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Adult ground beetles (Coleoptera: Carabidae) collected from tobacco fields and adjacent pastures and woodlands in East Tennessee

C. Dayton Hylton

To the Graduate Council:

I am submitting herewith a thesis written by C. Dayton Hylton entitled "Adult ground beetles (Coleoptera: Carabidae) collected from tobacco fields and adjacent pastures and woodlands in East Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agricultural Biology.

Charles D. Pless, Major Professor

We have read this thesis and recommend its acceptance:

R.R. Gerhardt, M.L. Pan

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

To the Graduate Council:

I am submitting herewith a thesis written by C. Dayton Hylton, Jr. entitled "Adult Ground Beetles (Coleoptera: Carabidae) Collected from Tobacco Fields and Adjacent Pastures and Woodlands in East Tennessee." I recommend that it be accepted in partial fulfillment of requirements for the degree of Master of Science, with a major in Agricultural Biology.

Charles D. Pless

Dr. Charles D. Pless, Major Professor

I have read this thesis and recommend its approval:

Boyd R. Gerhardt

Accepted for the Council:

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Vice Chancellor
Graduate Studies and Research

ADULT GROUND BEETLES (COLEOPTERA: CARABIDAE) COLLECTED FROM TOBACCO FIELDS AND ADJACENT PASTURES AND WOODLANDS IN EAST TENNESSEE

A Thesis

Presented for the

Master of Science

Degree

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C. Dayton Hylton, Jr.

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To Jesus Christ, the Light in the midst of darkness, thanks for making this time the most enjoyable time of my life.

ABSTRACT

Seasonal activity-abundance of 106 species in 48 genera of ground beetles (Coleoptera: Carabidae) was based on pitfall trapping records from tobacco fields, pastures, and woodlands in eastern Tennessee. Sixteen species of Carabinae and one species of Cicindelinae were considered abundant. Populations of Harpalus pennsylvanicus DeGeer comprised 30.6% of the total collections. No significant differences in numbers of ground beetles were observed between carbofuran treated and untreated tobacco fields.

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CHAPTER I

INTRODUCTION

With much emphasis on integrated pest management for controlling destructive insects in modern agricultural systems, many beneficial insects have been studied in relation to the crops with which they are associated. Efforts are being made to manipulate the beneficial insect fauna, including ground beetles, in agricultural lands. This study was initiated to identify the ground beetles (Coleoptera: Carabidae) that live within cultivated fields of tobacco in eastern Tennessee. Adjacent pastures and woodlands were sampled to determine if they served as reservoirs for various species of ground beetles.

Tobacco is an important agronomic crop in the southeastern United States. The tobacco crop is of major importance to the economy of Tennessee, especially to the many farmers in the eastern half of the state who grow small allotments. In 1978, 50,000 acres of burley tobacco were harvested in Tennessee; its market value was $143,220,000.

The major insect pests of tobacco in East Tennessee are: the tobacco flea beetle Epitrix hirtipennis (Melsheimer), tobacco hornworm Manduca sexta (L.), tobacco budworm Heliothis virescens (F.), and the green peach aphid Myzus persicae (Sulzer) (Chamberlin and Madden, 1942). A variety of broad spectrum insecticides are recommended to minimize damage to the tobacco crop. A widely used soil systemic insecticide that is recommended for use on tobacco fields by the University of Tennessee Agricultural Extension Service is carbofuran (Furadan 10G). Carbofuran is a broad spectrum carbamate insecticide that has been used with good

results to control infestations of tobacco hornworms (Mistric and Smith, 1973), tobacco budworms (Girardeau, 1971; Mistric and Smith, 1972), tobacco flea beetles (Dominick, 1967 and 1969; Thurston and Jones, 1973), green peach aphids (Danko, 1975; Dominick, 1971), and wireworms (Mistric and Smith, 1972). Since carbofuran is applied directly to the soil, fields treated with it were included in this study to determine its effect on populations of ground beetles.

The objectives of this study were to determine:

1. species of carabids present in tobacco fields and adjacent pastures and woodlands,
2. the seasonal abundance and diversity of the carabids present, and
3. the effect of the soil applied insecticide, carbofuran, on populations of carabids.

CHAPTER II

LITERATURE REVIEW

I. GENERAL BIOLOGY

The ground beetles are the second largest family of beetles in North America, comprised of approximately 2500 species (Borror, DeLong, and Triplehorn, 1976). The members of this family vary considerably in size, shape, and color. Family characters are as follows:

> head narrower than pronotum and directed forward; mentum deeply emarginate; antennae eleven-segmented, filiform, inserted between eyes and base of mandibles, all but basal segments finely pubescent; six abdominal sternites present; legs most usually slender, adapted for running; pro-and mesocoxae globular, metacoxal dilated on inner side; tarsi five-segmented (Dillon and Dillon, 1961).

Adult carabids vary in length from 3 to 85 mm and are elongate to oval in shape, with striate elytra. The legs follow a particularly consistent pattern as slender running legs which have led to the German name "Laufkafer" (running beetles) (Thiele, 1977). Most of the species are black or dull brownish in color, but some are yellow, metallic blue, green or purple (Dillon and Dillon, 1961). Many species have an orange prothorax, sometimes with orange markings on the elytra, while some species are brownish with black markings (Ball, 1960).

Ground beetles are commonly found under stones, debris, clods of soil, and running along the soil surface. They generally hide during the day and feed at night, and often come to lights in large numbers. Most adult and larval carabids are predaceous and are considered beneficial; although many species are considered omnivores (Kulman, 1974). A small group are considered to be herbivores (Dick and Johnson, 1958; Forbes,

1883; Johnson and Cameron, 1969; Lindroth, 1949; and Lund, 1975).

Females lay their eggs singly, either in the soil or in specially constructed mud cells (Balduf, 1935). Depending on the temperature and the species, eggs hatch in 3-10 days. Most species have three larval instars, the duration of which varies with environmental factors and the individual species (Allen, 1979). Pupation occurs in the soil. The life cycle requires one year in most cases and adults may live up to four years (Ball, 1960).

Adult carabid species have been shown to have either unimodal or bimodal annual activity-abundance cycles (Allen and Thompson, 1977; Frank, 1971a; and Harris and Whitcomb, 1971). Spring cycles of adult ground beetles begin in late April or early May, peak in June, and rapidly drop off in July. Fall cycles of adult ground beetles begin in late August to early September, peak in late September to early October, and drop off abruptly (Allen, 1979). These activity-abundance periods correspond to the breeding periods which Gilbert (1957), Larsson (1939), Lindroth (1949), and Rivard (1964b) have divided into spring and fall breeding ground beetles. Spring breeding ground beetles hibernate as adults and breed in the spring and early summer; fall breeding ground beetles overwinter as larvae and adults and breed in the late summer and fall. Larvae are abundant throughout the spring, summer, and fall, and some species overwinter in the larval stage.

II. GROUND BEETLES IN AGRICULTURAL HABITATS

Ground beetles are common in most agro-ecosystems. They have been shown to occur in large numbers and with considerable diversity by Esau and Peters (1975), Frank (1971a), Kirk (1971b), Rivard (1964a, 1965, 1966) and others.

Rivard (1964a, 1965) recorded 178 species of carabids from croplands near Belleville, Ontario, Canada. Of these, 12 species were abundant enough to warrant further investigation as possible pest control agents. Rivard 1966, completed a three year study of carabids in five fields under crop rotation. From his work he made these generalizations:

> (1) The largest captures of ground beetles were usually made in cereal crops, followed by cultivated, legume, and pasture fields...this progressive augmentation in beetle activity and (or) population from one field to the next appears to be correlated with increased humidity of the habitats, (2) therefore, the nature of the crop may greatly influence the number of ground beetles and from this it can be inferred that it also influences the extent to which the beetles exact a control influence on pest species.

Esau and Peters (1975), in a study of the carabid fauna of Iowa cornfields, fencerows, and prairies, identified 94 species and described a habitat perference for many species. Of the total number of individuals collected, 52% were collected in cornfields, 23% from fencerows, and 25% from prairies. Eleven of 45 species collected in cornfields were not collected elsewhere.

Kirk (1971b), in a 4 year study of ground beetles in cultivated fields in South Dakota, reported 127 species in fields planted continuously to corn or planted to corn in rotation with oats, wheat, soybeans, flax or alfalfa. Sixty species were collected only from cornfields, 63 were taken in both cornfields and other cropland, and 4 were found only in other croplands. Kirk, like Rivard, believes that relative humidity is the key to carabid activity. Basic research by Kirk on the biology of Pterostichus lucublandus (1971a), Harpalus pennsylvanicus (1973), Harpalus erraticus (1974), Stenolophus comma (1975a), Pterostichus chalcites (1975b) and Anisodactylus sanctaecrusis (1977) in croplands has increased knowledge in this area considerably.

Frank (1971a), recorded 63 species of carabids from croplands planted to barley and oats in Alberta, Canada. He stated that those species which are not merely stragglers into an area would be expected to have some food-chain relationships to the crop plant; therefore, a slightly different carabid fauna might be expected to exist in a tobacco field than in corn, cereal crops, or pastures.

No work has been published relative to the carabid fauna in tobacco fields. Midkiff (M.S. thesis, 1979) surveyed carabids in small tobacco plots treated with carbofuran and disulfoton in Kentucky. She reported 9 genera and 13 species of carabids collected during the growing season of the tobacco crop.

III. CARBOFURAN AND GROUND BEETLES

Carbofuran is a soil insecticide commonly used in corn and tobacco. With the interest in integrated pest management in agricultural practices, the impact of this insecticide on different components of the environment has been studied (Hsin et al., 1979). Carabid species in general are intolerant of most insecticides applied to crops at concentrations necessary to control target species (Croft and Brown, 1975). It is, therefore, necessary to study the effects of insecticides on non-target organisms and use the least harmful insecticides in order to preserve populations of beneficial insects in the field.

Thorvilson (1969) collected carabids in corn plots treated with carbofuran at a rate of 1.12 kg AI/ha. Three species, Pterostichus chalcites, Bembidion quadrimaculatum, and Stenolophus comma, were collected in significantly higher numbers in the insecticide treated plots than in the untreated check plots. Clivina bipustulata, Scarites substriatus,

and Tachys anceps were adversely affected by the carbofuran treatment.

Sechriest et al. (1971) evaluated insecticides for control of the slender seed corn beetle, Clivina impressifrons. In this case, carbofuran was toxic when applied topically, moderately toxic as a seed treatment, and less effective as a soil treatment when tested at 1.12 kg AI/ha in a 17.8 cm band.

Tomlin (1975) determined the toxicity of carbofuran to Stenolophus comma adults by contact and to Pterostichus melanarius larvae by soil treatment in the laboratory. The results again showed that contact exposure to carbofuran was extremely toxic, while the soil treatments were less toxic.

Gholson et al. (1978) exposed Scarites substriatus, Harpalus pennsylvanicus, Pterostichus chalcites, Bembidion rapidum, and Bembidion quadrimaculatum to carbofuran at recommended field rates in the laboratory. When the insecticide was applied to the soil at a rate of .84 kg AI/acre in an 18 cm band, beetle mortality was not significantly greater than the control. With direct exposure, as with the studies of Sechriest and Tomlin, 100% mortality occurred. A mortality of 82.5% occurred when carabids were fed carbofuran-poisoned black cutworm larvae.

Hsin et al.(1979) treated Pterostichus chalcites topically with carbofuran and found it to be very toxic to this species.

Midkiff (1979) pitfall-trapped carabids in tobacco plots treated with carbofuran. She found that ground beetle numbers were reduced significantly in the carbofuran plots as compared to the untreated plots. This decrease occurred early in the sampling period shortly after treatment with carbofuran. In 1977, Pterostichus chalcites, Evarthrus spp., Amara cupreolata, and Harpalus pseudophonus were all trapped in

significantly larger numbers in untreated plots. The next year, 1978, all species, Pterostichus chalcites, Anadaptus sanctaecrusis, Harpalus pseudophonus, Evarthrus spp., Agonoderus comma, Amara cupreolata, and Scarites subterraneus were trapped in significantly larger numbers in untreated plots.

Pless and Shamiyeh (personal communication) observed that following heavy rains numerous adult ground beetles were killed in carbofuran treated corn plots.

IV. PITFALL TRAPPING OF GROUND BEETLES

Pitfall traps have long been used to sample soil surface arthropods, one of the early styles was described by Fitcher (1941). Pitfall techniques and designs, however, vary from one researcher to the next. Luff (1975) reported size, shape, and construction materials of the trap to influence the capture and retention efficiency of beetle catches. Hsin et al. (1979) collected carabids in both metal (Humphrey and Dahm, 1976) and plastic (Best, 1977) pitfall traps. He reported metal traps significantly more efficient in collecting beetles than plastic traps. The relative trapping efficiency of metal traps was approximately twice that of plastic traps, and for the tiny species Bembidion quadrimaculatum metal traps caught 4.6 times greater numbers of beetles than plastic traps. In the field, Hsin et al. (1979) observed the rim of the plastic trap was easily exposed by wind and rain erosion, possible impeding the movement of carabids into the trap.

An easily constructed, inexpensive plastic pitfall trap was developed by Morrill (1975). Morrill (1975) used a 16 ounce plastic Solo® cup, with a coffee cup liner as a funnel, and a 3.5 ounce plastic Solo cup as the inner container. This trap was successfully used to sample

populations of spiders, slugs, crickets, ground beetles, and billbugs. Plastic pitfall traps are advantageous because they are commercially available, easy to stack for storage and handling, quickly made, and easily serviced.

Dr. Thomas C. Barr (personal communication) suggested the use of a specialized pitfall trap, an "intercept trap," to increase the number of individuals and the diversity of carabid species collected. He used the "intercept trap" to collect cave-dwelling species of ground beetles. Carabids are directed toward the trap by four pieces of garden edging placed into the ground in the shape of an X, with the pitfall trap in the middle. Slower moving and small species of carabids are collected more frequently in this trap than standard pitfall traps.

Pitfall traps have been used to study the seasonal incidence of adult carabids, the spatial pattern of distribution in populations, the relative numbers of a species in different vegetation types, and daily rhythms of activity (Allen and Thompson, 1977; van der Drift, 1951; Gilbert, 1956, 1958; Greenslade, 1963, 1964a, 1964b; Harris and Whitcomb, 1971; Williams, 1959a, 1959b). Several authors have criticized the use of pitfall traps. They felt that catches were difficult to interpret, since they were based on both population size and the activity of individuals in the population (Greenslade, 1964a; Mitchell, 1963). Briggs (1961) concluded that with Harpalus rufipes DeGeer the population size played a minor role in determining the numbers trapped. Both Briggs (1961) and Greenslade (1964a) agreed that pitfalls could not be properly used for the quantitative assessment of carabid fauna, or used to compare numbers of one species in different habitats. Pitfall traps sample insect populations selectively according to their behavior and according to

environmental factors, such as temperature, which increases locomotor activity, while activity is decreased during the reproductive period (Briggs, 1961). A variety of other factors known to influence activity and behavior are: weather (Briggs, 1961; Mitchell, 1963), vegetation around the traps (Greenslade, 1964a), stage in the life cycle (Hayes, 1970), and sex (Ericson, 1977, 1978). Preservatives in traps and the trap materials can influence the trap catch (Luff, 1968, 1975).

Even with the limitations inherent to pitfall collections, van der Drift (1959) believed that pitfall traps could yield information on activity periods, life cycles, fluctuations in population density, local distribution, and phenology. Greenslade (1964a) stated that pitfall catches in conjunction with hand collections could be employed for the qualitative assessment of different carabid faunas. He also felt pitfall results yielded some information on the frequency of species. Mitchell (1963) utilized pitfalls for studying distribution, abundance, behavior, and population changes. He felt that utilization of pitfall traps would be acceptable only if the population was large, continuous, and freely mobile.

In spite of their drawbacks, pitfall traps have several advantages for studying large populations of active insects such as carabids. According to Mitchell (1963), in spite of the practical and theoretical difficulties, pitfall trapping can give useful information for distribution, abundance, and behavior. With a minimum of material and labor, pitfalls can provide continuous sampling. This is a convenient method for sampling seasonal activity of carabids and is often the only method available for studies of carabid populations.

CHAPTER III

MATERIALS AND METHODS

I. STUDY AREA

Ground beetles were pitfall-trapped in tobacco fields at the Tobacco Experiment Station, Greeneville, Tennessee. Techniques were developed in a pilot study in 1978 and modified in 1979, at which time plots were enlarged. Four large tobacco fields (designated fields 1,2,3, 4) (Fig. 1,2,3, and 4) ranging in size from .44 to 1.66 ha were used as test plots. Field 1 (Figure 1), .44 ha, was bordered by grass medians and adjoined on opposite sides by a fescue hay field and an alfalfa field. Narrow plots of tobacco separated by a clover/fescue pasture comprised field 2 (Fig. 2). Field 3 (Fig. 3), the largest tobacco field at 1.66 ha, was bordered by pasture on three sides and a dense stand of mixed hardwoods on the fourth side. The most diversely bordered field, field 4 (Fig. 4), was adjoined by a stand of mixed hardwoods, pasture, and a grass median which dropped off abruptly to a stream. The ground beetle collections in the alfalfa field, grass medians, the clover/fescue pasture, and the fescue hay field were combined under the heading "pastures," although collections from the alfalfa field will be discussed separately under Amara spp. The soil type of all the fields was a silt loam.

II. INSECTICIDES USED

Carbofuran 10G was applied to field 1 and field 3 in 1979. Field 1 had carbofuran broadcast at 4.49 kg AI/ha over one-half of the field, and placed in the rows at 6.67 kg AI/ha over the remaining half of the

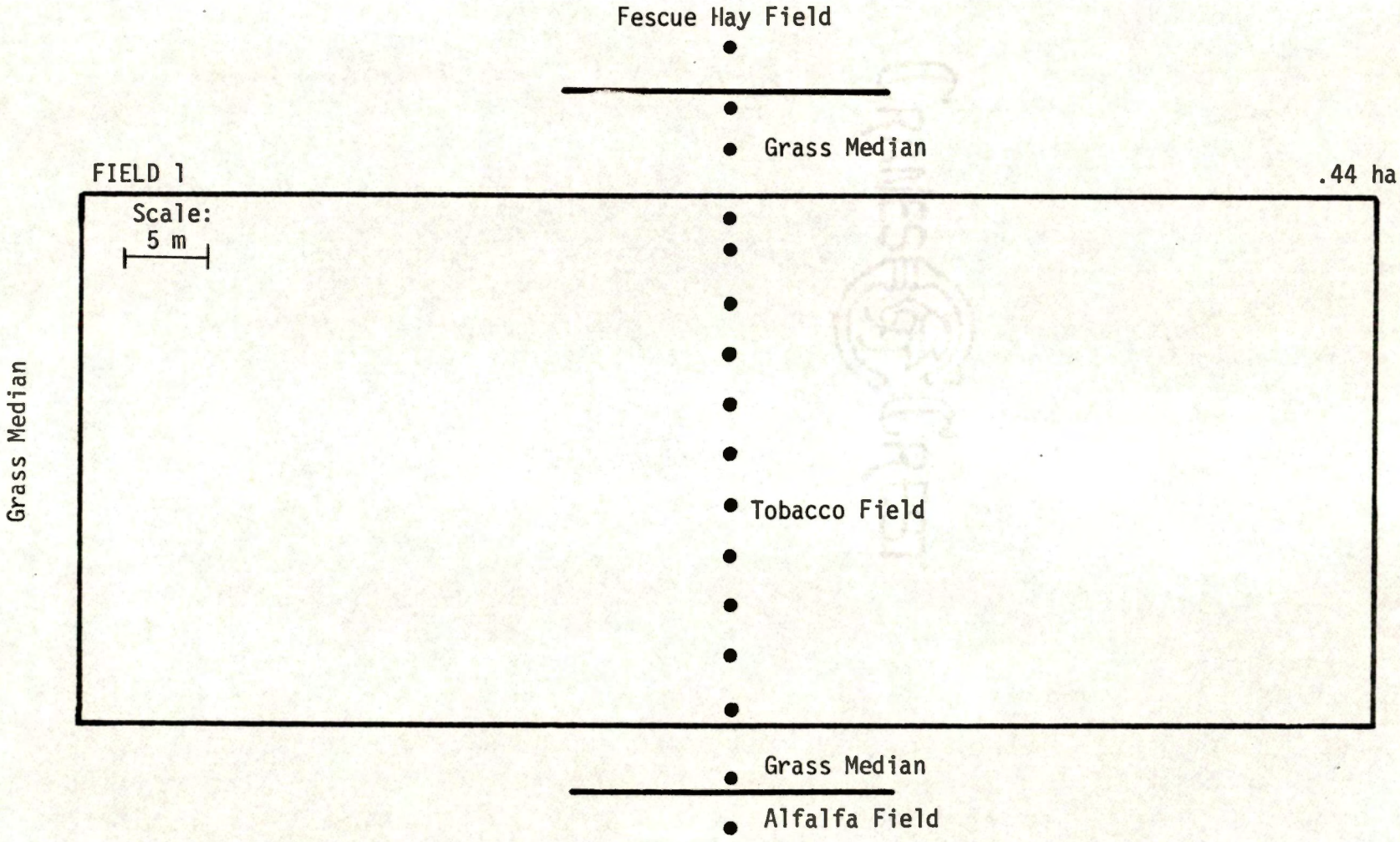

Figure 1. Locations of 16 pitfall stations in field 1 (carbofuran treated), Greene Co., TN, 1979. Each dot represents one station (5 traps)

