an efficient means of dispersal. Apolyse of hypopi to the tritonymphal stage requires a micro-environment with an adequate food supply and humidity. Such an environment tends to attract insects which carry hypopi (Cutcher and Woodring 1969).

In 1976, 98.4% of 4,827 mites collected on the carabids were hypopi. As hypopi, they lacked functional mouthparts, indicating that they were being transported and not feeding.

3.18 Relationship of Mites and Carabids

Hypopi collected from carabids in 1976 were physically incapable of feeding because of their lack of functional mouthparts. They would appear to be phoretic on the carabids, using them as a dispersal mechanism to reach environments more suitable to further development. Hypopi were found in greatest numbers on the carabids in mid-summer when the leaf litter could normally be expected to be driest and least favourable to mite development as regards moisture.

Deutonymphs of *Poecilochirus* spp. were probably also phoretic on the carabids, being normally considered to be free-living predaceous mites (Krantz 1975).

Other mite species found on the carabids were not normal associates of the carabids, being found infrequently and in low numbers on them. Their relationship with the carabids was not determined.

Hypopi of the genera *Anoetus*, *Acotyledon* and *Schwiebea* were found frequently associated with ants near Thunder Bay, Ontario, 1969, 1970 (March 1978 personal communication with W. M. Graham, Lakehead University). Some *Sancassania* hypopi were also present on the ants. The frequent association of these mites with two different orders of insects further suggests that the mites are phoretic associates of the carabids.

4.0 CONCLUSIONS

Carabid populations in the research sites were not seriously depleted after a year of continuous pitfall trapping. Greatest numbers and variety of carabids in Northwestern Ontario can generally be collected at the beginning of June (Table 6).

Carabids in Northwestern Ontario were found to follow one or another of three basic annual population curves (curves reflect activity and population levels). Carabids in general may follow these basic population and activity patterns.

The carabid species *Scaphinotus bilobus*, *Sphaeroderus nitidicollis*, *Pterostichus coracinus* and *Agonum decentis* were found to be primary associates (Lindquist 1975) of the mite genera (present as hypopi) *Acotyledon*, *Sancassania*, *Kuzinia* and *Schwiebea* in Northwestern Ontario. These mites and *Poecilochirus* deutonymphs were common associates of carabids in the present study. Other mite species were found infrequently on the carabids.

Few mites were found under the elytra of the carabids. The mites did not appear to be selective for either sex, particular species or particular regions of the carabids. They also did not appear to be associated with eggs or pupae of the carabids or to overwinter on hibernating adult carabids. Hypopi and *Poecilochirus* deutonymphs were most likely phoretic on the carabids, being transported to micro-environments more suitable to further development. Only one stage or sex of each mite genus present was found on carabids examined, further suggesting that carabids function as a dispersal mechanism for the mites.

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Table 1: List of common plants in forest sites near Thunder Bay, Ontario in which pitfall traps were set for collecting carabids

Site A

Trees-*Picea glauca* Moench
Picea mariana Miller
Abies balsamea Linnaeus
Pinus banksiana Lambert
Populus tremuloides Michaux

Shrubs-*Salix discolor* Muhlenberg
Alnus crispa Pursh
Rubus strigosus Michaux
Rosa acicularis Lindley

Other-*Equisetum sylvaticum* Linnaeus
Dryopteris spinulosa Müller
Clintonia borealis Aiton
Streptopus roseus Michaux
Actaea rubra Aiton
Fragaria virginiana Duchesne
Lathyrus ochroleucus Hooker
Epilobium angustifolium Linnaeus
Aralia nudicaulis Linnaeus
Cornus canadensis Linne
Cornus rugosa Lamarck
Pyrola asarifola Michaux
Ledum groenlandicum Linnaeus
Mertensia paniculata Aiton
Galium triflorum Michaux
Linnaea borealis Linnaeus
Aster macrophyllus Linnaeus

Table 1 continued

Site B

Trees- *Abies balsamea* Linnaeus
Picea glauca Moench
Picea mariana Miller
Populus tremuloides Michaux
Betula papyrifera Marshall

Shrubs-*Salix discolor* Muhlenberg
Alnus crispa Pursh
Rubus strigosus Michaux
Rosa acicularis Lindley

Other-*Lycopodium clavatum* Linnaeus
Lycopodium obscurum Linnaeus
Osmunda Claytoniana Linnaeus
Clintonia borealis Aiton
Maianthemum canadense Desfontaines
Lathyrus ochroleucus Hooker
Aralia nudicaulis Linnaeus
Cornus canadensis Linne
Pyrola asarifola Michaux
Ledum groenlandicum Linnaeus
Vaccinium myrtilloides Michaux
Galium triflorum Michaux
Diervilla lonicera Miller
Lonicera canadensis Marshall
Aster macrophyllus Linnaeus

Table 2: Record of weekly carabid collections from pitfall traps in two sites near Thunder Bay, Ontario (1976)

BEETLE SPECIES MOST COMMONLY COLLECTED		June 1	8	15	22	29	July 6	13	20	27	August 3	10	17	24	31	September 7	14	21	28	October 5	12	19	26	TOTALS
Sphaeroderus nitidicollis Chevrolat	♂	11	5	0	0	1	2	1	1	1	6	5	2	20	10	24	13	6	0	0	0	0	0	108
	♀	25	19	2	3	3	4	3	0	1	2	3	1	12	11	9	15	10	0	5	0	0	0	128
	Both	36	24	2	3	4	6	4	1	2	8	8	3	32	21	33	28	16	0	5	0	0	0	236
Pterostichus adstrictus Eschscholtz	♂	32	6	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	39
	♀	29	12	1	4	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	51
	Both	61	18	1	5	0	3	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	90
Pterostichus pensylvanicus Leconte	♂	52	17	0	1	0	2	0	0	1	2	1	1	1	1	6	4	5	10	14	4	3	0	125
	♀	57	37	2	7	1	8	0	1	2	1	0	1	1	3	6	10	6	16	24	5	5	0	193
	Both	109	54	2	8	1	10	0	1	3	3	1	2	2	4	12	14	11	26	38	9	8	0	318
Pterostichus coracinus Newman	♂	6	27	7	9	11	13	4	3	4	1	8	4	9	3	5	1	1	1	0	0	0	0	117
	♀	16	16	0	5	7	13	1	3	3	6	3	2	7	1	2	1	0	0	1	0	0	0	87
	Both	22	43	7	14	18	26	5	6	7	7	11	6	16	4	7	2	1	1	1	0	0	0	204
Agonum decentis Say	♂	17	9	4	4	2	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	38
	♀	19	20	2	7	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	54
	Both	36	29	6	11	7	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	92
OTHER BEETLE SPECIES COLLECTED																								
Scaphinotus bilobus Say	♂	0	0	0	0	1	3	1	2	0	2	5	3	3	0	4	1	0	1	0	0	0	0	26
	♀	0	0	0	0	0	1	1	2	0	2	2	0	2	1	1	4	0	0	1	0	0	0	17
Patrobus longicornis Say	♂	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	♀	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	3

Table 2 continued

(1976)		June					July				August					September				October				TOTALS
		1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	
Calathus	♂	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	1	0	1	0	0	5
ingratus Dejean	♀	1	8	0	1	0	10	3	2	2	0	1	0	0	0	2	0	0	0	0	0	0	0	30
Synuchus	♂	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	3
impunctatus Say	♀	0	0	0	0	0	1	0	1	2	3	2	5	0	0	0	0	0	0	0	0	0	0	14
Agonum	♂	1	2	0	3	3	4	2	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	17
retractum Leconte	♀	1	1	0	5	3	18	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33
Agonum	♂	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
superioris Lindroth	♀	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Harpalus	♂	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
fulvilabris Mannerheim	♀	0	1	0	0	0	0	1	4	1	2	1	0	1	1	0	0	0	0	0	0	0	0	12
Bradycellus	♂	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
lugubris Leconte	♀	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WEEKLY TOTALS		268	180	18	50	38	87	22	20	21	29	31	20	57	31	60	50	28	29	48	11	8	0	1106

Table 3: Record of carabid collections per tri-weekly period from pit-fall traps in two sites near Thunder Bay, Ontario (1976)

Three week period ending		June 15		July 6		July 27		Aug. 17		Sept. 7		Sept.28		Oct. 19	
Site		A	B	A	B	A	B	A	B	A	B	A	B	A	B
Sphaeroderus	♂	10	6	2	1	1	2	10	3	38	16	11	8	0	0
nitidicollis	♀	39	7	9	1	1	3	3	3	17	15	9	16	3	2
	both	49	13	11	2	2	5	13	6	55	31	20	24	3	2
Pterostichus	♂	6	32	1	0	0	0	0	0	0	0	0	0	0	0
adstrictus	♀	19	23	5	2	0	0	0	0	0	0	0	0	2	0
	both	25	55	6	2	0	0	0	0	0	0	0	0	2	0
Pterostichus	♂	40	29	1	2	1	0	3	1	8	0	17	2	16	5
pensylvanicus	♀	52	44	13	3	2	1	2	0	10	0	28	4	27	7
	both	92	73	14	5	3	1	5	1	18	0	45	6	43	12
Pterostichus	♂	37	3	28	5	11	0	13	0	16	1	3	0	0	0
coracinus	♀	30	2	18	7	5	2	11	0	10	0	1	0	1	0
	both	67	5	46	12	16	2	24	0	26	1	4	0	1	0
Agonum	♂	26	4	6	0	0	0	0	0	0	0	1	0	1	0
decentis	♀	36	5	11	2	0	0	0	0	0	0	0	0	0	0
	both	62	9	17	2	0	0	0	0	0	0	1	0	1	0
Total Numbers	♂	119	74	38	8	13	2	26	4	62	17	32	10	17	5
Total Numbers	♀	176	81	56	15	8	6	16	3	37	15	38	20	33	9
Total Numbers of Both Sexes		295	155	94	23	21	8	42	7	99	32	70	30	50	14
other carabids	♂	4	0	12	6	4	4	8	4	7	3	2	0	2	0
collected	♀	4	8	15	25	14	12	14	5	2	5	3	2	1	0
	both	8	8	27	31	18	16	22	9	9	8	5	2	3	0