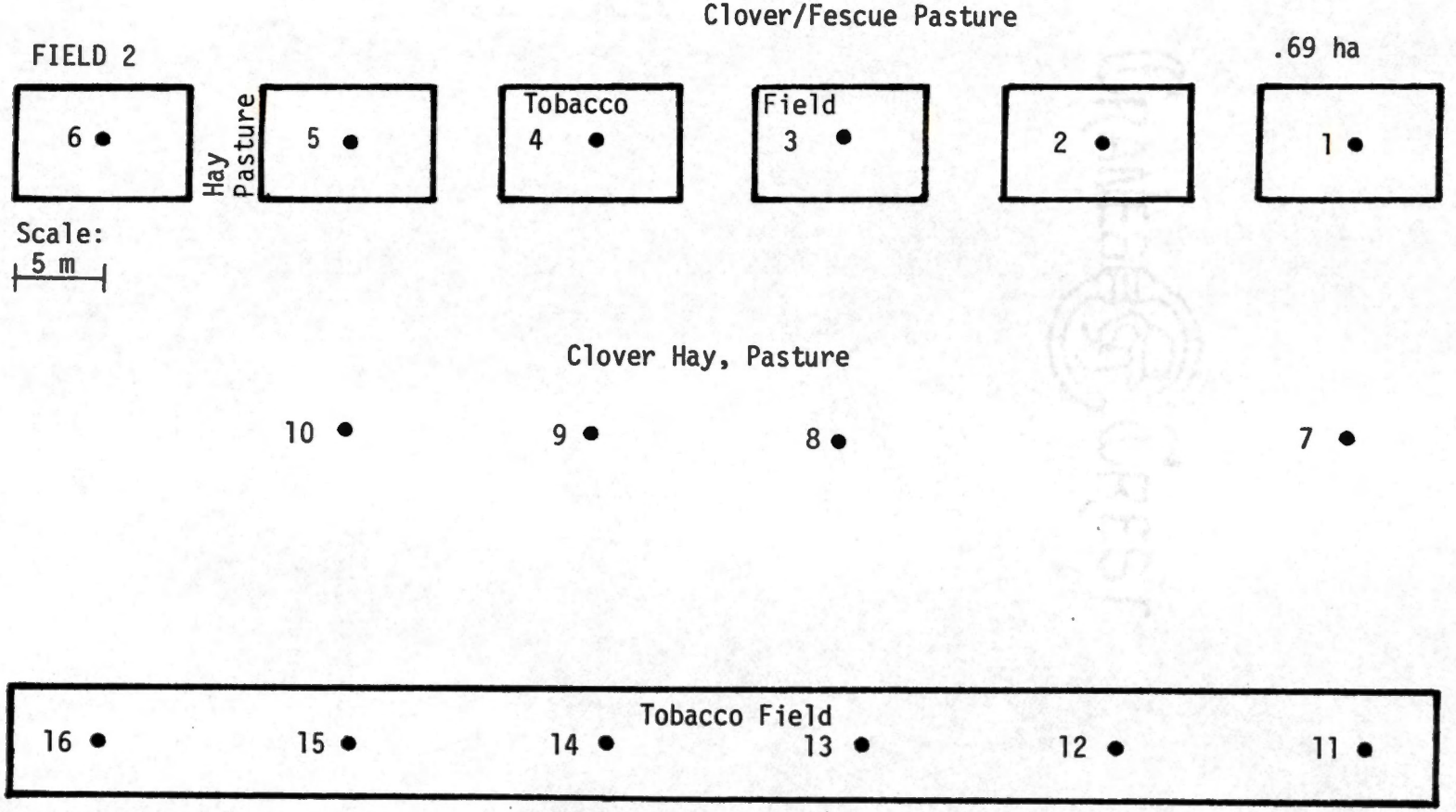

Figure 2. Locations of 16 pitfall stations in field 2 (untreated), Greene Co., TN, 1979. Each dot represents one station (5 traps)

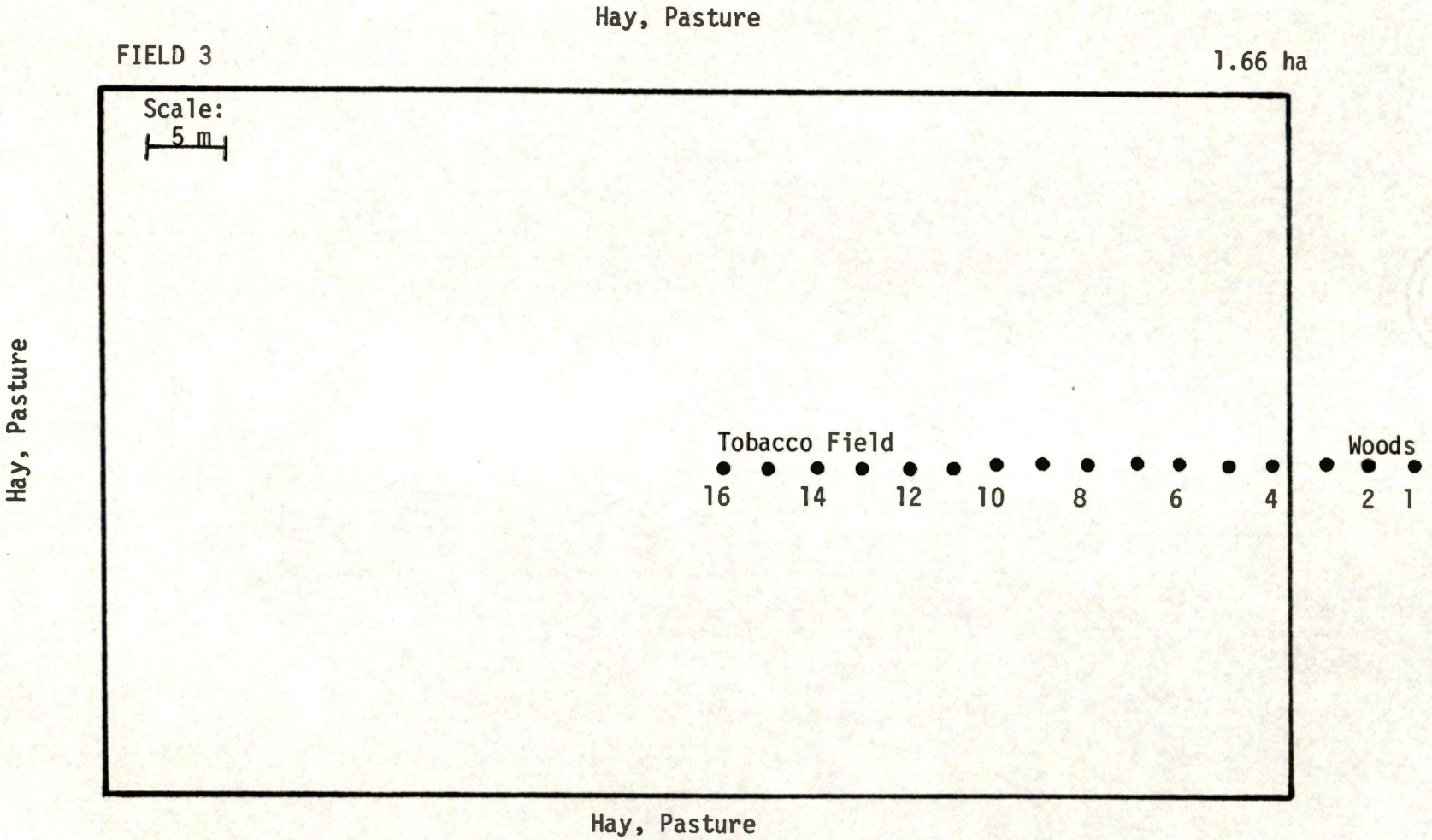

Figure 3. Locations of 16 pitfall stations in field 3 (carbofuran treated), Greene Co., TN, 1979. Each dot represents one station (5 traps)

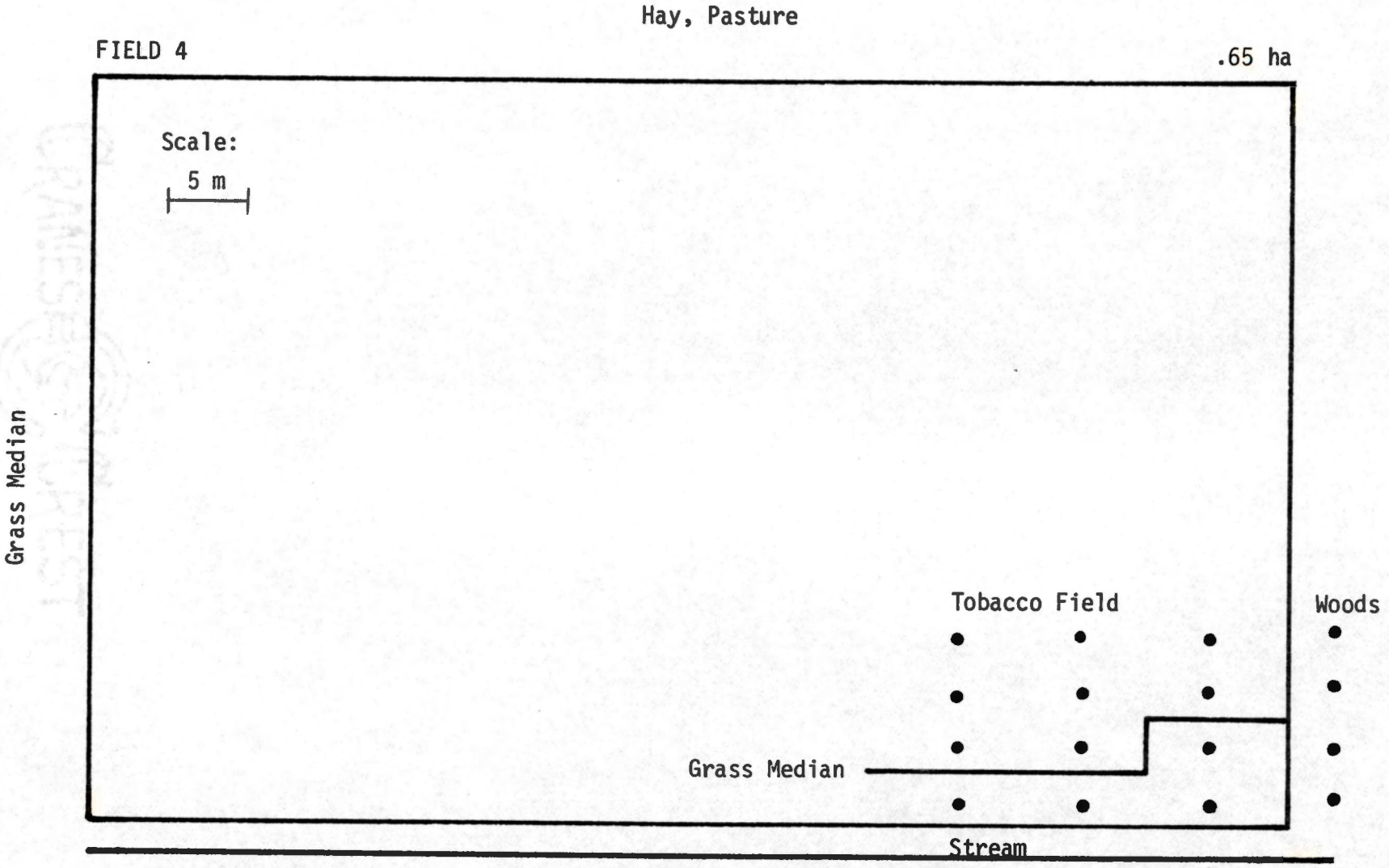

Figure 4. Locations of 16 pitfall stations in field 4 (untreated), Greene Co., TN, 1979. Each dot represents one station (5 traps)

field. Field 3 had carbofuran broadcast at 4.49 kg AI/ha over the entire field. Fields 2 and 4 were left untreated as control fields.

III. SAMPLING ADULT CARABIDS

Carabid beetle adults were sampled with pitfall traps. Each pitfall trap consisted of two Lilly® 12 ounce plastic cups, one nested inside the other. The cups were set upright into holes in the soil with the lips flush with the soil surface. For the collection of samples, the inner cup could be easily removed from the outer cup. The outer cup was perforated to prevent water from accumulating between the cups during rainfall. Surveyor flags were used to mark the pitfall locations. Ethelene glycol served as a killing and preserving agent.

The number of pitfall traps was increased from four traps/four row plot in 1978, to five traps, comprising a station, set at approximately 3.3m intervals across each field in 1979 (Fig. 5). Traps within stations were set in a row at .33m intervals. Four of the traps were standard pitfall traps; the fifth was an "intercept trap" (Barr, personal communication) (Fig. 6). Dr. Thomas C. Barr, Univ. of Kentucky (personal communication) suggested the use of the "intercept trap" to increase the number of individuals and the diversity of carabid species collected. The "intercept trap" had four .33 m long pieces of garden edging (baffels) placed into the ground forming an X, with the pitfall trap in the middle. Each field contained 80 traps (16 trap stations).

The traps were placed in fields 1 and 2 for one-day precounts, and were removed prior to treating and planting. Following planting of the tobacco, traps were placed in the fields over a one-week period:

Figure 5. A pitfall station (5 traps), Greene Co., TN, 1979.

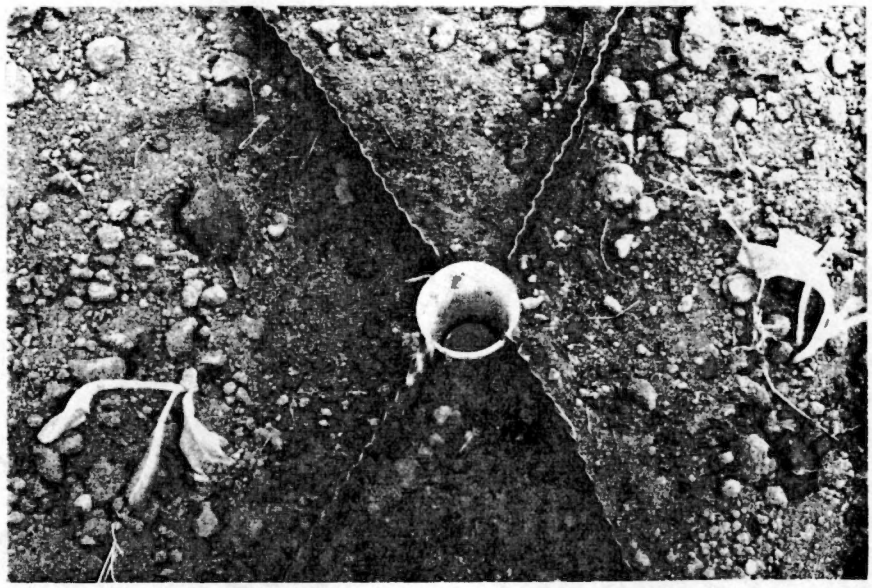

Figure 6. An "intercept trap," Greene Co., TN, 1979.

Field 1, June 7
Field 2, June 8
Field 3, June 14
Field 4, June 12

The arrangement of trap stations in each field is indicated in Figures 1, 2,3, and 4. Traps were sampled weekly from June 15 through October 15. The calendar dates for the collection weeks are given in Table 1. Specimens trapped in the four standard traps were collected and separated from the "intercept trap" specimens at each station. The trap contents were washed, sorted, stored, and later identified. All specimens were identified using keys by Ball (1960, 1962), Bell (1960), Dillon and Dillon (1961), Freitag (1969), Lindroth (1961, 1963, 1968, 1969a, 1969b), and Reichardt (1967). Specimens were sent for verification and occasional identification to Dr. Raymond G. Thompson of Texas A & M University (formerly University of Tennessee), Dr. Thomas C. Barr of the University of Kentucky, and Dr. George E. Ball of the University of Alberta, Canada.

Table 1. Calendar Dates for the 18 Collection Weeks of this Study, Greene Co., TN, 1979

Collection Week	Calendar Date
1	June 15-June 18
2	June 22-June 25
3	June 29-July 2
4	July 6-July 9
5	July 13-July 16
6	July 20-July 23
7	July 27-July 30
8	August 3-August 6
9	August 10-August 13
10	August 17-August 20
11	August 24-August 27
12	August 31-September 3
13	September 7-September 10
14	September 14-September 17
15	September 21-September 24
16	September 28-October 1
17	October 5-October 8
18	October 12-October 15

CHAPTER IV

RESULTS AND DISCUSSION

During the summer and fall of 1979, 106 species of carabid beetles were collected in tobacco fields and adjacent pastures and woodlands (Table 2). Of this number, 83 species occurred in tobacco fields. Midkiff (1979) collected 13 species in Kentucky tobacco plots. Six species of carabids commonly collected in Tennessee which also appeared in the Kentucky collections are:

1. Pterostichus chalcites Say
2. Amara cupreolata Putzeys
3. Anisodactylus sanctaecrusis F.
4. Harpalus pennsylvanicus DeGeer
5. Stenolophus (=Agonoderus) comma F.
6. Pterostichus lucublandus Say.

Evarthrus spp., among the most numerous species in Kentucky, were less common in the Tennessee collections. One species, Pterostichus stygicus Say, represented in the Kentucky collection was missing from the Tennessee collections. Seven species not in the Kentucky collection that were considered abundant (>200 individuals collected in one season) in Tennessee are:

1. Harpalus erythropus Dejean
2. Pterostichus coracinus Newman
3. Scarites substriatus Haldeman
4. Abacidus atratus Newman
5. Chlaenius (s. st.) tricolor Dejean
6. Harpalus bicolor F.

The total number of individuals of each species trapped during this study is shown in Table 3. Species were arbitrarily divided into three groups (most common, less common, and occasional or rare) on the basis of number collected, as done by Lund (1975). Sixteen species, designated the most common carabid beetles collected, will be discussed individually.

Table 2. Species of Carabids Collected in Pitfall Traps in 4 East Tennessee Tobacco Fields and Adjacent Pastures and Woodlands, Greene Co., TN, 1979

Cicindelinae

Cicindela punctulata Olivier
Cicindela repanda Dejean
Cicindela sexguttata F.
Megacephala virginica (L.)

Carabinae

Cychrini

Scaphinotus (s. st.) *unicolor* F.
Sphaeroderus stenostomus subsp. Dejean

Carabini

Calosoma externum Say
Calosoma sayi Dejean

Notiophilini

Notiophilus aeneus Herbst
Notiophilus novemstriatus LeConte

Scaritini

Clivina bipustulata F.
Clivina impressifrons LeConte
Clivina sp.
Dyshirius haemorrhoidalis Dejean
Scarites substriatus Haldeman
Scarites subterraneus F.

Patrobini

Patrobus longicornis Say

Table 2. (Continued)

Bembidiini

Bembidion quadrimaculatum L.
Bembidion rapidum LeConte
Bembidion affine Say
Elaphropus spp.
Paratachys sp.