Table 4: List of miscellaneous collections of carabids from two sites near Thunder Bay, Ontario in 1976 and 1977

	19 May to 26 May (1976)	26 Oct. to 9 Nov. (1976)	6 April to 26 April (1977)
Sphaeroderus nitidicollis	27		
Pterostichus adstrictus	24		4
Pterostichus pensylvanicus	57		11
Pterostichus coracinus	3	1	
Agonum retractum	1		
Agonum decentis	15		
Amara laevipennis Kirby	1		
Harpalus fulvilabris	1		
TOTAL	129	1	15

Winter 1977 Hand Collections

19 November - 3 *Sphaeroderus nitidicollis*
1 *Calosoma frigidum*
2 *Pterostichus pensylvanicus*
1 *Agonum decentis*

3 December - 1 *S. nitidicollis*

23 December - 1 *S. nitidicollis*

Table 5: List of carabids collected weekly during May, 1977 from pitfall traps in two sites near Thunder Bay, Ontario

BEETLE SPECIES MOST COMMONLY COLLECTED		May 4 A	May 4 B	May 11 A	May 11 B	May 18 A	May 18 B	May 25 A	May 25 B	Total
Sphaeroderus nitidicollis	♂	3	1	2	2	11	4	0	0	23
	♀	17	10	9	5	28	15	1	1	86
	Both	20	11	11	7	39	19	1	1	109
Pterostichus adstrictus	♂	13	4	5	3	17	12	0	0	54
	♀	19	7	8	5	21	14	1	0	75
	Both	32	11	13	8	38	26	1	0	129
Pterostichus pensylvanicus	♂	23	8	11	5	32	14	0	1	94
	♀	29	14	14	7	37	22	2	2	127
	Both	52	22	25	12	69	36	2	3	221
Pterostichus coracinus	♂	4	2	2	2	14	6	1	1	32
	♀	2	0	0	1	10	3	0	0	16
	Both	6	2	2	3	24	9	1	1	48
Agonum decentis	♂	9	3	4	3	9	4	0	0	32
	♀	7	2	4	2	13	7	1	1	37
	Both	16	5	8	5	22	11	1	1	69
OTHER BEETLE SPECIES COLLECTED										
Scaphinotus bilobus		0	0	0	0	0	0	2	0	2
Patrobus longicornis		1	0	0	1	2	0	0	0	4
Calathus ingratus		0	1	1	0	4	2	0	0	8
Agonum retractum		1	0	1	0	3	1	0	0	6
Amara laevipennis		0	0	1	0	1	0	0	0	2
Harpalus fulvilabris		1	0	2	0	1	1	0	0	5
TOTAL		129	52	64	36	203	105	8	6	603

Table 6: List of total weekly carabid collections from (100) pitfall traps in sites in Northwestern Ontario

Study		May			June					July				August					September				October				Total
		12	19	26	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	
Freitag and	1968	50	0	20	5	10	10	45	105	115	140	85	50	55	10	20											720
Poulter	(1)1969	80	170	165	180	150	115	90	110	190	135	80	45	40	5	5											1560
Mercer	1969									102	144	138	48	40	20	16	22	14	14	4	2						533
Ostaff (2)	1970									40	28	20	12	12	4	8	4	8	0	4	0	0	0				140
Ostaff	1970									16	4	16	4	4	0	0	0	0	0	0	0	0	0				44
Benson	1971		316	217	262	308	444	278	239	133	118	51	42	34	41	37	21										2541
Freitag *et al*	1971	(3)	130	5	90	125	130	70	35	20	20	35	20	5	5	5	0										700
Olynyk "A"	1976			129	165	128	9	33	31	56	8	13	18	23	27	14	43	17	49	27	19	28	37	10	6	0	890
Olynyk "B"	1976				103	52	9	17	7	31	14	7	3	6	4	6	14	14	11	23	9	1	11	1	2	0	345

(1) data for control station collections

(2) the first set of data is from mixed forest and the latter for black spruce collections

(3) weekly records were estimated from a graph and do not match the total exactly

(1) to (3) all apply to Tables 6 to 9

Table 7: List of total weekly collections of *Sphaeroderus nitidicollis* and *Pterostichus adstrictus* from (100) pitfall traps in sites in Northwestern Ontario

Sphaeroderus		May		June					July				August					September				October				Total
nitidicollis		19	26	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	
Mercer	1969								0	0	2	2	2	10	10	8	8	4	2	2						50
Benson	1971	0	1	2	3	1	5	4	0	2	3	2	0	2	7	2										34
Freitag *et al*	1971	2	0	0	3	0	0	0	0	0	0	0	0	0	0											5
Olynyk "A"	1976		27	28	21	0	3	4	4	0	0	2	7	5	1	22	9	24	13	7	0	3	0	0	0	180
Olynyk "B"	1976			8	3	2	0	0	2	4	1	0	1	3	2	10	12	9	15	9	0	2	0	0	0	83
Pterostichus adstrictus																										
Ostaff	1970								8	4	0	0	4	0	4	0	0	0	0	0	0	0				20
Ostaff	1970								4	0	0	0	0	0	0	0	0	0	0	0	0	0				4
Benson	1971	107	53	117	107	129	83	113	55	23	4	1	0	1	1	1										795
Freitag *et al*	1971	5	0	0	0	0	0	0	2	0	0	0	0	0	0											
Olynyk "A"	1976		24	19	5	1	4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	57
Olynyk "B"	1976			42	13	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	57

Table 8: List of total weekly collections of *Pterostichus pensylvanicus* from (100) pitfall traps in sites in Northwestern Ontario

Pterostichus		May			June					July				August					September				October				Total
pensylvanicus		12	19	26	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	
Freitag and	1968	50	0	20	5	10	10	25	55	30	30	10	0	5	5	5											260
Poulter	1969	75	155	140	165	145	100	65	40	65	15	15	15	5	0	0											1000
Mercer	1969									28	32	28	6	4	0	0	0	0	2	2	0						102
Ostaff (mixed)	1970									16	28	4	0	0	4	4	0	12	0	0	0	8	0				76
Benson	1971		74	19	51	47	47	18	33	16	9	1	2	0	0	0	0										317
Freitag *et al*	1971		3	0	3	2	3	0	3	0	1	1	0	0	0	1											17
Olynyk "A"	1976			57	58	33	1	5	1	8	0	1	2	2	1	2	2	4	12	8	11	25	29	8	6	0	276
Olynyk "B"	1976				51	21	1	3	0	2	0	0	1	1	0	0	0	0	0	6	0	1	9	1	2	0	99

Table 9: List of total weekly collections of *Pterostichus coracinus* and *Agonum decentis* from pitfall traps in sites in Northwestern Ontario

Pterostichus		May		June					July				August					September				October				Total
coracinus		19	26	1	8	15	22	29	6	13	20	27	3	10	17	24	31	7	14	21	28	5	12	19	26	
Mercer	1969								16	14	28	18	18	6	2	8	2	8	0	0						120
Benson	1971	1	0	1	18	12	12	19	31	28	13	13	12	21	5	3										189
Freitag *et al*	1971	1	0	0	2	3	2	4	1	1	3	4	1	3	2											27
Olynyk "A"	1976		3	21	41	4	10	15	21	4	6	6	7	11	6	15	4	7	2	1	1	1	0	0	0	186
Olynyk "B"	1976			1	2	3	4	3	5	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	21
Agonum																										
decentis																										
Ostaff	1970								8	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
Ostaff	1970								8	0	12	4	0	0	0	0	0	0	0	0	0	0	0	0	0	24
Benson	1971	114	129	75	99	215	134	30	1	1	1	0	0	0	0	0										799
Freitag *et al*	1971	30	5	30	70	100	25	0	0	0	0	0	0	0	0											257
Olynyk "A"	1976		15	36	23	3	7	9	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	96
Olynyk "B"	1976			0	6	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	11

Table 10: Numbers of male and female carabids of five species commonly collected from pitfall traps in Northwestern Ontario

Species	Time Period and Collector	Sex ♂	♀
Sphaeroderus	season - Mercer 1969	18	7
nitidicollis	season - Benson 1971	21	13
	26 May - 14 July, Olynyk 1976	27	79
	4 August - 6 October, Olynyk 1976	86	68
	season - Olynyk 1976	115	148
	May - Olynyk 1977	23	86
Pterostichus	season - Ostaff 1970	3	3
adstrictus	season - Benson 1971	294	501
	season - Olynyk 1976	53	61
	May - Olynyk 1977	54	75
Pterostichus	season - Ostaff 1970	6	13
pensylvanicus	season - Benson 1971	113	204
	26 May - 7 July, Olynyk 1976	102	139
	1 September - 20 October, Olynyk 1976	47	75
	season - Olynyk 1976	155	220
	May - Olynyk 1977	94	127
Pterostichus	season - Mercer 1969	32	28
coracinus	season - Benson 1971	143	46
	season - Olynyk 1976	118	89
	May - Olynyk 1977	32	16
Agonum	season - Ostaff 1970	2	7
decentis	season - Benson 1971	250	549
	season - Olynyk 1976	47	60
	May - Olynyk 1977	32	37

Table 11: List of carabids collected weekly in May, 1977 in two sites from central and peripheral pitfall traps

DATE	BEETLES COLLECTED (NO.)		NO. OF BEETLES/10 TRAPS	
	Central	Peripheral	Central	Peripheral
3 May	74	107	8.8	9.2
10 May	47	53	5.6	4.6
17 May	122	186	14.5	16.0
24 May	6	8	0.7	0.7
TOTAL	243	346	7.5	7.2

Peripheral Traps: Numbers 1-27, 49-52, 74-100

58 traps per site; total 116 traps

Central Traps: Numbers 28-48, 53-73

42 traps per site; total 84 traps

Table 12: List of mites and associated carabids from three studies done near Thunder Bay, Ontario