Pterostichini

Abacidus atratus Newman
Agonum octopunctatum F.
Agonum pallipes F.
Agonum placidum Say
Agonum punctiforme Say
Calathus gregarius Say
Calathus opaculus LeConte
Evarthrus spp.
Evarthrus sigillatus Say
Odontonyx sp.
Piesmus mondalis Germar
Platynus decentis Say
Pterostichus chalcites Say
Pterostichus coracinus Newman
Pterostichus crenicollis LeConte
Pterostichus fatuus Mannerheim
Pterostichus lucublandus Say
Pterostichus rostratus Newman
Rhadine caudata

Amarini

Amara exarata Dejean
Amara obesa Say
Amara pennsylvanica Hayward
Amara rubrica Haldeman
Amara spp.
Amara cupreolata Putzneys
Amara impuncticollis Say
Amara littoralis Mannerheim

Table 2. (Continued)

Harpalini

Acupalpus partiarus Say
Acupalpus pauperculus Dejean
Amphasia interstitialis Say
Anisodactylus dulcicollis LaFerte
Anisodactylus furvus LeConte
Anisodactylus nigerrimus Dejean
Anisodactylus ovularis Casey
Anisodactylus rusticus Say
Anisodactylus sanctaecrusis F.
Anisotarsus terminatus Say
Bradycellus rupestris Say
Cratacanthus dubis Beauvois
Discoderus parallelus Haldeman
Harpalus bicolor F.
Harpalus caligenosis F.
Harpalus erythropus Dejean
Harpalus faunus Say
Harpalus fulgens Csiki
Harpalus herbivagus Say
Harpalus longicollis LeConte
Harpalus pennsylvanicus DeGeer
Harpalus protractus Casey
Notiobia nitidipennis LeConte
Selenophorus ellipticus Dejean
Selenophorus pedicularius Dejean
Stenolophus comma F.
Stenolophus lecontei Chaudoir
Stenolophus ochropezus Say
Stenolophus rotundatus LeConte
Trichotichnus dichrous Dejean

Licinini

Badister notatus Haldeman
Dicaelus dilatatus Say
Dicaelus elongatus Bonelli
Dicaelus furvus Dejean
Dicaelus politus Dejean
Diplocheila (Isorembus) sp.

Table 2. (Continued)

Chlaeniini
Chlaenius emarginatus Say
Chlaenius laticollis Say
Chlaenius pusillus Say
Chlaenius sericeus Forster
Chlaenius (s. st.) tomentosus Say
Chlaenius (s. st.) tricolor Dejean
Odadanthini
Colliuris pennsylvanica L.
Masoreini
Tetragonoderus intersectus Germar
Lebiini
Apenes lucidula Dejean
Apenes sinuata Say
Cymindis americana Dejean
Lebia Abdominalis Chaudoir
Lebia spp.
Lebia viridis Say
Microlestes pusio LeConte
Pinacodera limbata Dejean
Galeritini
Galerita bicolor Drury
Galerita janus F.
Galerita lecontei Dejean
Brachininae
Brachinus sp.

Table 3. Species of Carabids Trapped During 1979, Greene Co., TN

	In 256 Standard Traps	In 64 Intercept Traps	Total
Group A. Most Common			
Harpalus pennsylvanicus	2174	2227	4401
Amara spp.	853	472	1325
cupreolata			
impuncticollis			
littoralis			
Pterostichus chalcites	428	385	813
Stenolophus comma	429	379	808
Cicindela punctulata	417	317	734
Pterostichus coracinus	299	403	702
Harpalus erythropus	340	292	632
Scarites substriatus	195	315	510
Abacidus atratus	160	230	390
Chlaenius (s. st.) tricolor	210	155	355
Anisodactylus sanctaecrusis	183	122	305
Harpalus bicolor	162	120	282
Calathus gregarius	114	147	261
Pterostichus lucublandus	140	116	256
Agonum placidum	122	117	239
Bembidion rapidum	126	106	232
Galerita bicolor	121	110	231
Group B: Less Common			
Scarites subterraneus	61	133	194
Megacephala virginica	122	44	166
Harpalus caligenosis	78	83	161
Agonum punctiforme	69	80	149
Anisodactylus dulcicollis	63	83	146
Harpalus longicollis	76	57	133
Harpalus faunus	80	50	130
Cratacanthus dubis	68	56	124
Rhadine caudata	36	76	112
Agonum octopunctatum	69	39	108
Chlaenius laticollis	52	53	105
Patrobus longicornis	56	49	105
Chlaenius pusillus	45	45	90
Galerita janus	25	50	76
Pterostichus crenicollis	22	30	52
Stenolophus lecontei	25	22	47
Bembidion quadrimaculatum	30	14	44
Anisodactylus rusticus	18	25	43
Notiophilus aeneus	25	17	42
Galerita lecontei	27	12	39
Harpalus fulgens	11	22	

Table 3. (Continued)

	In 256 Standard Traps	In 64 Intercept Traps	Total
Group B: Less Common (Continued)			
Sphaeroderus stenostomus	11	22	33
Stenolophus rotundatus	14	19	33
Evarthrus spp.	17	13	30
Group C: Occasional or Rare			
Chlaenius emarginatus	11	18	29
Anisodactylus furvus	9	17	36
Chlaenius sericeus	17	9	26
Bradycellus rupestris	13	7	22
Trichotichnus dichrous	15	7	22
Tachys sp.	13	7	20
Colliuris pennsylvanicus	12	7	19
Cymindis americana	9	9	18
Dicaelus politus	4	11	15
Dicaelus furvus	5	8	13
Dicaelus elongatus	5	6	11
Clivina bipustulata	5	5	10
Dicaelus dilatatus	4	5	9
Amara obesa	1	7	8
Calosoma sayi	3	5	8
Chlaenius (s. st.) tomentosus	4	4	8
Piesmus mondalis	8		8
Amara pennsylvanica	2	4	6
Apenes lucidula	1	5	6
Evarthrus sigillatus	4	2	6
Lebia spp.	5		5
Agonum pallipes	2	2	4
Amphasia interstitialis	2	2	4
Notiophilus novemstriatus	2	2	4
Platynus decentis	2	2	4
Anisodactylus nigerrimus	2	1	3
Cicindela repanda	2	1	3
Discoderus parallelus	1	2	3
Pterostichus fatuus	1	2	3
Pterostichus rostratus	2	1	3
Amara exarata		2	2
Amara rubrica	1	1	2
Anisotarsus terminatus	2		2
Calathus opaculus	2		2
Diplocheila sp.	1	1	2
Selenophorus pedicularius	2		2
Tetragonoderus intersectus	2		2

Table 3. (Continued)

	In 256 Standard Traps	In 64 Intercept Traps	Total
Group C: Occasional or Rare (Continued)			
Anisodactylus ovularis	1		1
Apenes sinuata		1	1
Badister notatus		1	1
Bembidion affine	1		1
Brachinus sp.		1	1
Calosoma externum	1		1
Cicindela sexgutlata	1		1
Clivina impressifrons		1	1
Clivina sp.	1		1
Dyschirius haemorrhoidalis		1	1
Lebia abdominalis	1		1
Notiobia nitidipennis	1		1
Pinacodera limbata	1		1
Scaphinotus (s. st.) unicolor		1	1
Selenophorus ellipticus		1	1

These species comprised more than 75% of the total number collected. Numerical data for individual fields, for less common or rare species, and a comparison of other researchers' data are in the Appendix.

A total of 14,382 carabid beetles was collected during 1979. Of this total, 9,438 beetles were trapped in tobacco fields, 3,034 in pastures, and 1,548 in woodlands. All three habitats had almost equal numbers of beetles when compared on the basis of numbers of beetles per trap station. Of the total number of species, 28 were collected primarily from woodlands, 26 from the tobacco fields, and 14 from pastures. Another 20 species were equally divided between two habitats and 4 were present in all three habitats in approximately equal numbers (Table 4).

Hiebsch(1964), Thiele (1964b), and other European researchers have sampled hedges and wind-breaks adjacent to cultivated areas and have come to several conclusions. "Dominant carabids of the hedgerow, being forest species, scarcely penetrate at all into the fields, which are climatically unsuitable for them" (Thiele, 1964b). Hiebsch (1964) concluded, "the mutual influence of the fauna of hedges and the adjoining fields is negligible and is of little importance in biological pest control." In contrast, Pterostichus coracinus , Abacidus atratus, Calathus gregarius Pterostichus lucublandus, and Harpalus bicolor, all primarily designated as woodland species in this study, were collected in large numbers within tobacco fields. All of these species, with the exception of Pterostichus lucublandus, reached peak numbers in the fall and presumably migrated from woodlands into the tobacco fields.

Harpalus pennsylvanicus was found to occur in almost equal numbers/ station in cultivated tobacco fields and in pastures. A total of 4401

Table 4. Species of Carabids Collected in Tobacco Fields and Adjacent Pastures and Woodlands Grouped According to Habitat Which They Were Trapped Most Commonly

	Avg. No. Beetles/Pitfall Station		
	Tobacco Field	Pasture	Woods
Tobacco			
Agonum pallipes	4		3
Agonum placidum	36.41	3.76	
Amara pennsylvanica	6		
Amara rubrica	2		
Anisodactylus sanctaecrusis	43.24	17.74	
Anisotarsus terminatus	2		
Bembidion affine	1		
Brachinus sp.	1		
Chlaenius (s. st.) tricolor	47.38	27.42	6
Cicindela repanda	3		
Cicindela sexguttata	1		
Clivina bipustulata	10		
Clivina impressifrons	1		
Clivina sp.	1		
Diplocheila sp.	2		
Discoderus parallelus	3		
Dyschirius haemorrhoidalis	1		
Harpalus erythropus	99.05	1.08	7
Harpalus faunus	17.01	9.68	5
Lebia abdominalis	1		
Patrobus longicornis	13.51	6.45	8
Scaphinotus (s. st.) unicolor	1		
Selenophorus ellipticus	1		
Stenolophus comma	107.79	68.82	2
Stenolophus lecontei	7.31	.54	
Trichotichnus dichrous	3.34		1
Pasture			
Agonum octopunctatum	11.29	19.89	
Amara spp.	56.12	503.32	36
Anisodactylus furvus	.16	12.9	
Anisodactylus rusticus	4.13	9.14	
Calosoma externum		1	
Calosoma sayi	.64	2.15	
Chlaenius laticollis	5.41	31.72	12
Chlaenius (s. st.) tomentosus	.64	2.15	
Cicindela punctulata	72.34	149.86	1
Cratacanthus dubis	11.45	27.42	1
Galerita lecontei	.79	17.74	1
Harpalus fulgens	1.75	11.83	
Pinacodera limbata		1	
Stenolophus rotundatus	1.11	13.44	2

Table 4. (Continued)

Tobacco	Avg. No. Beetles/Pitfall Station		
	Tobacco Field	Pasture	Woods
Woods			
Abacidus atratus	31	21.51	155
Amara exarata			2
Amara obesa			1
Amphasia interstitialis			4
Apenes lucidula	.16		5
Apenes sinuata			1
Badister notatus			2
Bembidion quadrimaculatum	1.11	1.08	35
Calathus gregarius	16.85	3.23	149
Chlaenius emarginatus	.95	2.69	18
Cymindis americana	1.11		11
Dicaelus dilatatus	.32	1.08	4
Dicaelus elongatus	.64		7
Dicaelus furvus	.16	1.08	10
Dicaelus politus	.64		11
Galerita bicolor	12.4	8.06	138
Galerita janus	4.77	6.45	34
Harpalus bicolor	25.6	9.14	104
Harpalus longicollis	5.72	9.14	80
Notiobia nitidipennis			1
Notiophilus aeneus	.32		40
Odontonyx sp.			1
Platynus decentis			4
Pterostichus coracinus	69.79	7.53	249
Pterostichus crenicollis	1.91		40
Pterostichus fatuus			3
Pterostichus lucublandus	15.26	39.78	86
Rhadine caudata	.95		106
Sphaeroderus stenostomus			33
Tobacco and Pasture			
Anisodactylus dulcicollis	18.6	15.59	
Anisodactylus nigerrimus	.32	1.54	
Anisodactylus ovularis	.16	.54	
Bembidion rapidum	26.71	34.41	
Colliurus pennsylvanicus	2.54	1.61	
Harpalus pennsylvanicus	549.28	436.56	134
Lebia spp.	.64	.54	
Megacephala virginica	18.44	26.88	
Pterostichus chalcites	99.68	100	

Table 4. (Continued)

Tobacco	Avg. No. Beetles/Pitfall Station		
	Tobacco Field	Pasture	Woods
Tobacco and Pasture (Continued)			
Pterostichus rostratus	.32	.54	
Scarites substriatus	58.66	67.2	16
Scarites subterraneus	21.14	26.34	12
Selenophorus pedicularius	.16	.54	
Tachys spp.	2.7	1.61	
Tetragonoderus intersectus	.16	.54	
Tobacco and Woods			
Harpalus caligenosis	19.55	11.83	16
Agonum punctiforme	17.65	10.22	19
Notiophilus novemstriatus	.48		1
Evarthrus sigillatus	.64		2
Calathus opaculus	.16		1
Tobacco, Pasture, and Woods			
Bradycellus rupestris	2.54	2.15	2
Chlaenius pusillus	10.65	8.6	7
Chlaenius sericeus	2.54	3.76	3
Evarthrus spp.	2.54	4.3	6

specimens of H. pennsylvanicus were collected comprising 30.6% of the seasonal total of ground beetles. This species of ground beetles, collected in numbers far surpassing all other species, was chosen as an indicator species to determine if ground beetle populations were significantly reduced in carbofuran treated tobacco fields compared with untreated tobacco fields. Statistical analysis of the data indicated populations of H. pennsylvanicus were not significantly reduced in carbofuran treated tobacco fields as compared to untreated fields when tested at the 10% level of significance ($\alpha = .10$).

The "intercept trap," which samples a larger area and a larger diversity of species than the standard pitfall traps, was found to be more effective than standard pitfall traps in sampling populations of carabid beetles. A total of 6,981 beetles were collected in 64 "intercept traps" and 7,401 were collected in 256 standard pitfall traps; therefore, there were caught in each "intercept trap" 3.8 times as many beetles as in a standard pitfall trap (Table 3). Since slow-moving and small species of carabids fall into standard pitfall traps less frequently, the "intercept trap" was used to better sample species diversity and relative abundance.

The sixteen most abundant ground beetles were considered worthy of discussion. Lindroth (1961) included the tiger beetles (Coleoptera: Cicindelidae) as a subfamily of the ground beetles (Coleoptera: Carabidae). On the advice of Dr. Raymond Thompson (personal communication), I have followed this precedent, breaking tradition. One abundant species of tiger beetle (Coleoptera: Cicindelinae) was noted. In the following discussions, individual species are discussed in order of their abundance in pitfall trap collections.

I. NOTES ON INDIVIDUAL SPECIES

Harpalus pennsylvanicus DeGeer

This medium sized, shiny, brown species (Fig. 7) was represented by 4401 specimens, and comprised 30.6% of the seasonal total. Harpalus pennsylvanicus, present at moderate levels until late August, peaked in early September, then declined slowly until mid October (Fig. 8). The seasonal activity-abundance cycle of H. pennsylvanicus was unimodal and indicated a fall breeding season. This seasonal distribution pattern is consistent with data from pitfall studies by Hsin et al. (1979), Kirk (1973), Lund (1975), and Rivard (1964a, 1966). Rivard concluded that adults of H. pennsylvanicus probably emerge over a short period of time.

Habitat preferences were determined for species on the basis of numbers of beetles/pitfall station (Table 4). H. pennsylvanicus was most commonly collected in tobacco fields but was abundant in pastures as well. Rivard (1964a) collected H. pennsylvanicus predominantly in areas of open ground, pasture and cultivated lands.

Kirk (1973), Lindroth (1968), and Shough (1940) reported that H. pennsylvanicus would accept both plant and animal matter as food. Seed, grasses, roots and plant debris have been listed as food sources (Lindroth, 1968). In feeding studies by Shough (1940), H. pennsylvanicus was observed to feed on lepidopteran larvae. Kirk (1973) reported feeding by this species on various stages of western corn rootworms, Diabrotica virgifera LeConte.

A B C D E F G

Figure 7. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Harpalus fulgens B. Harpalus erythropus C. Harpalus faunus D. Harpalus longicollis E. Harpalus pennsylvanicus F. Harpalus bicolor G. Harpalus caligenosis

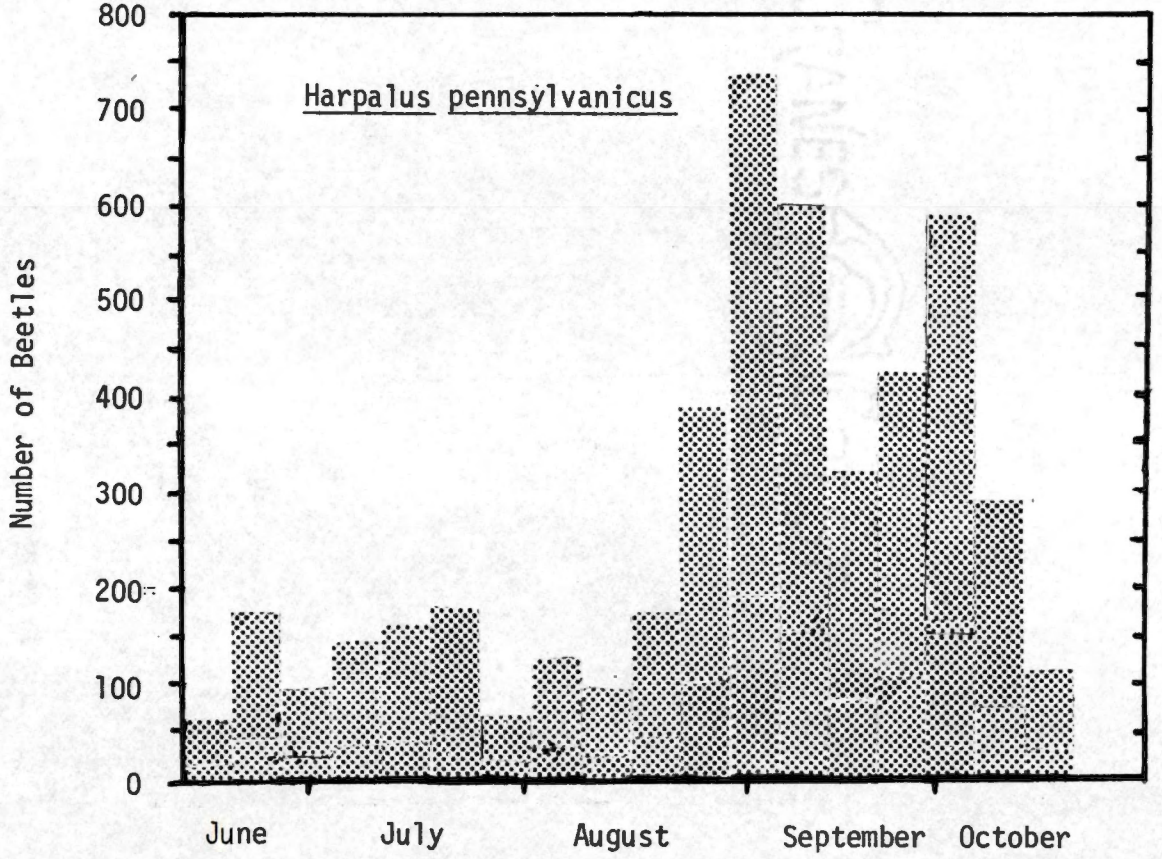

Figure 8. Weekly collections of Harpalus pennsylvanicus DeGeer in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

Amara spp.

A. cupreolata Putzeys
A. impuncticollis Say
A. littoralis Mannerheim

Amara cupreolata, Amara impuncticollis, and Amara littoralis were identified from the collections by Dr. George Ball and Dr. Raymond Thompson. These small, oval, shiny, feebly bronzed species of ground beetles (Fig. 9) were extremely difficult to distinguish and were therefore grouped as Amara spp. Larger and more distinctive species of Amara were identified to species. Populations of Amara spp., represented by 1325 individuals, were present in large numbers in mid June, peaked in late June, then declined slowly to early August, and persisted at low numbers until early October (Fig. 10). The seasonal activity-abundance cycle of Amara spp. was unimodal and indicated a spring breeding season.

Rare or occasional collections of A. cupreolata were reported in croplands by Esau and Peters(1975), Frank (1971a), and Kirk (1971b), while Kirk(1971b) and Rivard (1964a) observed A. impuncticollis to occur rarely in croplands, and A. littoralis was collected rarely by Esau and Peters (1975) in Iowa and abundantly by Frank (1971a) in Canadian croplands. In Kentucky, Midkiff (1979) reported A. cupreolata as an abundant species in tobacco fields with peak abundance in early August, which indicated a fall breeding season. Lindroth (1968) stated that A. impuncticollis might be a fall breeder, and A. littoralis, a close relative, as definitely a spring breeder. Lindroth (1968) made no mention of the breeding season of A. cupreolata. In the Tennessee collections, the spring peak activity-abundance indicated a spring breeding season, and suggests A. littoralis is the most abundant species in the Amara complex.