Mite Taxa	Associated Carabids	Mite Stage or Sex	No. of Mites
OLYNYK 1976			
Parasitidae *Poecilochirus* sp. nr. *carabi* Canestrini and Canestrini	*Scaphinotus bilobus* *Sphaeroderus nitidicollis* *Pterostichus coracinus* *Agonum decentis*	deutonymph	63
Digamasellidae *Dendrolaelaps* sp. in *spinosus* group	*S. nitidicollis*	deutonymph	1
Ascidae *Antennoseius* sp. nr. *pannonicus* Sellnick	*P. pensylvanicus*	female	2
Zerconopsis labradorensis Evans and Hyatt	*A. retractum*	male	1
Pygmephoridae (=Pyemotidae) *Bakerdania* sp. nr. *cultratus* Berlese	*P. pensylvanicus*	female	2
Acaridae *Acotyledon* sp.	*A. decentis*	tritonymph	1
Anoetidae *Anoetus* (=*Histiostoma*) sp.	*S. bilobus* *S. nitidicollis* *P. adstrictus* *P. pensylvanicus* *P. coracinus* *A. decentis*	hypopi	4749
Acaridae *Sancassania* (=*Caloglyphus*) sp.		hypopi	
Kuzinia sp.		hypopi	
Schwiebea sp. nr. *nova* Oudemans		hypopi	
Eniochthoniidae *Hypochthoniella* (=*Eniochthonus*) *pallidula* Koch	*P. coracinus*	adult	1

Table 12 continued

Metriopiidae	*Ceratoppia* sp. nr. *quadridentata* Haller	*P. coracinus*	adult	1
Oribatulidae	*Scheloribates* sp.	*P. pensylvanicus* *P. coracinus*	adult	5
OSTAFF 1971				
Parasitidae	*Poecilochirus* sp.	*Carabus nemoralis* Müller	deutonymph	
	Parasitus sp.	*P. melanarius* Illiger	deutonymph, female	
Ascidae	*Blattisocius keegani* Fox	*Calathus ingratus*	female	
Anoetidae	genus undetermined	*C. nemoralis*	hypopi	
Acaridae	*Tyrophagus putrescentiae*	*C. ingratus*	male	
	Acotyledon sp. nr. *schmitizi* Oudemans	*P. pensylvanicus* *Synuchus impunctatus*	hypopi	339
	Sancassania sp. nr. *spinitarsus* Herman	*P. pensylvanicus, P. melanarius, C. ingratus, S. impunctatus*	hypopi	
	Schwiebea sp. nr. *scheucherae* Turk and Turk	*C. nemoralis, P. pensylvanicus, C. ingratus, S. impunctatus*	hypopi	
Glycyphagidae	*Glycyphagus domesticus* DeGeer	*C. ingratus*	female	
MERCER 1970				
Anoetidae	*Spinanoetus* sp. *Acotyledon* sp. *Sancassania* sp. *Schwiebea* sp.	*S. bilobus* *S. nitidicollis* *P. coracinus* *A. retractum*		11,206

Table 13: List of mites found beneath elytra of carabids collected in 1976 near Thunder Bay Ontario

BEETLE SPECIES	NO. CHECKED	MITES PRESENT ON (NO.)	LOCATION	NO. OF MITES	MITE SPECIES
Scaphinotus					
bilobus	6	0			
Sphaeroderus					
nitidicollis	51	0			
Pterostichus					
adstrictus	27	1	underside of elytra	2	*Sancassania* (=*Caloglyphus*) sp.
Pterostichus					
pensylvanicus	75	1	as above	2	*Antennoseius* sp. nr. *pannonicus* Sellnick
Pterostichus					
coracinus	58	2	under elytra	1	*Scheloribates* sp.
			on body	1	*Ceratoppia* sp. nr. *quadridentata* Haller
Agonum					
decentis	28	0	-	-	-
TOTAL	245	4		6	

Table 14: Density and frequency of occurrence of mites on carabid beetles collected from pitfall traps in two sites near Thunder Bay, Ontario (1976)

BEETLE SPECIES MOST COMMONLY COLLECTED	NO. OF MITES	NO. OF BEETLES SAMPLED	NO. OF BEETLES WITH MITES	% BEETLES INFESTED	AVG. NO. OF MITES/INFESTED BEETLE
Scaphinotus bilobus	893	22	21	95.5	42.5
Sphaeroderus nitidicollis	2553	118	94	79.7	27.2
Pterostichus adstrictus	78	45	22	48.9	3.5
Pterostichus pensylvanicus	258	159	62	39.0	4.2
Pterostichus coracinus	718	102	76	74.5	9.4
Agonum decentis	230	47	35	74.5	6.6
OTHER BEETLE SPECIES COLLECTED					
Patrobus longicornis	7	3	3	100.0	1.4
Calathus ingratus	23	18	7	38.9	3.3
Synuchus impunctatus	30	9	7	77.8	4.3
Agonum retractum	34	25	15	60.0	2.3
Harpalus fulvilabris	2	6	1	16.7	2.0

Table 15: Weekly mite density on six species of carabids collected from pitfall traps in two sites in 1976 near Thunder Bay Ontario

	Scaphinotus bilobus	*Sphaeroderus nitidicollis*	*Pterostichus adstrictus*	*Pterostichus pensylvanicus*	*Pterostichus coracinus*	*Agonum decentis*
June 1		37.8	2.0	2.2	3.0	2.7
8		4.2	1.4	2.2	6.2	2.9
15		4.0		1.0	1.7	4.7
22		25.0	0.7	0.5	16.6	17.0
29	51.0	31.5			12.3	2.0
July 6	29.0	35.0	1.0	8.4	12.3	17.0
13	99.0	49.0			5.0	
20	73.0			3.0	10.0	
27		4.0		16.0	8.0	
August 3	13.5	30.0		0.5	6.3	
10	16.7	85.0			6.2	
17	117.0	29.5		5.0	3.0	
24	84.0	23.4		0.0	2.0	
31	3.0	25.1		0.5	0.5	
September 7	12.5	10.9		0.0	0.0	
14	10.7	6.4		0.3	0.0	0.0
21		10.3		0.0	0.0	
28				0.1		
October 5		0.0	0.0	0.1		
12				0.3		
19				0.5		

Table 16: Weekly changes in density of mites on male and female carabids of five species collected from pitfall traps in two sites near Thunder Bay, Ontario (1976).

Beetle Species	Date	No. of Mites/Beetle ♂	♀
Sphaeroderus nitidicollis	1 June	8.0 (32/4)	46.3 (648/14)
	8 June	2.0 (6/3)	4.9 (44/9)
	10 August	62.0 (62/1)	92.7 (278/ 3)
	24 August	29.6 (237/8)	17.1 (137/8)
	31 August	74.3 (223/3)	4.0 (28/7)
	7 September	8.2 (106/13)	20.0 (80/4)
	14 September	10.0 (70/7)	2.7 (19/7)
	21 September	1.7 (5/3)	15.4 (77/5)
	Total	17.6	23.0
Pterostichus adstrictus	1 June	3.2 (55/17)	0.5 (7/14)
	8 June	4.0 (12/3)	0.2 (1/6)
	Total	3.3	0.4
Pterostichus pensylvanicus	1 June	2.5 (63/25)	1.9 (56/30)
	8 June	1.9 (15/8)	2.4 (45/19)
	28 September	0.0 (0/5)	0.1 (1/8)
	5 October	0.1 (1/7)	0.1 (1/12)
	Total	1.8	1.5
Pterostichus coracinus	1 June	0.3 (1/3)	4.0 (32/8)
	8 June	7.5 (113/15)	3.4 (24/7)
	22 June	26.8 (107/4)	3.0 (9/3)
	29 June	16.5 (66/4)	9.0 (45/5)
	6 July	12.9 (103/8)	11.4 (57/5)
	10 August	2.8 (11/4)	13.0 (26/2)
	24 August	1.2 (6/5)	3.3 (10/3)
	Total	9.1	6.1
Agonum decentis	1 June	3.3 (26/8)	2.3 (23/10)
	8 June	1.0 (4/4)	3.6 (40/11)
	22 June	15.0 (30/2)	18.0 (72/4)
	Total	4.3	5.4

Figure 1: Generalized annual phenology curves for carabid species commonly collected near Thunder Bay, Ontario