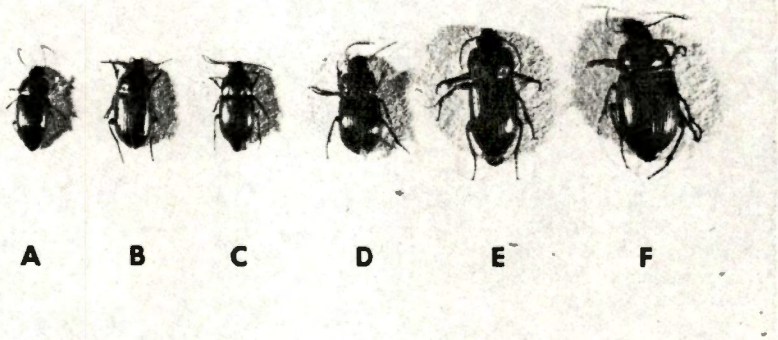

Figure 9. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Amara impunctcollis B. Amara cupreolata C. Amara rubrica D. Amara exarata E. Amara pennsylvanica F. Amara obesa

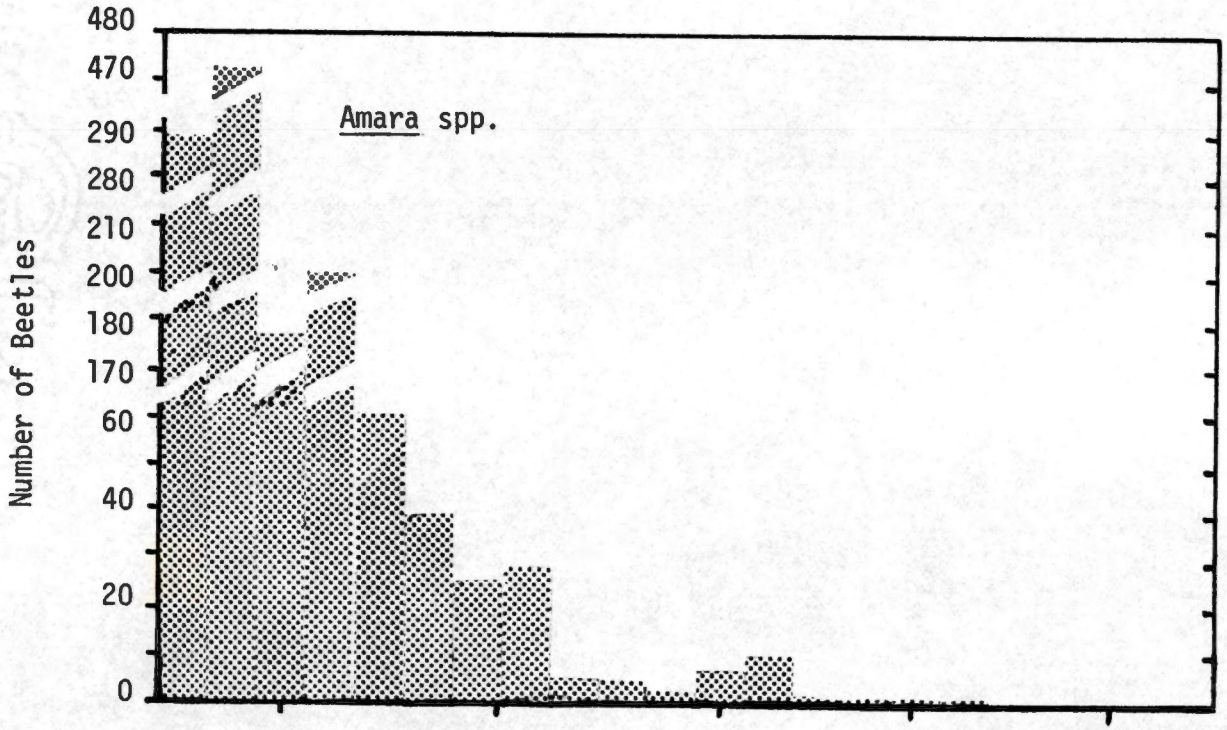

Figure 10. Weekly collections of Amara spp. in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

In the Tennessee study, Amara spp. were collected primarily in and beside an alfalfa field adjacent to a tobacco field. The large numbers of Amara spp. collected, indicates a preference for that habitat. Lindroth (1968) and Rivard (1964a) both reported open ground with moderate to dense vegetation as the main habitat type for Amara cupreolata and Amara impuncticollis. Johnson and Cameron (1969) studied the feeding habits of Amara cupreolata and determined it to be "principally a grass feeder," perhaps explaining the large numbers of Amara collected in alfalfa.

Pterostichus chalcites Say

This metallic green, or bronzed species (Fig. 11) was represented by 813 specimens. Moderate numbers of P. chalcites were present in mid June, they peaked in early August, then declined slowly until early October, at which time a secondary peak occurred (Fig. 12). Seasonal activity-abundance of P. chalcites was consistent with Kirk's (1975b) results showing a bimodal activity cycle for this spring breeder. Hsin et al. (1979) and Lund (1975) did not observe late-season activity. Pterostichus chalcites was trapped in similar numbers in tobacco fields and pastures. Rivard's (1964a) work supported these results with collections of P. chalcites from open ground with moderate to dense vegetation. Basic research by Kirk (1975b) has shown that late summer activity peaks of P. chalcites and its close relative P. lucublandus coincide with the peak oviposition period of the western corn rootworm. In the lab and in the field, Kirk observed that these ground beetles would readily eat western corn rootworm adults, suggesting their potential for biological control of pests.

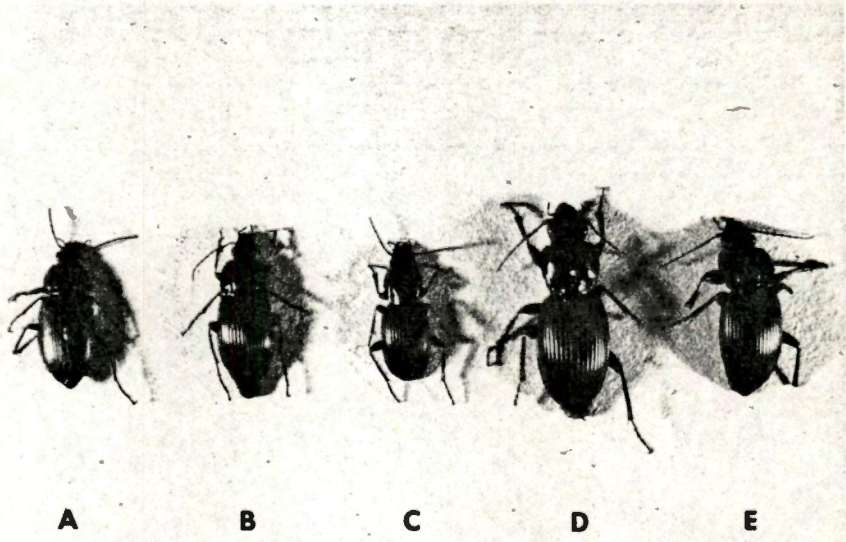

Figure 11. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Pterostichus chalcites B. Pterostichus lucublandus C. Pterostichus crenicollis D. Pterostichus coracinus E. Evarthrus sp.

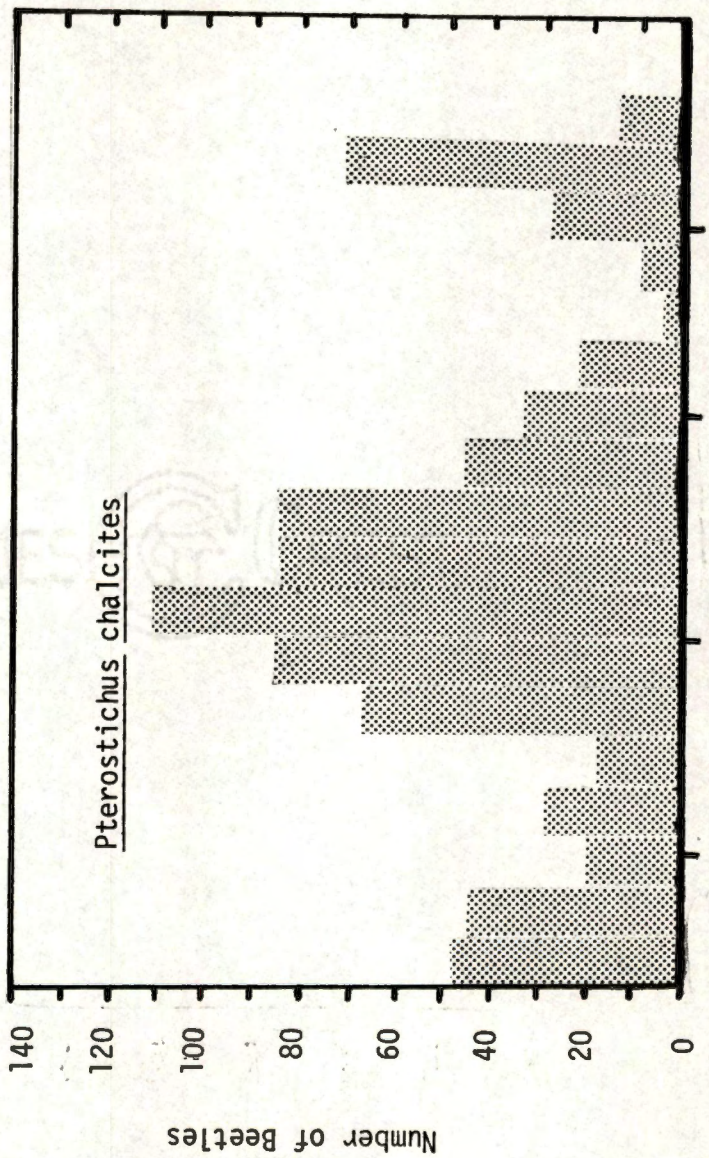

Figure 12. Weekly collections of Pterostichus chalcites Say in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

Stenolophus (=Agonoderus) comma F.

Populations of S. comma, represented by 808 individuals, peaked in mid June and slowly declined until mid July, remaining at negligible levels until October (Fig. 13). Seasonal activity of S. comma reported by Kirk (1971b), Lund (1975), and Pausch (1979) was similar to that found in Tennessee. In contrast, these researchers observed an additional population peak late in the year not observed in Tennessee. In biological studies on S. comma, Kirk (1975a) and Pausch (1979) observed that this small, yellowish brown beetle (Fig. 14) was a spring breeder, but occurred in croplands all year due to overlapping generations. Rivard (1964a) concluded that moist, open ground with sparce vegetation is the preferred habitat of S. comma. This study indicated tobacco fields to be the preferred habitat of S. comma, as compared to pastures and woodlands.

Stenolophus comma, a seed corn beetle, has been labeled as an herbivore by many researchers: Johnson and Cameron (1969), Severin (1947), and others. Work by Bryson and Dillon (1941) and Pausch (1979) indicates that Stenolophus spp. prefer animal food, eating vegetable food when their preferred food is in short supply.

Pterostichus coracinus Newman

This large, black, shining species (Fig. 11, p. 41) was represented by 702 specimens. Catches of P. coracinus remained at low levels until mid August, at which time beetle collections peaked abruptly. Large numbers of beetles were then collected throughout September, and decreased slowly during October (Fig. 15). Rivard (1964a) collected P. coracinus in moderate numbers over a corresponding time schedule. The seasonal

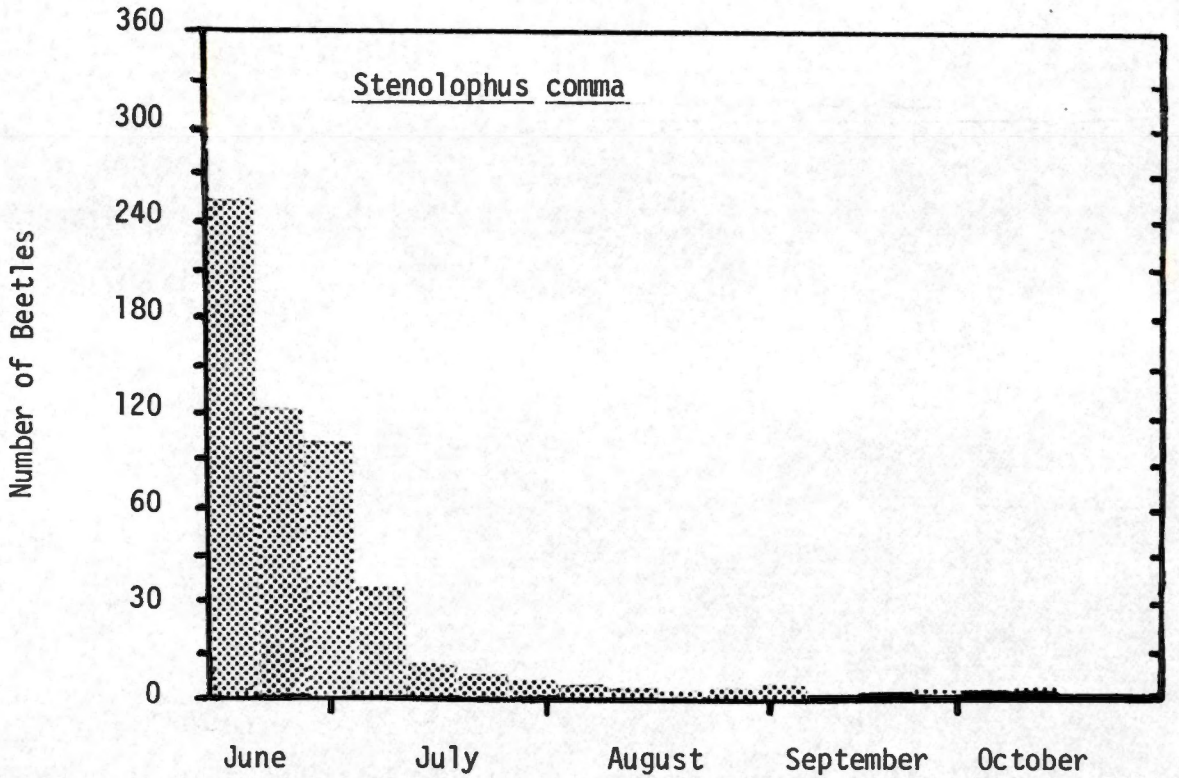

Figure 13. Weekly collections of Stenolophus comma F. in pitfall traps from June 15 through October 15, 1979, Greene Co., TN

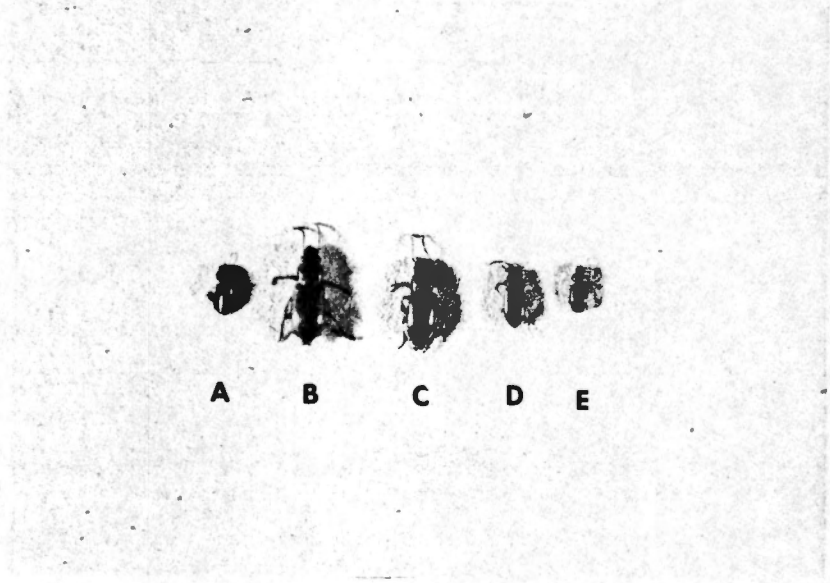

Figure 14. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Stenolophus rotundatus B. Stenolophus comma C. Stenolophus lecontei D. Bradycellus rupestris E. Acupalpus pauperculus

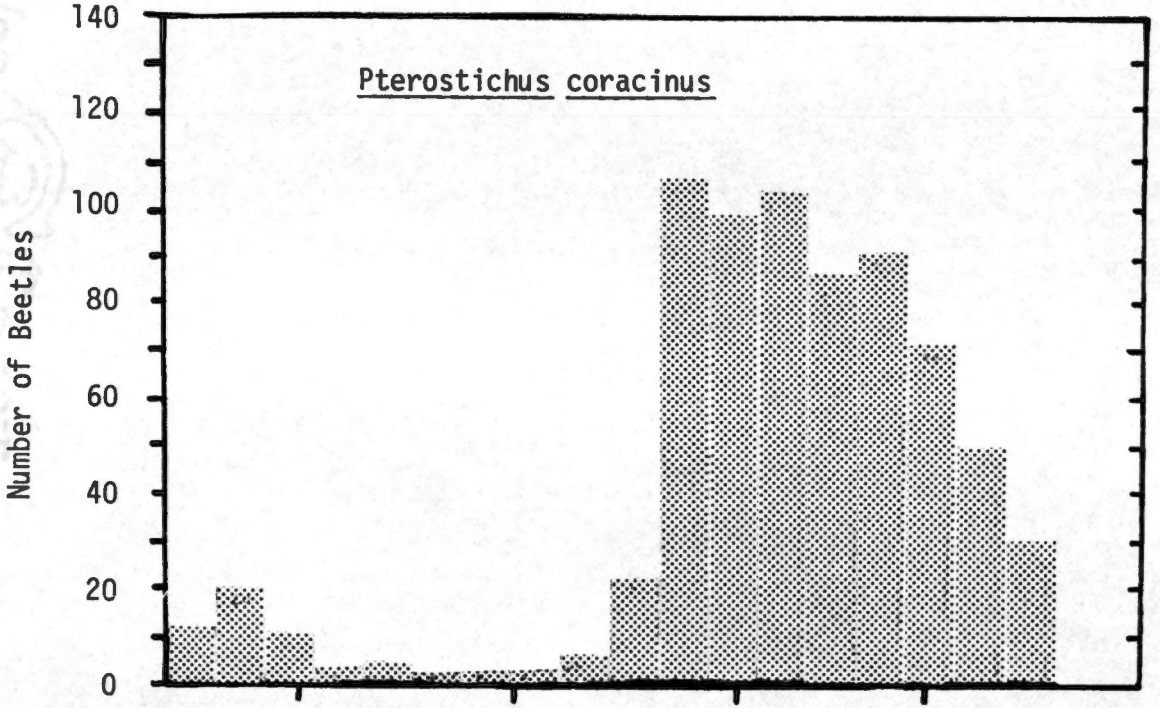

Figure 15. Weekly collections of Pterostichus coracinus Newman in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

activity-abundance cycle of P. coracinus was unimodal and indicated a fall breeding season. Rivard (1964a) reported that P. coracinus was most abundant in or near woods. In this study, P. coracinus was most abundant in woodlands with tobacco fields second in abundance.

Harpalus erythropus Dejean

Populations of H. erythropus, represented by 632 individuals, began to increase in early September, peaked in late September, and declined slowly until mid October (Fig. 16). Esau and Peters (1975) and Rivard (1964b) reported this medium-sized, dark brown beetle (Fig. 7 , p.35) to occur only rarely in croplands in Iowa and Canada, respectively. In Tennessee collections, H. erythropus was trapped in abundance in tobacco fields. The seasonal activity-abundance of H. erythropus was unimodal and indicated a fall breeding season.

Scarites substriatus Haldeman

Populations of S. substriatus, represented by 510 specimens, peaked in mid June, declined to negligible levels by August, then slowly increased to moderate levels in September (Fig. 17). This large, black slow-moving species, commonly known as a "pincher bug" (Fig. 18), was collected in abundance, probably because the "intercept trap" was used. Collections indicate a unimodal activity-abundance cycle and a spring breeding period. Esau and Peters (1975) and Kirk (1971b) recorded occasional specimens of S. substriatus in croplands. In this study, S. substriatus was abundant both in tobacco fields and in pastures.

Forbes (1883) reported S. subterraneus, differentiated from S. substriatus by size, fed on insects and other animal food. All species of Scarites are considered predaceous and very beneficial (Dillon & Dillon, 1961).

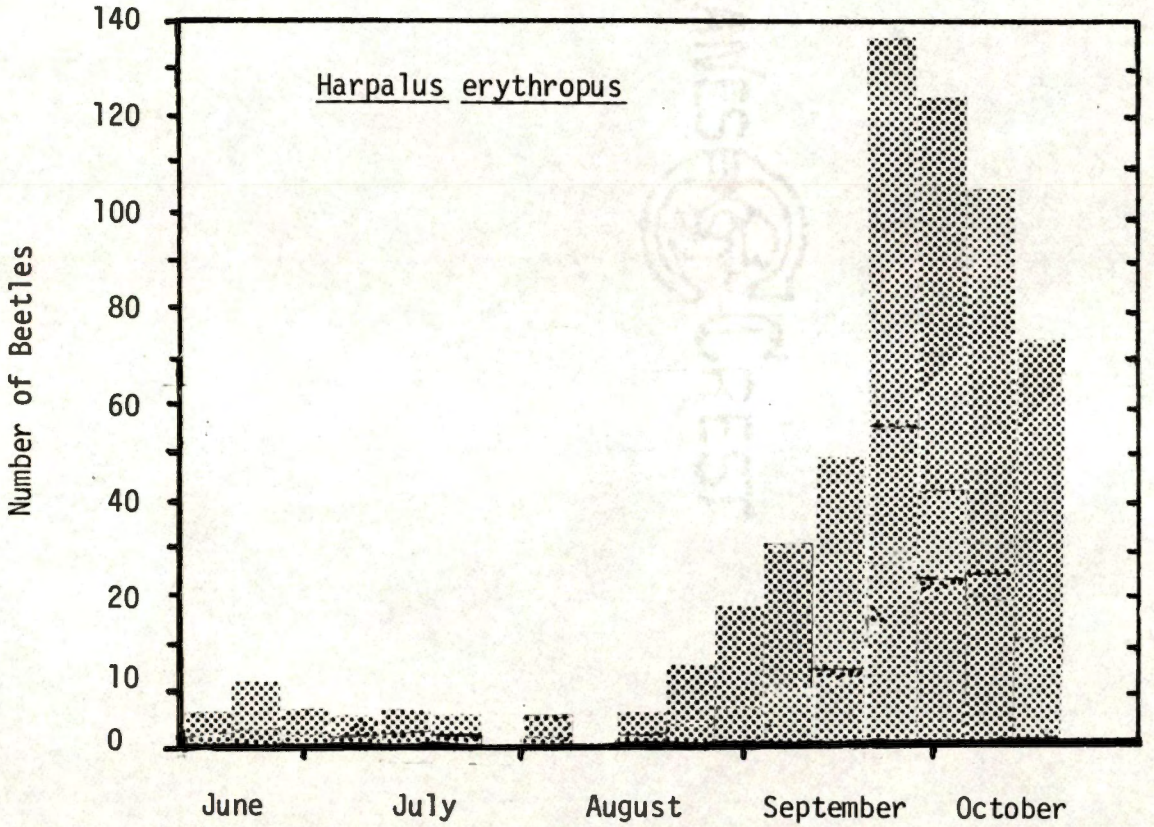

Figure 16. Weekly collections of Harpalus erythropus Dejean in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

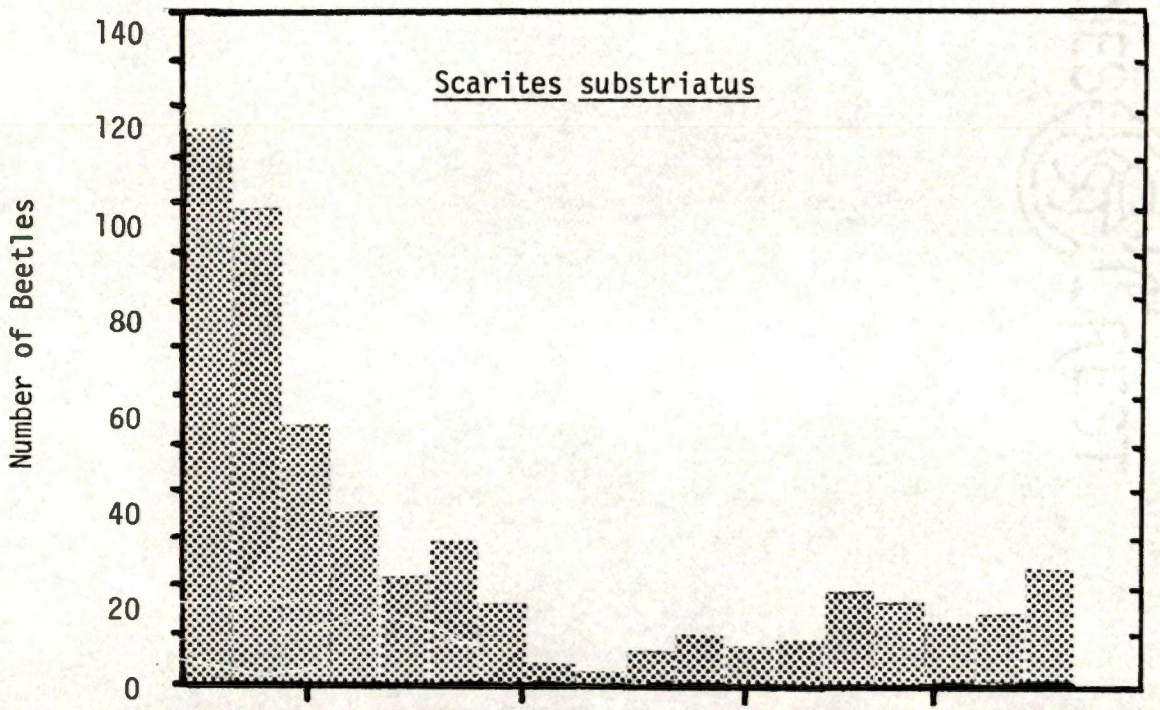

Figure 17. Weekly collections of Scarites substriatus Haldeman in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

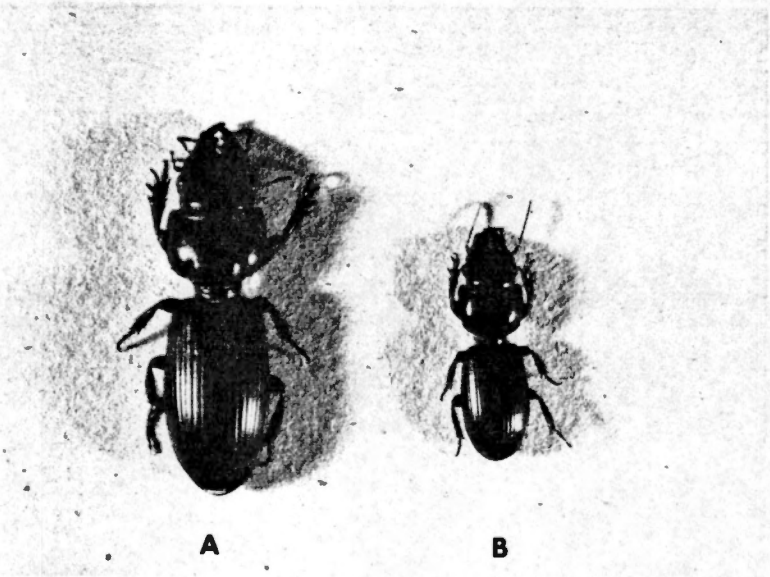

Figure 18. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Scarites substriatus B. Scarites subterraneus

Abacidus atratus Newman

This species (elytra black, shining, and purplish-bronzed) (Fig. 19) was represented by 390 individuals. Collections of Abacidus atratus were rare until mid September at which time numbers began to increase, and peaked in early October (Fig. 20). The season activity-abundance cycle of Abacidus atratus was unimodal and indicated this species was a fall breeder. Abacidus permundus was collected in low numbers from croplands by Esau and Peters (1975) and Kirk (1971b). In the Tennessee collections, woodlands were indicated as the preferred habitat of Abacidus atratus.

Chlaenius (s. st.) tricolor Say

A green, feebly bronzed head and pronotum and a bluish black elytra characterize this species (Fig. 21), represented by 355 specimens in the seasonal collections. Catches of C. tricolor increased until early August, reached the primary peak in late August and early September, and then declined rapidly (Fig. 22). The seasonal activity-abundance cycle of C. tricolor was unimodal and indicated a fall breeding season. Larger numbers of C. tricolor occurred in tobacco fields, than in pastures and woodlands.

Members of the genus Chlaenius are considered destroyers of caterpillars and grubs, suggesting their potential for biological control of pests (Larochelle, 1974). The same author reported C. tricolor to feed on insects and animal matter.

Anisodactylus sanctaecrusis F.

This medium-sized beetle (elytra orange-brown and pronotum dark brown) (Fig. 23) was represented by 305 specimens. Peak collections occurred in mid June and early July, then declined to insignificant

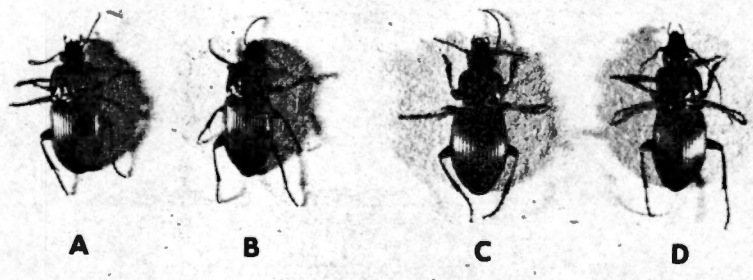

Figure 19. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Piesmus mondalis B. Abacidus atratus C. Evarthrus sp. D. Evarthrus sigillatus

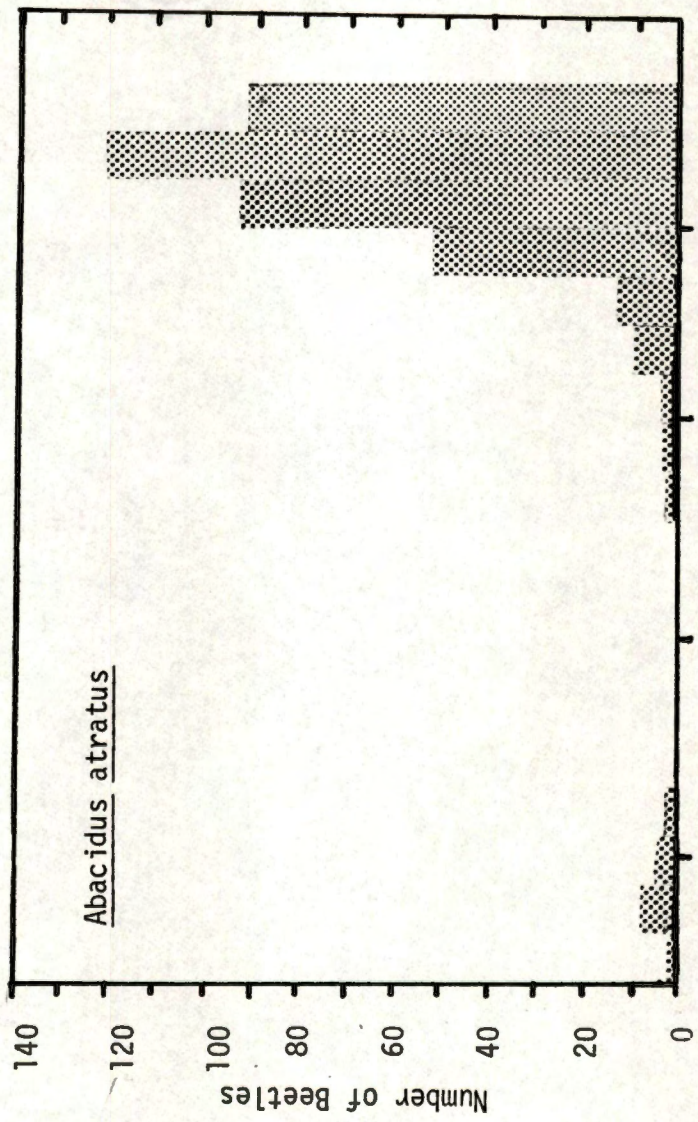

Figure 20. Weekly collections of Abacidus atratus Newman in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

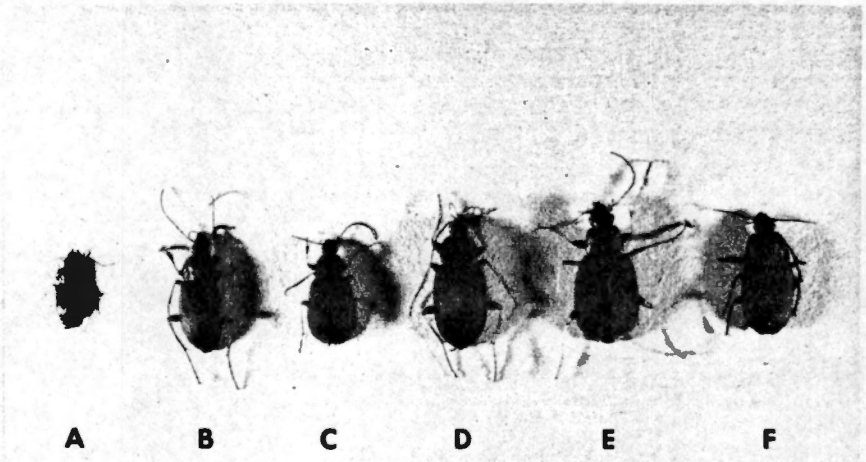

Figure 21. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Chlaenius pusillus B. Chlaenius emarginatus C. Chlaenius (s. st.) tricolor D. Chlaenius laticollis E. Chlaenius sericeus F. Chlaenius (s. st.) tomentosus

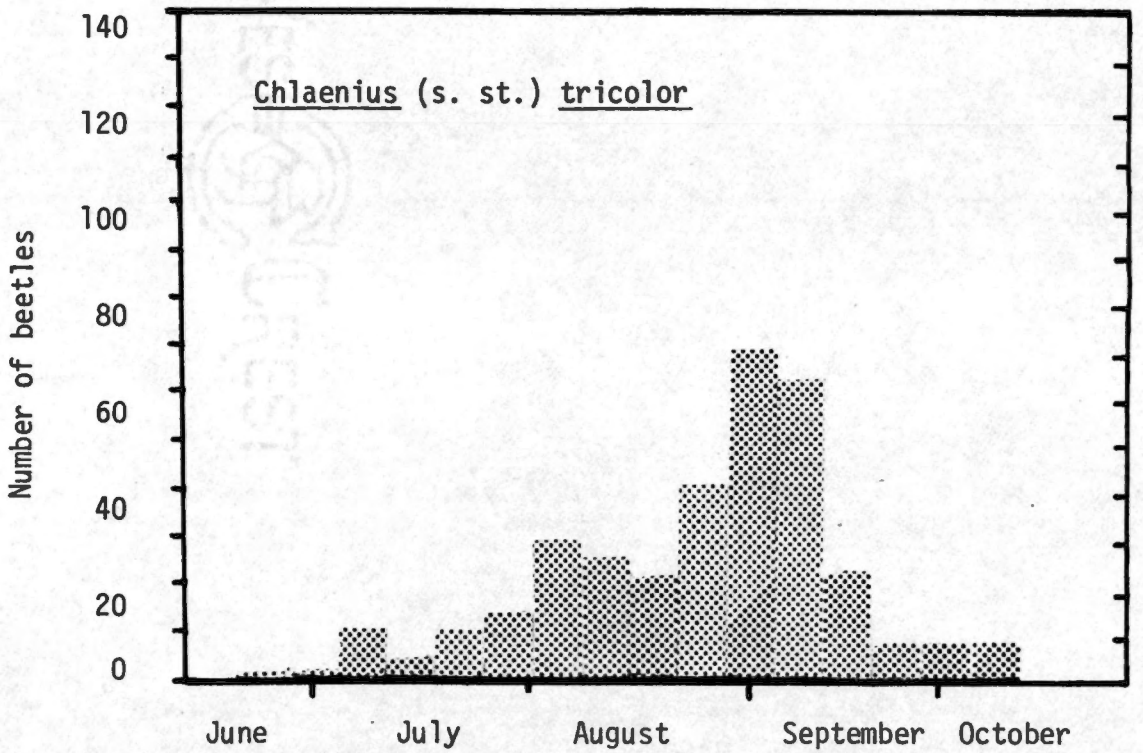

Figure 22. Weekly collections of Chlaenius (s. st.) tricolor Say in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

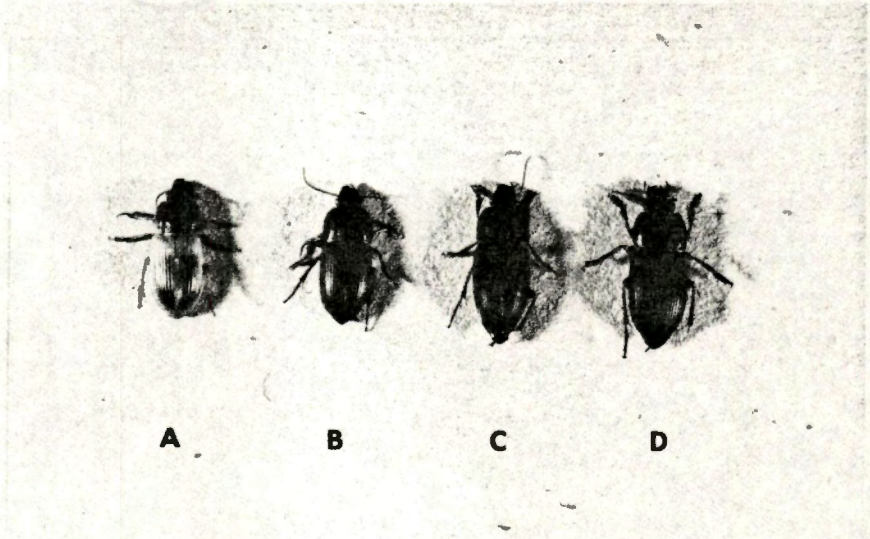

Figure 23. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Anisodactylus sanctaecrusis. B. Anisodactylus dulcicollis C. Anisodactylus rusticus D. Anisodactylus furvus

levels by September (Fig. 24). Seasonal activity-abundance was unimodal and indicate that A. sanctaecrusis is a spring breeder (Kirk, 1977). Tennessee activity patterns for A. sanctaecrusis were similar to that observed by Lund (1975), however, peaks of abundance occurred earlier in Tennessee than Kirk (1977) reported from South Dakota. Rivard (1964a) observed open ground with moderate to dense vegetation to be the main habitat type of A. sanctaecrusis. In this study, A. sanctaecrusis was trapped more commonly within tobacco fields than within pastures and woodlands.

Harpalus bicolor F.

Populations of H. bicolor, represented by 282 individuals, increased in abundance during late August, peaked in late September, and then declined abruptly in October (Fig. 7, p.35, and Fig. 25). Lund (1975) reported similar seasonal activity by H. bicolor in Indiana cornfields, but she showed a small peak in abundance in June, which was not observed in Tennessee. The seasonal activity-abundance cycle of H. bicolor was unimodal and indicated a fall breeding season, as noted by Lindroth (1968). Lund (1975) found that H. pennsylvanicus and H. bicolor occurred together in Indiana cornfields, but H. bicolor was trapped in much lower numbers. In Tennessee, larger numbers of H. bicolor occured in woodlands than in pastures and tobacco fields.