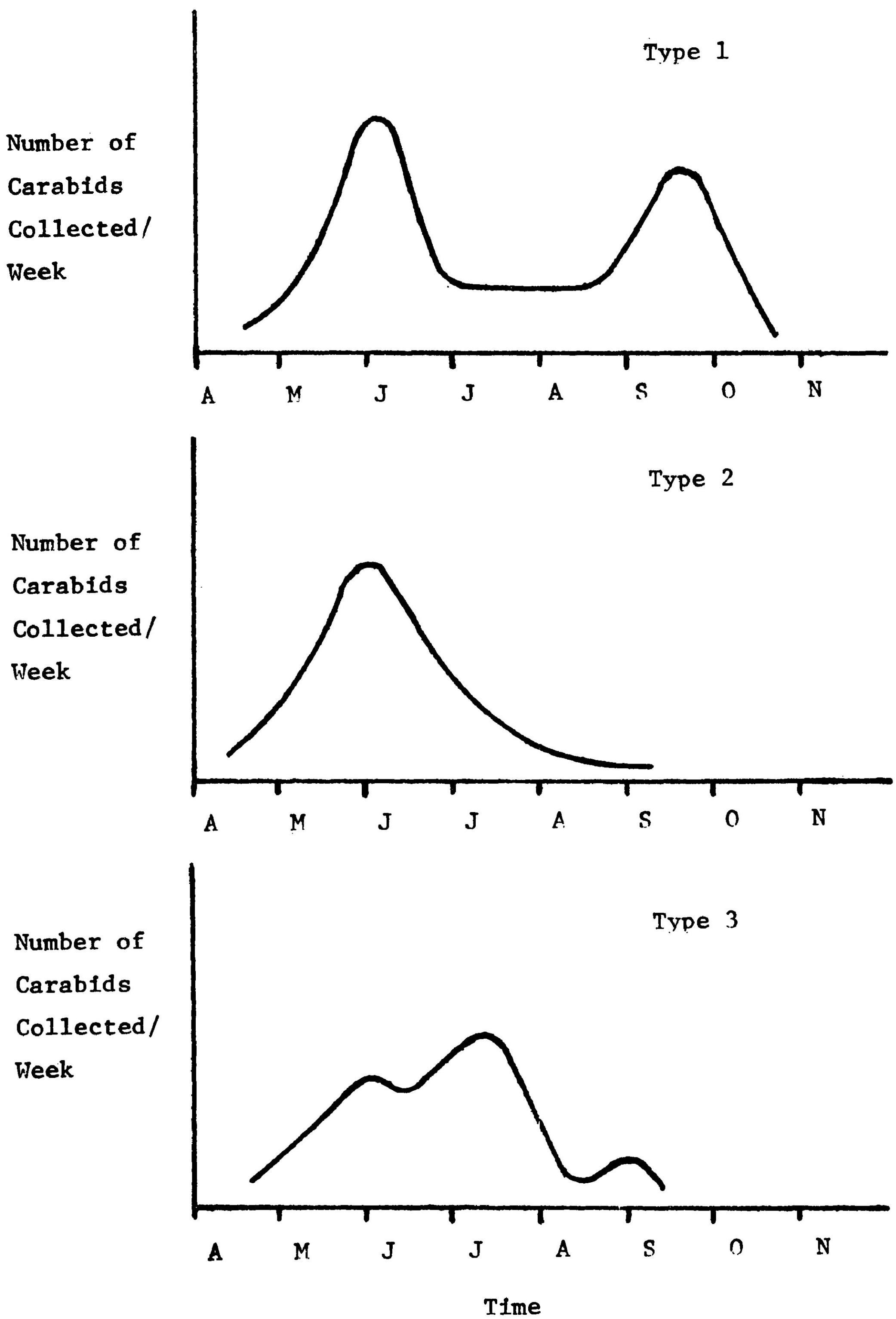

Figure 2: Total weekly carabid collections from two sites *vs.* total weekly rainfall per week (mm) (1976, near Thunder Bay, Ontario)

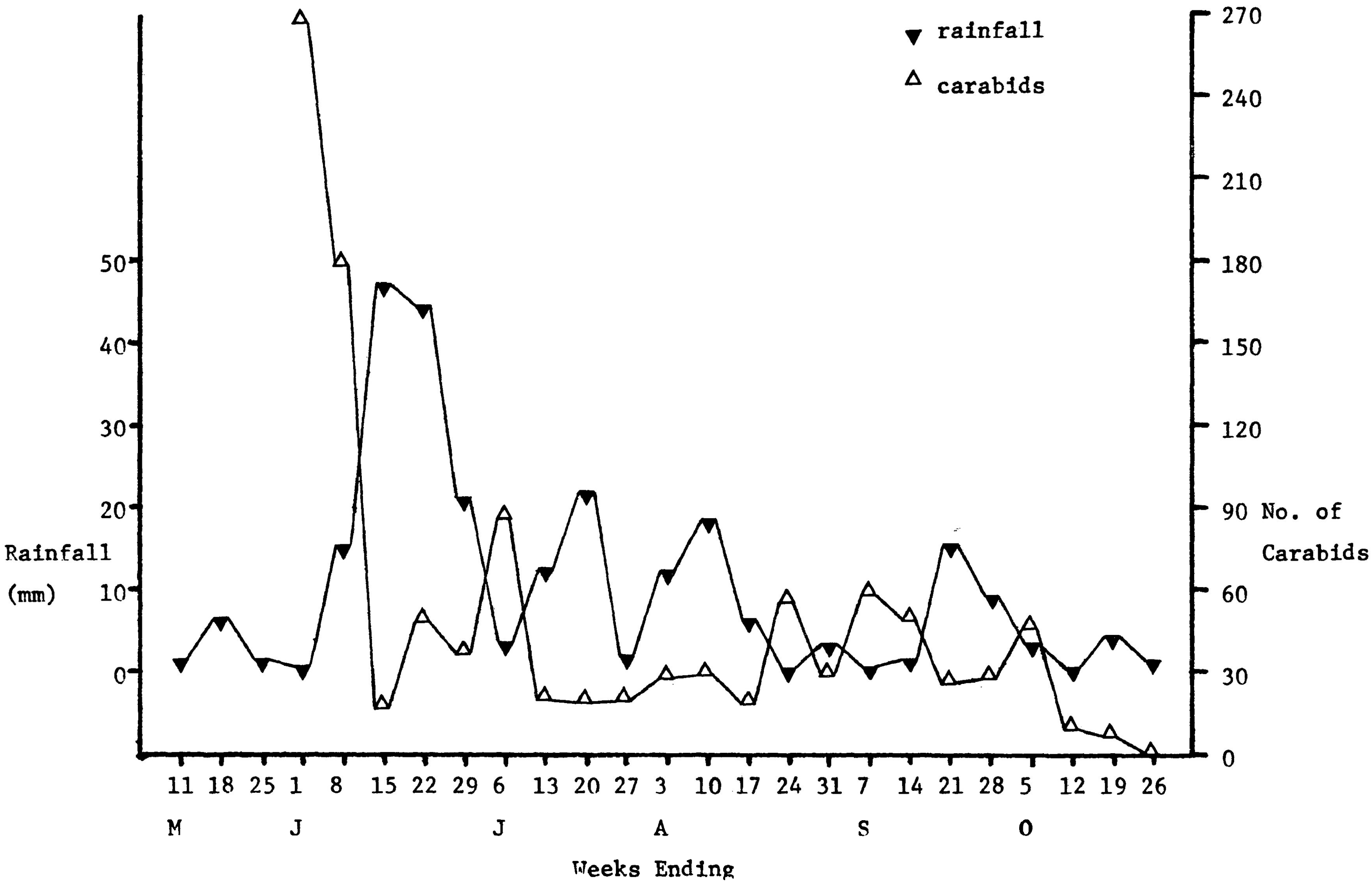

Figure 3: Total weekly carabid collections from two sites *vs.* total number of hours of bright sunshine per week (1976, near Thunder Bay, Ontario)

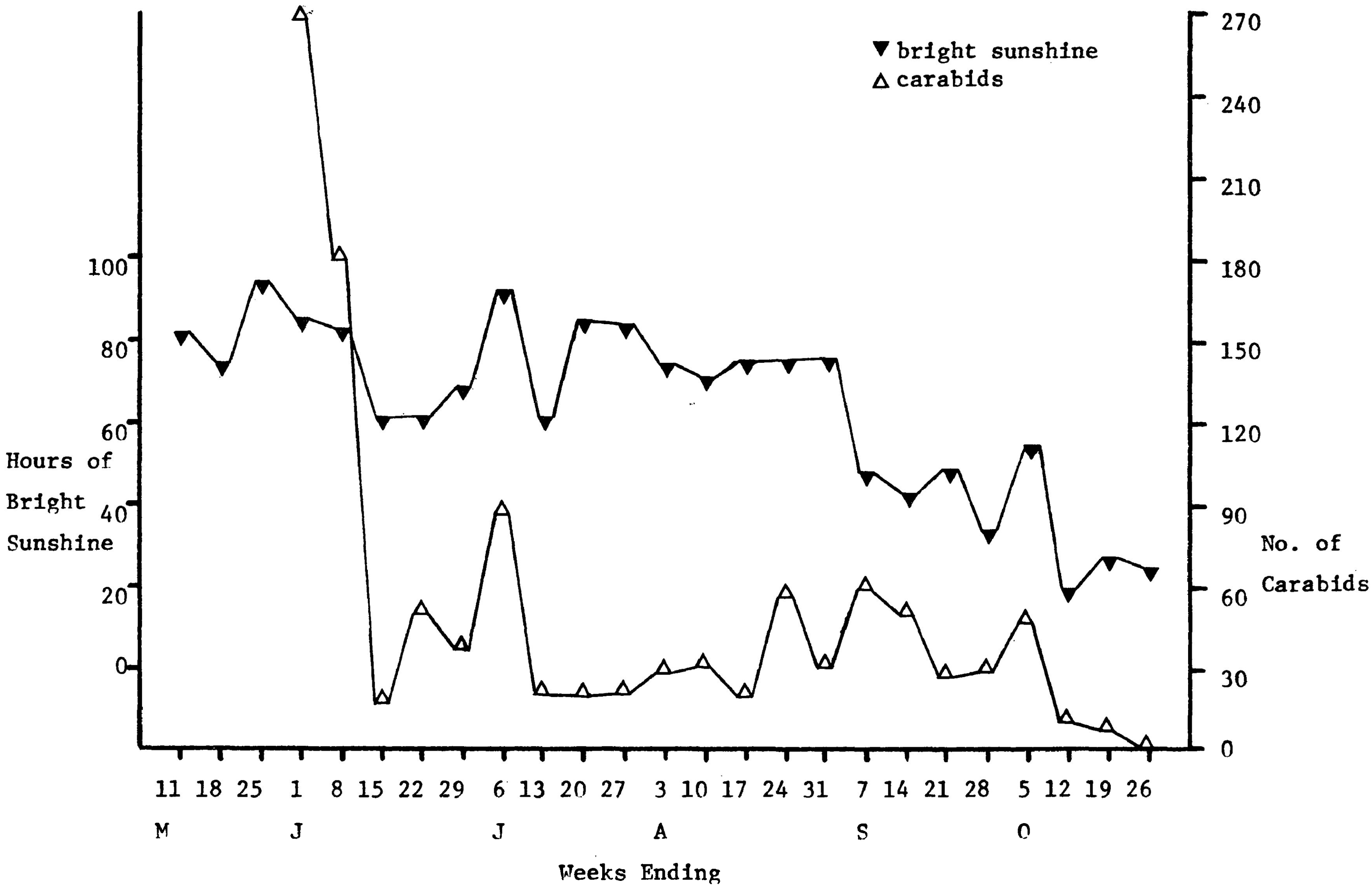

Figure 4: Total weekly carabid collections from two sites *vs.* average mean temperature per week (^{o}C) (1976, near Thunder Bay, Ontario)