Calathus gregarius Say

Catches of C. gregarius, totaling 261 individuals, remained low in numbers until September, thereafter, numbers increased rapidly until mid October (Fig. 26). This slender, reddish brown species (Fig. 27) was commonly collected in croplands by Esau and Peters (1975), Kirk (1971b), and

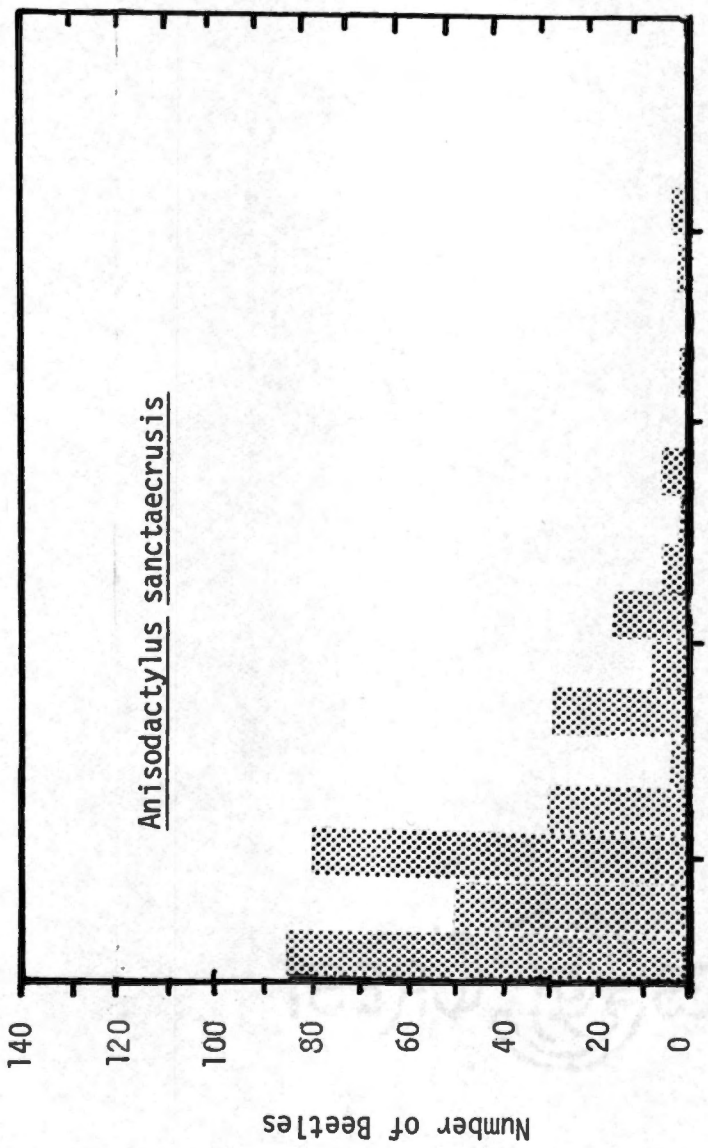

Figure 24. Weekly collections of Anisodactylus sanctaecrusis F. in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

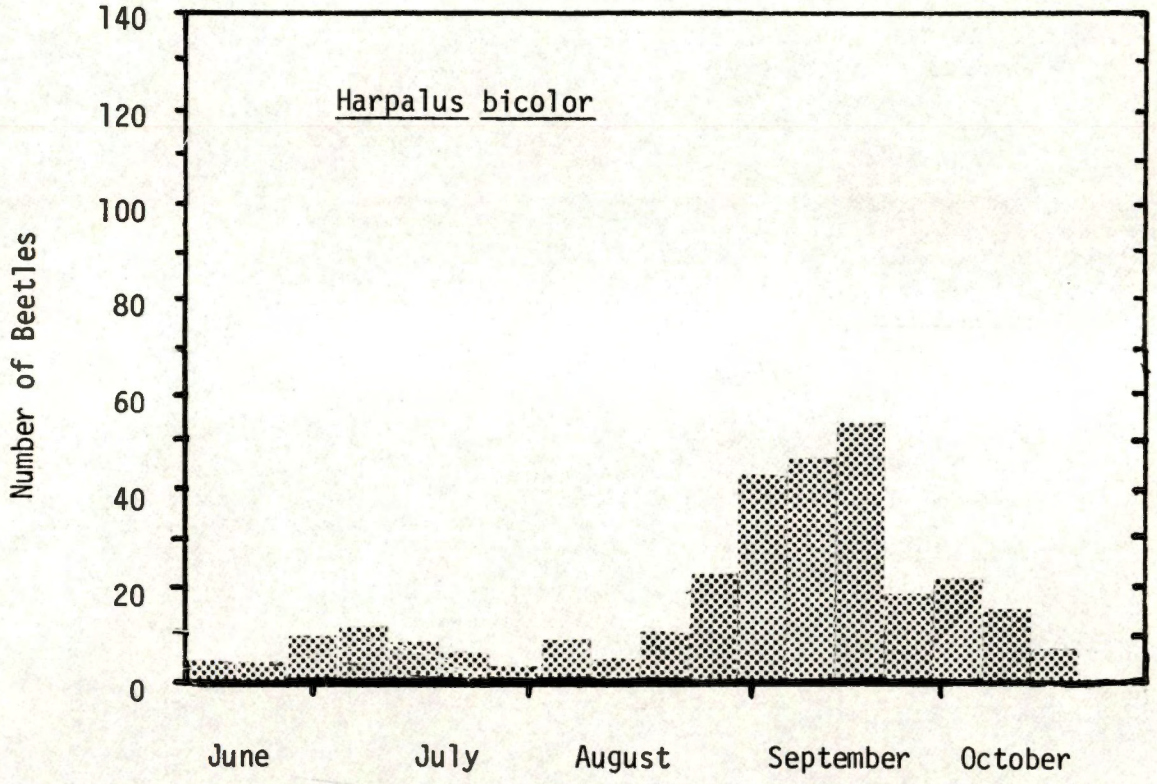

Figure 25. Weekly collections of Harpalus bicolor F. in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

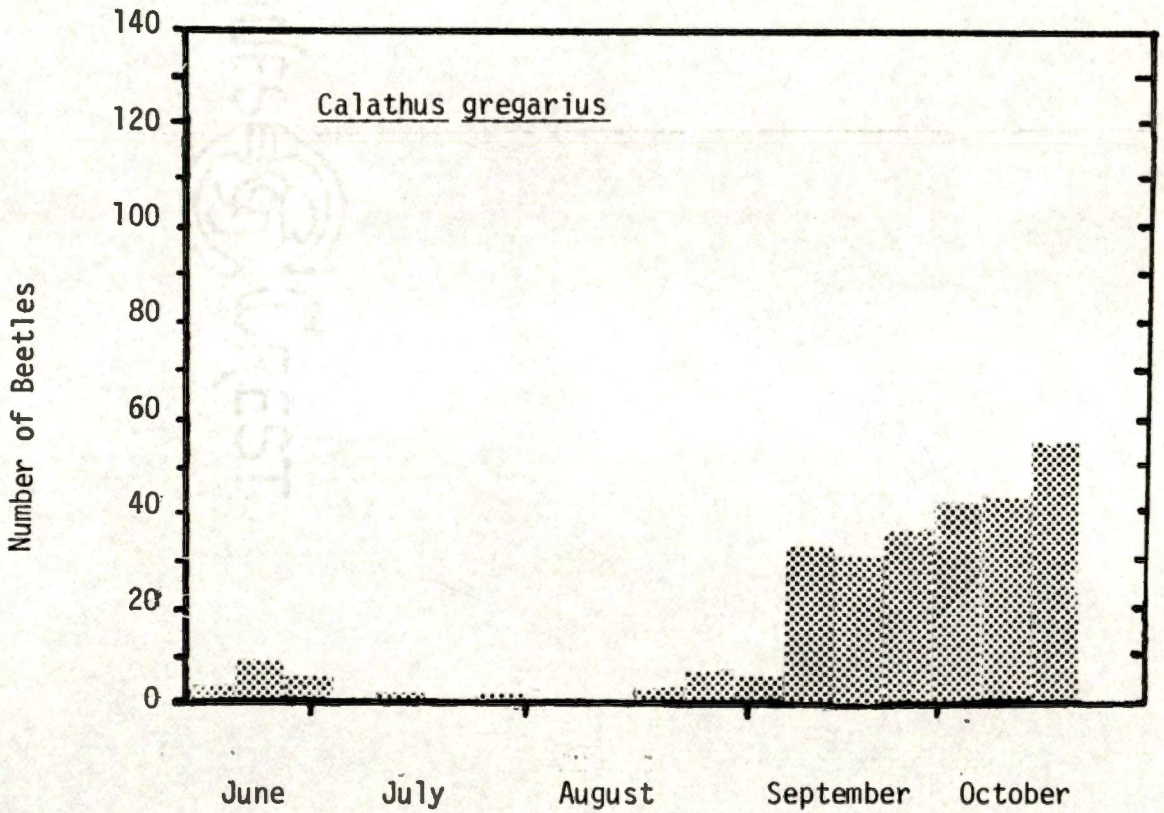

Figure 26. Weekly collections of Calathus gregarius Say in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

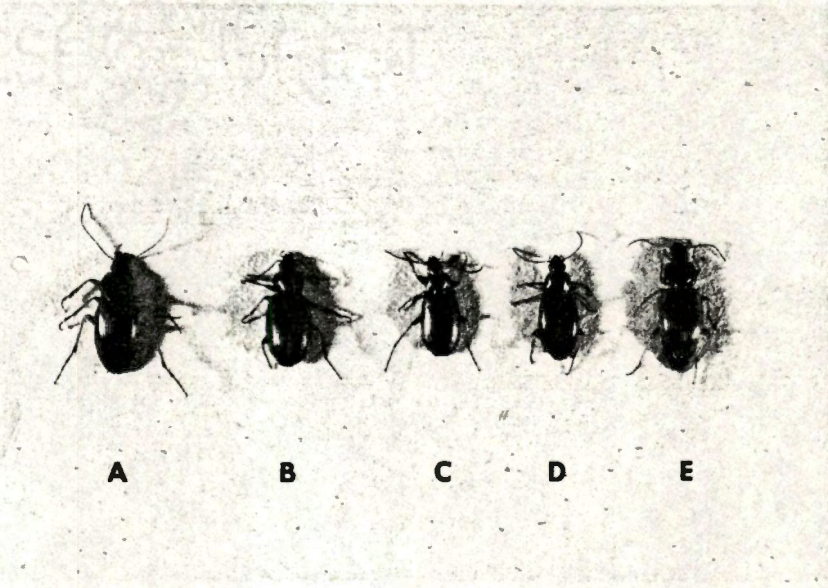

Figure 27. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Calathus gregarius B. Agonum placidum C. Agonum octopunctatum D. Agonum punctiforme E. Agonum pallipes

Rivard (1964a). The seasonal activity-abundance cycle of C. gregarius was unimodal and indicated a fall breeding season. Rivard (1964a) collected C. gregarius predominantly in or near woods, while Esau and Peters (1975) collected them in highest numbers in fencerows and prairies. In this study, the greatest numbers of C. gregarius were collected from woodlands.

Pterostichus lucublandus Say

This dull green, medium-sized beetle (Fig. 11, p. 41) was represented by 256 specimens. Moderate numbers of beetles were collected in mid June numbers peaked in early August, and declined until October, at which time a secondary peak occurred (Fig. 28). Barlow (1970), Frank (1971a), and Kirk (1971a) observed a similar bimodal activity-abundance cycle in this spring breeding species. Lund (1975) did not observe a late season peak in activity. In Tennessee, P. lucublandus was collected predominantly in woodlands; Rivard (1964a) found this species to be most abundant in open ground with or without vegetation. Feeding trials by Shough (1940), indicated P. lucublandus was predominantly predaceous and demonstrated that this species readily attacked butterfly larvae three times its size.

Agonum placidum Say

Populations of A. placidum, represented by 239 individuals, reached peaks in early September and early October (Fig. 29). Although present in large numbers from early September until mid October, this species was regarded as unimodal. This medium-sized, bluish black beetle (Fig. 27, p.61) was reported to readily feed on certain pest species by Johnson and Cameron (1968). Lindroth (1966) and Rivard (1964a) reported that A. placidum was a spring breeder, while Lund (1975) reported peak populations in

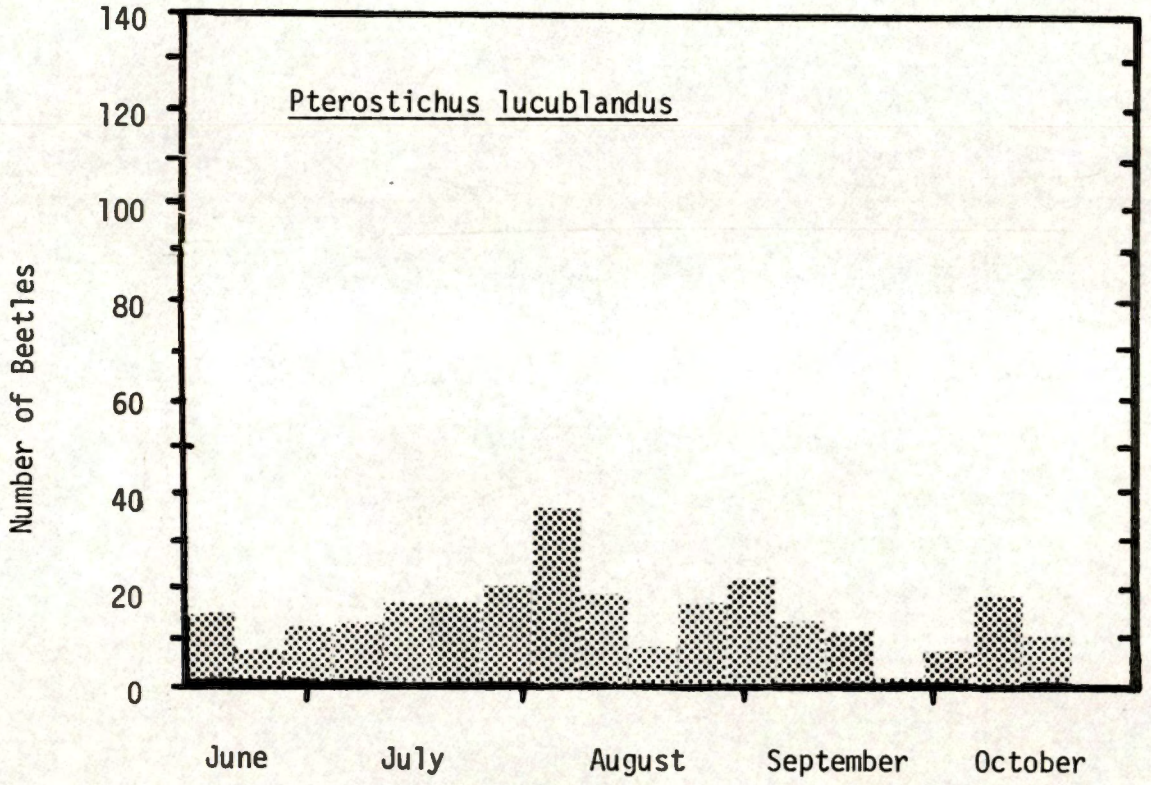

Figure 28. Weekly collections of Pterostichus lucublandus Say in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

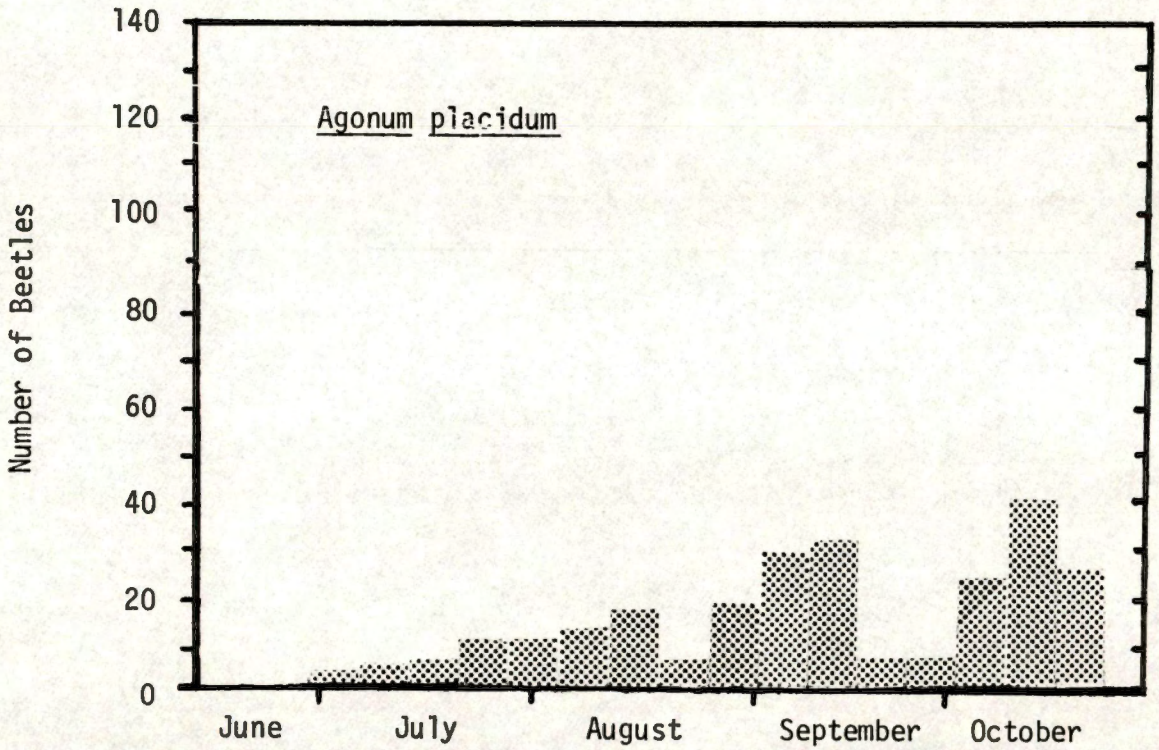

Figure 29. Weekly collections of Agonum placidum Say in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

August and suggested they were mid summer breeders. Data from this study indicates that it is a summer-to-fall breeder. Rivard (1964a) reported that A. placidum occurs on open ground; it occurred primarily in tobacco fields in Tennessee.

Bembidion rapidum LeConte

This tiny beetle (3.7 to 4.5 mm in length) (Fig. 30), represented by 232 individuals, was collected in moderate numbers in mid June and gradually increased to a peak in early August. After a drastic reduction, numbers increased to a secondary peak in early September (Fig. 31) Hsin et al. (1979) and Kirk (1971b) observed B. rapidum to be common in croplands, while Esau and Peters (1975) reported them as less frequent. The activity-abundance cycle suggested B. rapidum is a summer or fall breeder. Hsin et al. (1979) reports similar activity patterns for B. rapidum, with peak abundance several weeks later in the season. The main habitat type for B. rapidum was pastureland and secondarily tobacco fields.

Galerita bicolor Drury

This elongate, blue-black beetle with an orange pronotum (Fig. 32) was represented by 231 specimens. Occurring in moderate numbers, G. bicolor gradually increased in abundance until mid July, peaked in early August, and remained at moderate population levels until mid October (Fig. 33). The seasonal activity-abundance cycle is unimodal and apparently it is a spring breeder. Collections of G. bicolor indicated its main habitat type was woodlands.

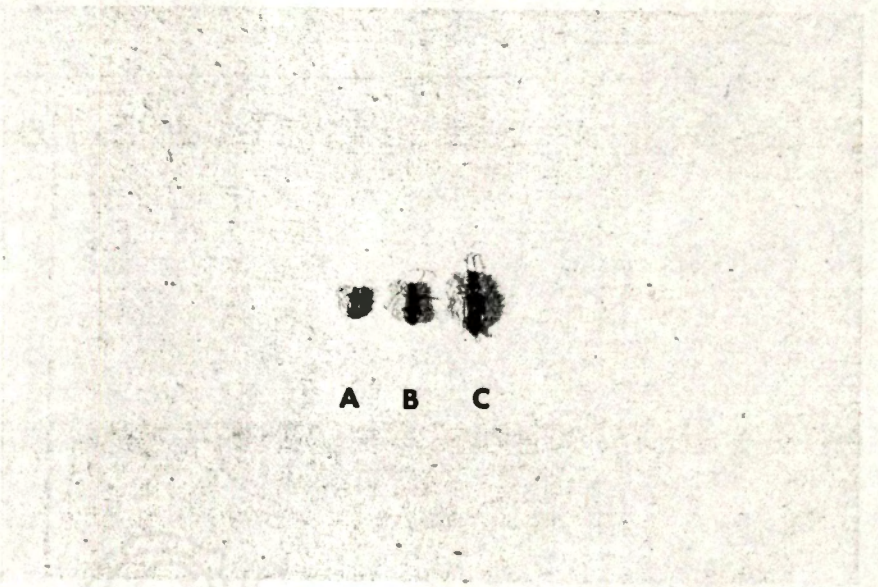

Figure 30. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Tachys sp. B. Bembidion quadrimaculatum C. Bembidion rapidum

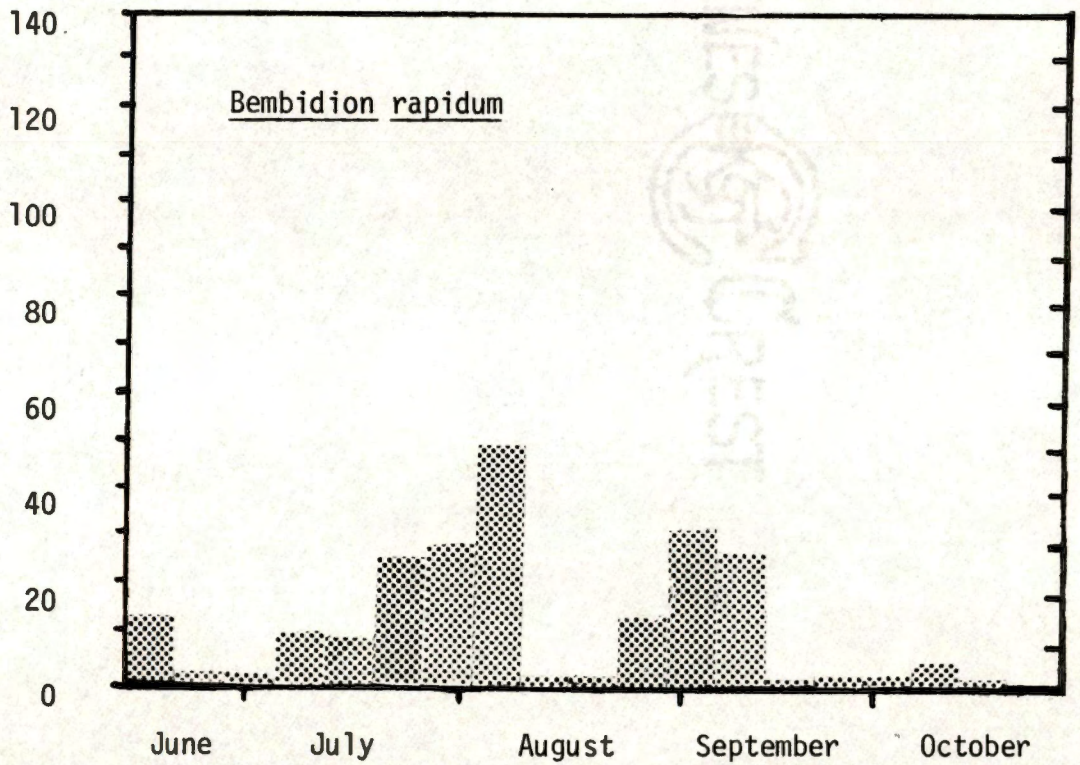

Figure 31. Weekly collections of Bembidion rapidum LeConte in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

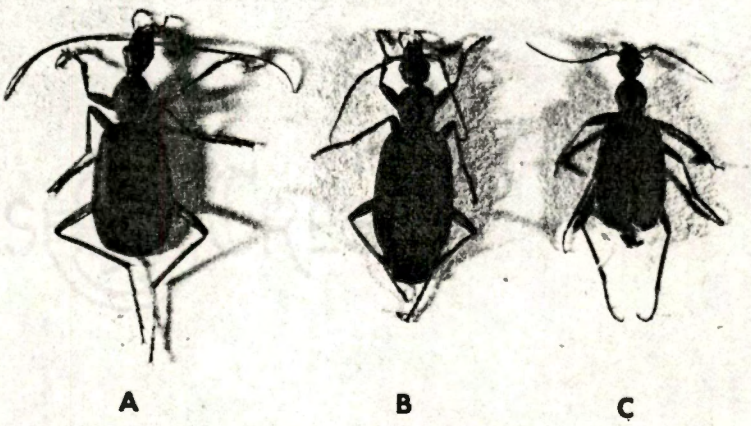

Figure 32. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Galerita bicolor B. Galerita janus C. Galerita lecontei

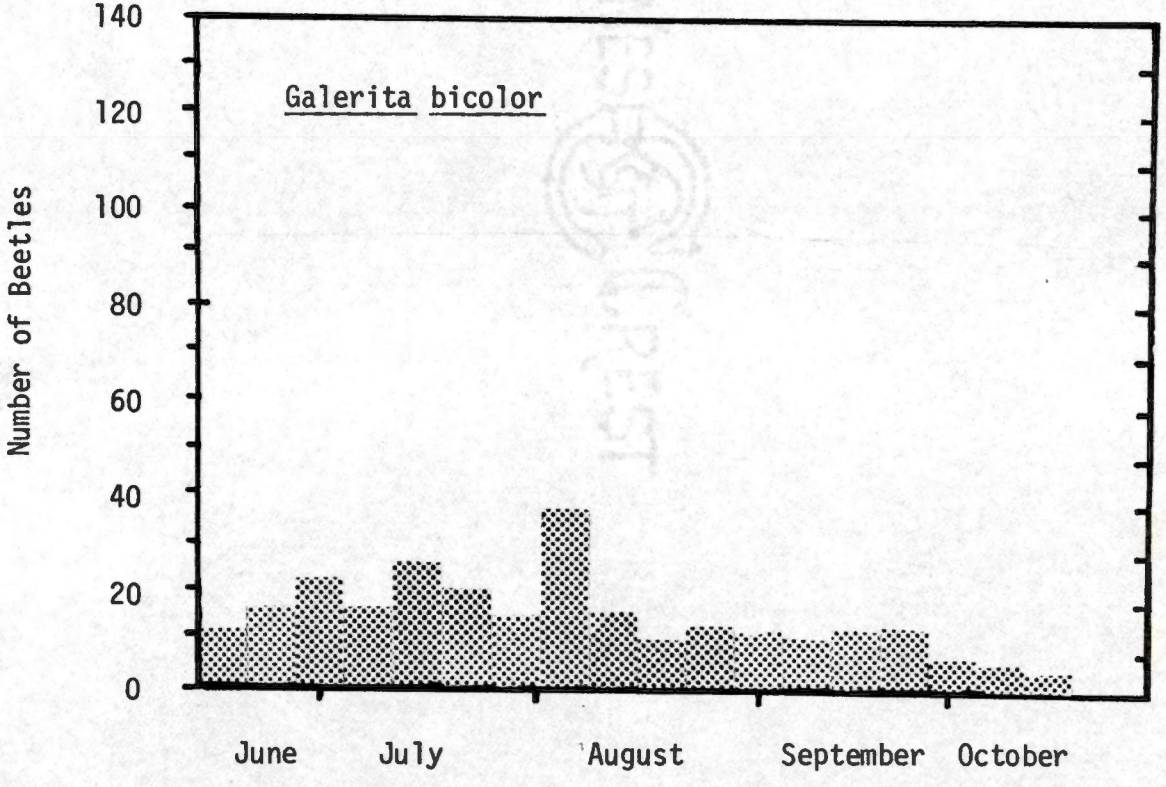

Figure 33. Weekly collections of Galerita bicolor Drury in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

Cicindela punctulata Olivier

This dark brown, white-spotted tiger beetle (Coleoptera; Cicindelinae) (Fig. 34) was represented by 734 specimens. Catches of Cicindela punctulata gradually increased to a peak in early August and then decreased to low levels by early September (Fig. 35). The activity-abundance cycle is unimodal and indicated C. punctulata is a summer breeder. Highest numbers of C. punctulata occurred in pastures, but they were also common in tobacco fields. Members of the family are predaceous and have potential for biological control (Dillon & Dillon, 1961).

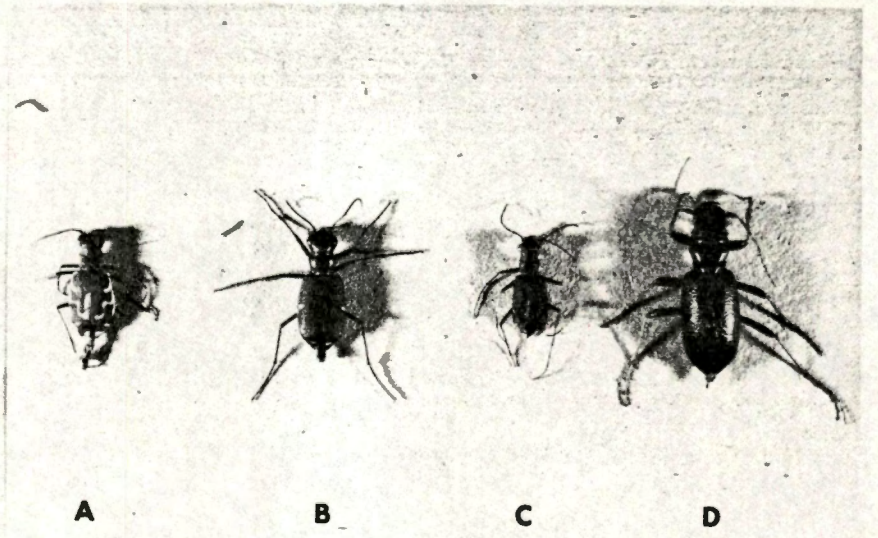

Figure 34. Species of carabids collected from pitfall traps, Greene Co., TN, 1979. A. Cicindela repanda B. Cicindela sex-guttata C. Cicindela punctulata D. Megacephala virginica

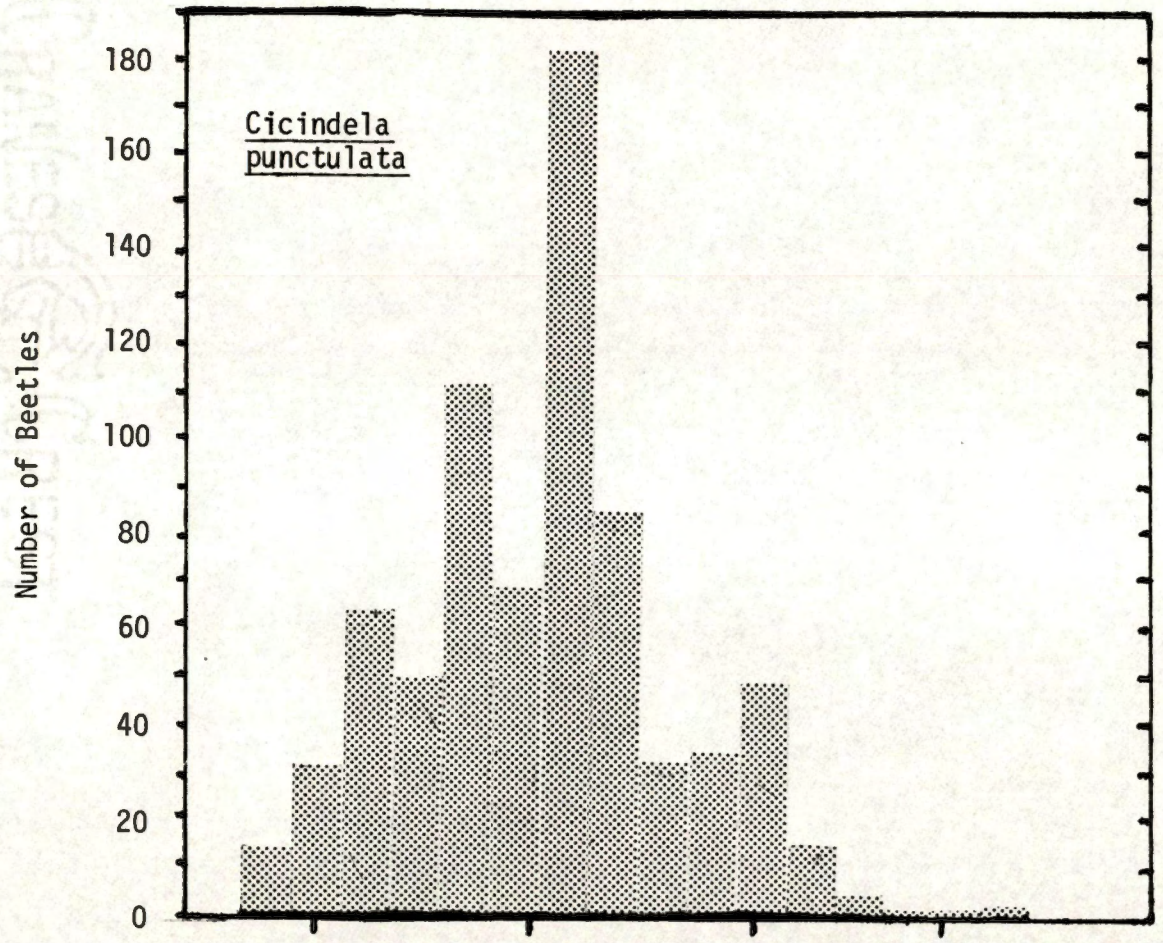

Figure 35. Weekly collections of Cicindela punctulata Olivier in pitfall traps from June 15 through October 15, 1979, Greene Co., TN.

CHAPTER V

SUMMARY AND CONCLUSIONS

The first step in integrated pest management is basic research designed to gain a complete understanding of the agro-ecosystem including the organisms that interact within it. The purpose of this research was to identify the species of carabids present in tobacco fields and adjacent pastures and woodlands. Ground beetles were pitfall-trapped in two carbofuran treated and two untreated tobacco fields at the Tobacco Experment Station, Greeneville, Tennessee. Sixteen trap stations, 5 traps comprising a station, were placed in each field and its borders. Four traps in each station were standard pitfall traps, the fifth was an "intercept trap." The "intercept trap" was collected separately from the standard pitfall traps in the 18 collection weeks from June 15 through October 15. One hundred and six species of carabids in 48 genera were collected from tobacco fields, pastures, and woodlands. Sixteen species of Carabinae and 1 species of Cicindelinae were considered abundant.

The Tennessee collection data was comparable in numbers of individuals and species diversity to that of Esau and Peters (1975), Frank (1971a), Hsin et al. (1979), Kirk (1971b), Lund (1975), and Rivard (1964a, 1965, 1966). Only Kirk and Rivard reported more species of carabids collected in croplands than identified from eastern Tennessee tobacco fields, pastures, and woodlands. The abundance and diversity of ground beetles observed in this study indicated environmental conditions were favorable to sustain such a large carabid fauna. Abundant rainfall and high humidity in East Tennessee during the summer could enable carabids to reach

high population levels. Kirk and Rivard stated that relative humidity is the key to carabid activity. With large numbers of individuals and increased locomotor activity of carabids due to high humidity in eastern Tennessee croplands, carabid beetles could be expected to exert a greater influence on insect pest species than in other locales.

The data indicate large numbers of predaceous ground beetles were present in tobacco fields and the adjacent acreage. Four of the predaceous carabids present in peak numbers in the spring and early summer were Pterostichus chalcites Say, Scarites substriatus Haldeman, Pterostichus lucublandus Say, and Galerita bicolor Drury. These ground beetles were present during the tobacco growing season and had the potential to interact with insect pests of tobacco. The first three were noted to feed on lepidopteran larvae (Shough, 1940), all stages of western corn rootworms (Kirk, 1971a, 1975), and various other insects. One species, Cicindela punctulata Olivier, was present in peak abundance in mid summer. This tiger beetle is considered to be highly predaceous and has a high potential for biological control (Dillon and Dillon, 1961). Pterostichus coracinus Newman, Abacidus atratus Newman, Chlaenius (s. st.) tricolor Dejean, Calathus gregarius Say, Agonum placidum Say, Bembidion rapidum LeConte were present in peak numbers in the late summer to fall.
Beetles in the genera Pterostichus and Chlaenius are noted predators and, along with the other ground beetles, might help to reduce overwintering cutworms, flea beetle larvae, wireworms, and other soil insects.

In the Tennessee study, ground beetle numbers were not significantly reduced in carbofuran treated fields when compared with untreated tobacco fields. Statistical analysis of numbers of H. pennsylvanicus, which comprised 30.6% of the total seasonal collections, showed no

significant reductions when tested at the 10% level of significance. Gholson et al. (1978), Sechriest et al. (1971), Thorvilson (1969), and Tomlin (1975) reported that carbofuran soil treatments failed to produce significant beetle mortality with selected species of ground beetles. Yet, Clivina bipustulata, Scarites substriatus, and Tachys anceps were adversely affected by the carbofuran treatment in Iowa cornfields (Thorvilson, 1969), which suggested that burrowing and small species were affected to a greater extent. Midkiff (1979) in Kentucky found ground beetles were significantly reduced in carbofuran treated tobacco plots. The results of this two year study show carbofuran to have, at best, a slight effect on ground beetle populations in tobacco fields. Large numbers of beetles were observed in the field during most of the year. Since ground beetles in general are intolerant to insecticides applied at recommended rates, carbofuran appears to be an exception to the rule, showing a compatibility with the concepts of integrated pest management.

The plastic pitfall traps used in this study were believed adequate to measure species diversity and seasonal activity-abundance of most species of carabids. Hsin et al. (1979) reported the rim of the plastic pitfall trap was easily exposed by wind and rain erosion reducing collections of the tiny species Bembidion quadrimaculatum. I observed this same problem, but felt that except for the tiny species, this impedence posed no problem in beetle collections. Combining the "intercept trap" with standard pitfall traps was designed to increase numbers of individuals collected and the diversity of species collected. There were caught in each "intercept trap" 3.8 times more beetles than in a standard pitfall trap. In spite of this, larger numbers of Bembidion quadrimaculatum and Bembidion

rapidum were observed in the field than in actual pitfall collections. Some species of carabids were collected infrequently in both types of pitfall traps, while others, such as Scarites substriatus and Scarites subterraneus, were frequently collected in the "intercept traps" but were uncommon in the standard traps. Allen and Thompson (1977) stated "no data on the seasonal activity of North American species belonging to the tribe Scaritini have been published" until they reported Pasimachus elongatus. My data indicate a unimodal activity-abundance cycle for the scaritine species Scarites substriatus (Fig. 18, p.50). It was present in the collections from mid June until mid October with peak activity in mid June.

LITERATURE CITED

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Allen, R.T. 1979. The occurrence and importance of ground beetles in agricultural and surrounding habitats. In A. Halpern (Cood. Ed.), Carabid Beetles: Their Evolution, Natural History, and Classification. Dr. W.W. Junk by Publishers, Boston. pp. 485-505.

Allen, R.T. and R.G. Thompson. 1977. Faunal composition and seasonal activity of Carabidae (Insecta: Coleoptera) in three different woodland communities in Arkansas. Ann. Entomol. Soc. Amer. 70:31-34.

Ball, G.E. 1960. Carabidae (Latreille, 1810). In R. Arnett, 1960-1863, The Beetles of the United States. (A Manual for Indentification). Cathol. Univ. Amer. Press, Washington, D.C. pp. 55-181.

Ball, G.E. and J.N. Anderson. 1962. The Taxonomy and Speciation of Pseudophonus. Studies on Speciation. 1. Cathol. Univ. Amer. Press, Washington, D.C. pp. 1-94.

Baldruf, W.V. 1935. The Bionomics of Entomo phagous Coleoptera. J.S. Swift Co., St. Louis. pp. 220.

Barlow, C.A. 1970. Phenology and distribution of some Pterostichus (Coleoptera: Carbidae) of Eastern Canada. J.N.Y. Entomol. Soc. 78:215-236.

Barr, T.C. Professor, Department of Biological Science, University of Kentucky, Lexington, Ky. Personal communication, April, 1979 to March, 1980.

Bell, R.T. 1960. A revision of the genus Chlaenius Bonelli (Coleoptera: Carabidae) in North America. Misc. Pap. Entomol. Soc. Amer. 1:98-166.

Best, R.L. 1977. The pitfall trap. Carolina Tips. 40:7-18.

Borror, D.J., DeLong, D.W., and C.A. Triplehorn. 1976. An Introduction to the Study of Insects. Holt, Rinehart and Winston. Atlanta, GA. pp. 764.

Briggs, J.B. 1961. A comparison of pitfall trapping and soil sampling in assessing populations of two species of ground beetles (Coleoptera: Carbidae). East Malling Research Station Annual Report. 1960:108-112.

Bryson, H.R. and G.F. Dillon. 1941. Observations on the morphology of the corn seed beetle (Agonoderus pallipes F., Carbidae). Ann. Entomol. Soc. Amer. 34:43-50.

Croft, B.A. and A.W.A. Brown. 1975. Responses of arthropod natural enemies to insecticides. Ann. Review Entomol. 20:285-335.

Danko, J. 1975. Effectiveness of granulated insecticides against the aphids on tobacco. Agrochemia. 15: 280-282.

Dick, J. and N.E. Johnson. 1958. Carabid beetles damage Douglas-fir seed. J. Econ. Entomol. 51:542-544.

Dillon, E. and L. Dillon. 1961. A Manual of the Common Beetles of Eastern North America. Row, Peterson & Company, Evanston, Ill. 884 pp.

Dominick, C.B. 1967. Systemic insecticides applied to the soil for control of insect pests on citrus. J. Econ. Entomol. 44:372-383.

Dominick, C.B. 1969. Evaluation of insecticides for tobacco flea beetle control. Tob. Sci. 13:164-165.

Dominick, C.B. 1971. Evaluation of systemic insecticides for green peach aphid control on tobacco. J. Econ. Entomol. 64:1565-1566.

Drift, J. van der. 1951. Analysis of the animal community in a beech forest floor. Tijdschr. Entomol. 94:1-168.

Ericson, D. 1977. Estimating population parameters of Pterostichus cupreus and Pterostichus melanarius in arable fields by means of capture-recapture. Oikos. 29:407-417.

Ericson, D. 1978. The interpretation of pitfall catches of Pterostichus cupreus and P. melanarius (Coleoptera, Carabidae) in cereal fields. Pedobiologia. 19:320-328.

Esau, K.L. and D.C. Peters. 1975. Carabidae collected in pitfall traps in Iowa cornfields, fencerows, and prairies. Environ. Entomol. 4:509-513.

Fichter, E. 1941. An apparatus for the comparison of soil surface arthropod populations. Ecology. 22:338-339.

Forbes, S.A. 1883. The food-relation of the Carabidae and Coccinelidae. Ill. St. Lab. Nat. Hist. Bull. 1:33-47.

Frank, J.H. 1971a. Carabidae (Coleoptera) of an arable field in central Alberta. Quaest. Entomol. 7:237-252.

Frank, J.H. 1971b. Carabidae (Coleoptera) as predators of the red-backed cutworm (Lepidoptera: Noctuidae) in central Alberta. Can. Entomol. 103:1039-1044.

Freitag, R. 1969. A revision of the species of the genus Evarthrus LeConte (Coleoptera: Carabidae). Quaest. Entomol. 5:89-212.

Gholson, L.E., and C.C. Beagle, R.L. Best, and J.C. Owens. 1978. Effects of several commonly used insecticides on cornfield carabids in Iowa. J. Econ. Entomol. 71:416-418.

Gilbert, O. 1956. The natural histories of four species of Calathus (Coleoptera: Carabidae) living on sand dunes in Anglesey, North Wales. Oikos. 7:22-47.

Gilbert, O. 1957. Notes on the breeding seasons of some Illinois carabid beetles. Pan-Pacific Entomol. 33:53-58.

Gilbert, O. 1958. The history patterns of Nebria degenerata Schaufuss and N. brevicollis (F.) (Coleoptera: Carabidae). J. Soc. Brit. Entomol. 6:11-14.

Girardeau, J.J., Jr. 1971. Carbofuran, a systemic insecticide for control of the tobacco budworm on tobacco. J. Econ. Entomol. 64:102-104.

Greenslade, P.J.M. 1963. A concentration of Carabidae (Coleoptera) at Fleet in Dorset. Ent. Mon. Mag. 99:46-48.

Greenslade, P.J.M. 1964a. Pitfall trapping as a method for studying populations of Carabidae (Coleoptera). J. Anim. Ecol. 33:301-310.

Greenslade, P.J.M. 1964b. The distribution, dispersal and size of a population of Nebria brevicollis (F.) with comparative studies on three other Carabidae. J. Anim. Ecol. 33:311-333.

Harris, D.L. and W.H. Whitcomb. 1971. Habitat relationship and seasonal abundance of four species of Evarthrus (Coleoptera: Carabidae). Coleop. Bull. 25:67-72.

Hiebsch, H. Faunistisch-okologische Urtersuchungen in Steinrucken, Windschuttzhecken und den angrenzender Wiesen und Feldflachen. Tag-ber. Deut. Akad. Lardw. Wiss. Berl. 60:25-35.

Hsin, C., L.G. Sellers, and P.A. Dahm. 1979. Seasonal activity of carabids and the toxicity of carbofuran and terbufos to Pterostichus chalcites. Environ. Entomol. 8:154-159.

Humphrey, B.J. and P.A. Dahm. 1976. Chlorinated hydrocarbon insecticide residues in Carabidae and the toxicity of dieldrin to Pterostichus chalcites. Environ. Entomol. 5:729-34.

Johnson, N.E. and R.S. Cameron. 1969. Phytophagous ground beetles. Ann. Entomol. Soc. Amer. 62:909-914.

Kirk, V.M. 1971a. Biological studies of a ground beetle, Pterostichus lucublandus. Ann. Entomol. Soc. Amer. 64:540-544.

Kirk, V.M. 1973. Biology of a ground beetle, Harpalus pennsylvanicus. Ann. Entomol. Soc. Amer. 66:513-518.

Kirk, V.M. 1974. Biology of a ground beetle, Harpalus erraticus. Ann. Entomol. Soc. Amer. 67:24-28.

Kirk, V.M. 1975a. Biology of Stenolophus (=Agonoderus) comma, a ground beetle of cropland. Ann. Entomol. Soc. Amer. 68:135-138.

Kirk, V.M. 1975b. Biology of Pterostichus chalcites, a ground beetle of cropland. Ann. Entomol. Soc. Amer. 68:855-858.

Kirk, V.M. 1977. Notes on the biology of Anisodactylus sanctaecrusis, a ground beetle of cropland. Ann. Entomol. Soc. Amer. 70:596-598.

Kulman, H.M. 1974. Comparative ecology of North America Carabidae with special reference to biological control. Entomophaga Mem. 7:61-70.

Larochelle, A. 1974. A world list of prey of Chlaenius (Coleoptera: Carabidae). Great Lakes Entomol. 7:137-142.

Larsson, S.G. 1939. Entwicklungstypen and Entwicklungszeiten der danishcen Carabiden. Entomol. Meddelels. 20:275-560.

Lindroth, C.H. 1949. Die Fennoskandischen Carabidae. III. Allgemeiner Tiel. Kgl. Vetenskaps Vitterhets-samhallets Handl. F6 Ser. B. 4:911.

Lindroth, C.H. 1961. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Part 2. Opuscula Entomol. Suppl. 20. pp. 1-200.

Lindroth, C.H. 1963. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Part 3. Opuscula Entomol. Suppl. 24. pp. 201-408.

Lindroth, C.H. 1966. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Part 4. Opuscula Entomol. Suppl. 29. pp. 409-648.

Lindroth, C.H. 1968. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Part 5. Opuscula Entomol. Suppl. 33. pp. 649-944.

Lindroth, C.H. 1969a. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Part 6. Opuscula Entomol. Suppl. 34. pp. 945-1192.

Lindroth, C.H. 1969b. The ground-beetles (Carabidae, excl. Cicindelinae) of Canada and Alaska, Part 1. Opuscula Entomol. Suppl. 35. pp. I-XLVII.

Luff, M.L. 1968. Some effects of formalin on the numbers of Coleoptera caught in pitfall traps. Entomol. Mon. Mag. 104:115-116.

Luff, M.L. 1975. Some features influencing the efficiency of pitfall traps. Oekologia (Berl.) 19:345-357.

Lund, R.D. 1975. The field activity and feeding habits of Carabidae associated with Indiana cornfields. M.S. thesis. Purdue University, Lafayette, IN. p. 171.

Midkiff, A.E. 1979. Seasonal abundance of carabid adults in treated and untreated tobacco fields. M.S. thesis. University of Kentucky, Lexington, KY. p. 69.

Mistric, W.J., Jr. and F.D. Smith. 1972. Carbofuran and disulfoton applied to soil in flue-cured tobacco plant beds for control of certain insects attacking plants in bed and transplants in field. J. Econ. Entomol. 65:1203-1204.

Mistric, W.J., Jr. and F.D. Smith. 1973. Carbofuran and other systemic insecticides for control of insects on flue-cured tobacco. J. Econ. Entomol. 66:480-484.

Mitchell, B. 1963. Ecology of two carabid beetles, Bembidion lampros and Trechus quadristiatus. J. Anim. Ecol. 32:377-392.

Morrill, W.L. 1975. Plastic pitfall traps. Environ. Entomol. 4:596.

Pausch, R.D. 1979. Observations on the biology of the seed corn beetles, Stenolophus comma and Stenolophus lecontei. Ann. Entomol. Soc. Amer. 72:24-28.

Pless, C.D. Professor, and N.B. Shamiyeh, Research Assistant, Department of Entomology and Plant Pathology, University of Tennessee, Knoxville, TN. Personal communication, June 1978 to March 1980.

Reichardt. H. 1967. A monographic revision of the American Galeritini (Coleoptera: Carabidae). Ariquivos de Zool.15. Sao Paulo. pp. 1-176.

Rivard, I. 1964a. Carabid beetles (Coleoptera: Carabidae) from agricultural lands near Belleville, Ontario. Can. Entomol. 96:517-520.

Rivard, I. 1964b. Observations on the breeding periods of some ground beetles (Coleoptera:Carabidae) in Eastern Ontario. Can. J. Zool. 42: 1081-1084.

Rivard, I. 1965. Additions to the list of carabid beetles (Coleoptera: Carabidae) from agricultural lands near Belleville, Ontario. Can. Entomol. 96: 332-333.

Rivard, I. 1966. Ground beetles (Coleoptera: Carabidae) in relation to agricultural crops. Can. Entomol. 98:189-195.

Sechriest, R.E., and H.B. Petty, and R.E. Kuhlman. 1971. Toxicity of selected insecticides to Clivina impressifrons (Coleoptera: Carabidae). J. Econ. Entomol. 64:210-213.

Severin, H.C. 1947. Report of the 20th annual meeting of the international Great Plains conference of entomologists. p. 87.

Shough, W.W. 1940. The feeding of ground beetles. Amer. Midland Nat. 24:336-344.

Thiele, H.U. 1964. Okologische untersuchungen an bodenbewohnenden Coleopteren einer Heckenlandschaft. Z. Morphol. Oekol. Tiere. 53:537-586.

Thiele, H.U. 1977. Carabid Beetles in Their Environments. Springer-Verlag, New York, p.327.

Thompson, R.G. Area Entomologist, Texas Agricultural Extension Service, Texas A & M University, Lubbock, TX. Personal communication, March 1979 to March 1980.

Thorvilson, H.G. 1969. Pitfall sampling of carabid populations in restricted corn plots treated with soil pesticides. M.S. thesis. Iowa State University, Ames, IO. p. 64.

Thurston, R. and G.A. Jones. 1975. Biology and control of tobacco insects. Ky. Agri. Exp. Stat. Lexington Ann. Rep. 88:71-72.

Tomlin, A.D. 1975. The toxicity of insecticides by contact and soil treatment to two species of ground beetles (Coleoptera: Carabidae). Can. Entomol. 107:529-532.

Williams, G. 1959a. The seasonal and diurnal activity of the fauna sampled by pitfall traps in different habitats. J. Anim. Ecol. 28:1-13.

Williams, G. 1959b. Seasonal and daily activity of Carabidae with particular reference to Nebria, Notiophilus, and Feronia. J. Anim. Ecol. 28:309-330.

APPENDIX

Table 5. Total Seasonal Abundance of Carabid Beetles in Croplands as Reported by 8 Researchers

	Hylton (1980)	Midkiff (1979)	Hsin (1979)	Lund (1975)	Esau & Peters (1975)	Frank (1971)	Kirk (1971)	Rivard (1964)
Harpalus pennsylvanicus	**1	**2	**	**	**		**	**
Amara spp.	**	**3						
Harpalus erythropus	**							
Pterostichus chalcites	**	**	**	**	**		**	
Stenolophus comma	**	*	**				**	**
Pterostichus coracinus	**							*
Scarites substriatus	**			*	*			
Abacidus atratus	**							
Chlaenius (s. st.) tricolor	**							*
Anisodactylus sanctaecrusis	**	*	**	**			*	
Harpalus bicolor	**			**				
Calathus gregarius	**			*4	*		*	*
Pterostichus lucublandus	**			**	*	**	**	**
Agonum placidum	**			**	*	**	**	*
Bembidion rapidum	**		**				*	
Galerita bicolor	**							
Amara obesa							**	**
Harpalus caligenosis	*			*				**
Bembidion quadrimaculatum	*		**	*	**	**	**	**
Evarthrus alternans					**		**	
Tachys anceps					*		*	
Chlaenius pusillus	*		**	*				
Scarites subterraneus	*	*		*				

1. Frequency of occurrence:
   ** considered abundant (≥ 200, Hylton)
   * considered common (>50<200, Hylton)
2. Harpalus pseudophonus
3. Amara cupreolata
4. C. gregarius & C. opaculus not separated

Table 6. Species of Carabids Collected in Pitfall Traps in Field 1

Species	No. Collected				
	Standard	Intercept Trap	Tobacco	Pasture	Total
Agonum octopunctatum	23	12	2	33	35
Agonum placidum	5	11	9	7	16
Agonum punctiforme	1	3	0	4	4
Amara spp.	658	377	219	816	1035
Anisodactylus dulcicollis	21	26	23	24	47
Anisodactylus furvus	9	16	1	24	25
Anisodactylus rusticus	7	14	7	14	21
Anisodactylus sanctaecrusis	23	9	16	16	32
Bembidion rapidum	40	27	4	63	67
Bradycellus rupestris	4	1	1	4	5
Calathus gregarius	0	1	0	1	1
Calosoma externum	1	0	0	1	1
Calosoma sayi	1	2	0	3	3
Chlaenius pusillus	0	3	2	1	3
Chlaenius (s. st.) tomentosus	4	3	3	4	7
Chlaenius (s. st.) tricolor	35	12	4	33	37
Cicindela punctulata	296	274	294	276	570
Colliuris pennsylvanicus	2	0	0	2	2
Cratacanthus dubis	63	52	66	49	115
Dicaelus dilatatus	0	1	0	1	1
Evarthrus sp.	1	0	0	1	1
Galerita lecontei	22	10	0	32	32
Harpalus bicolor	3	2	4	1	5
Harpalus caligenosis	6	9	10	5	15
Harpalus erythropus	2	1	2	1	3
Harpalus faunus	9	5	13	1	14
Harpalus fulgens	2	4	0	6	6
Harpalus pennsylvanicus	566	488	447	607	1054
Lebia spp.	2	0	1	1	2
Megacephala virginica	24	16	7	33	40
Pterostichus chalcites	100	116	55	161	216
Scarites substriatus	3	1	2	2	4
Scarites subterraneus	3	2	0	5	5
Selenophorus pedicularius	2	0	1	1	2
Stenolophus comma	44	38	15	67	82
Stenolophus rotundatus	12	16	5	23	28
Tetragonoderus intersectus	1	0	0	1	1

Table 7. Species of Carabids Collected in Pitfall Traps in Field 2

Species	No. Collected				
	Standard	Intercept Trap	Tobacco	Pasture	Total
Abacidus atratus	22	42	58	6	64
Agonum octopunctatum	6	3	8	1	9
Agonum pallipes	2	1	3	0	3
Agonum placidum	5	1	6	0	6
Agonum punctiforme	48	38	74	12	86
Amara pennsylvanica	0	4	4	0	4
Amara rubrica	0	1	1	0	1
Amara spp.	1	1	1	1	2
Anisodactylus dulcicollis	40	51	86	5	91
Anisodactylus ovularis	1	0	1	0	1
Anisodactylus rusticus	5	7	12	0	12
Anisodactylus sanctaecrusis	26	29	53	2	55
Bembidion rapidum	9	3	12	0	12
Brachinus sp.	0	1	1	0	1
Bradycellus rupestris	1	0	1	0	1
Calathus gregarius	5	4	9	0	9
Calosoma sayi	1	1	1	1	2
Chlaenius emarginatus	0	1	1	0	1
Chlaenius laticollis	1	1	1	1	2
Chlaenius sericeus	5	2	6	1	7
Chlaenius (s. st.) tricolor	164	130	282	12	294
Cicindela punctulata	75	24	98	1	99
Cicindela repanda	1	0	1	0	1
Clivina sp.	1	0	1	0	1
Colliuris pennsylvanicus	4	2	6	0	6
Cratacanthus dubis	1	1	2	0	2
Dicaelus elongatus	2	1	3	0	3
Diplocheila sp.	1	1	2	0	2
Discoderus parallelus	1	1	2	0	2
Evarthrus spp.	5	4	7	2	9
Galerita janus	8	18	16	10	26
Galerita lecontei	4	1	4	1	5
Harpalus bicolor	21	12	32	1	33
Harpalus caligenosis	13	17	26	4	30
Harpalus erythropus	1	0	0	1	1
Harpalus faunus	5	2	7	0	7
Harpalus fulgens	1	0	1	0	1
Harpalus longicollis	0	1	1	0	1
Harpalus pennsylvanicus	923	1023	1786	160	1946
Lebia sp.	1	0	1	0	1
Megacephala virginica	70	20	81	9	90
Patrobus longicornis	3	6	9	0	9
Pterostichus chalcites	207	137	325	19	344
Pterostichus coracinus	0	4	4	0	4
Pterostichus lucublandus	76	50	55	71	126

Table 7. (Continued)

Species	No. Collected				
	Standard	Intercept Trap	Tobacco	Pasture	Total
Scarites substriatus	84	174	212	46	258
Scarites subterraneus	32	86	98	20	118
Stenolophus ellipticus	0	1	1	0	1
Stenolophus comma	4	6	8	2	10
Tachys sp.	1	0	1	0	1
Tetragonoderus intersectus	1	0	1	0	1

Table 8. Species of Carabids Collected in Pitfall Traps in Field 3

Species	No. Collected				
	Standard	Intercept Trap	Tobacco	Woods	Total
Abacidus atratus	21	43	60	4	64
Agonum octopunctatum	36	21	57	0	57
Agonum placidum	111	102	210	3	213
Agonum punctiforme	6	3	8	1	9
Amara pennsylvanica	2	0	2	0	2
Amara rubrica	1	0	1	0	1
Amara spp.	10	6	5	11	16
Amphasia interstitialis	1	2	0	3	3
Anisodactylus dulcicollis	1	4	5	0	5
Anisodactylus rusticus	4	1	5	0	5
Anisodactylus sanctaecrusis	53	41	94	0	94
Anisotarsus terminatus	2	0	2	0	2
Apenes lucidula	1	5	1	5	6
Apenes sinuata	0	1	0	1	1
Badister notatus	0	1	0	1	1
Bembidion affine	1	0	1	0	1
Bembidion quadrimaculatum	4	1	5	0	5
Bembidion rapidum	70	67	137	0	137
Bradycellus rupestris	3	5	7	1	8
Calathus gregarius	69	98	88	79	167
Calathus opaculus	1	0	0	1	1
Calosoma sayi	0	2	2	0	2
Chlaenius emarginatus	0	6	3	3	6
Chlaenius laticollis	5	7	12	0	12
Chlaenius (s. st.) tomentosus	0	1	1	0	1
Chlaenius (s. st.) tricolor	1	1	2	0	2
Cicindela punctulata	24	10	34	0	34
Cicindela sexgulatta	1	0	1	0	1
Colliuris pennsylvanicus	4	4	8	0	8
Cymindis americana	9	9	7	11	18
Dicaelus dilatatus	1	4	2	3	5
Dicaelus elongatus	1	0	0	1	1
Dicaelus furvus	2	3	1	4	5
Dicaelus politus	4	11	4	11	15
Discoderus parallelus	0	1	1	0	1
Evarathrus sigillatus	4	2	4	2	6
Evarthrus spp.	2	4	6	0	6
Galerita bicolor	101	88	73	116	189
Galerita janus	16	31	14	33	47
Galerita lecontei	1	1	1	1	2
Harpalus bicolor	102	74	105	71	176
Harpalus caligenosis	33	32	53	12	65
Harpalus erythropus	336	291	620	7	627
Harpalus faunus	6	0	6	0	6

Table 8. (Continued)

Species	No. Collected Standard	Intercept Trap	Tobacco	Woods	Total
Harpalus fulgens	0	4	4	0	4
Harpalus longicollis	18	9	25	2	27
Harpalus pennsylvanicus	312	384	635	61	696
Megacephala virginica	1	0	1	0	1
Notiophilus aeneus	25	17	2	40	42
Piesmus mondalis	8	0	0	8	8
Pinacodera limbata	1	0	0	1	1
Platynus decentis	2	2	0	4	4
Pterostichus chalcites	80	84	164	0	164
Pterostichus coracinus	272	340	433	179	612
Pterostichus crenicollis	22	30	12	40	52
Pterostichus lucublandus	33	29	39	23	62
Pterostichus rostratus	1	1	2	0	2
Rhadine caudata	36	76	6	106	112
Scaphinotus (s. st.) unicolor	1	0	1	0	1
Scarites substriatus	4	10	14	0	14
Scarites subterraneus	2	10	10	2	12
Sphaeroderus stenostomus	11	22	0	33	33
Stenolophus comma	29	27	56	0	56
Stenolophus lecontei	1	1	2	0	2
Tachys sp.	1	0	1	0	1
Trichotichnus dichrous	14	5	18	1	19

Table 9. Species of Carabids Collected in Pitfall Traps in Field 4

	No. Collected					
	Standard	Intercept Trap	Tobacco	Pasture	Woods	Total
Abacidus atratus	117	145	77	34	151	262
Agonum octopunctatum	4	3	4	3	0	7
Agonum pallipes	0	1	1	0	0	4
Agonum placidum	1	3	4	0	0	4
Agonum punctiforme	14	36	29	3	18	50
Amara exarata	0	2	0	0	2	2
Amara obesa	0	1	0	0	1	1
Amara spp.	184	88	128	119	25	272
Amphasia interstitialis	1	0	0	0	1	2
Anisodactylus dulcicollis	1	2	3	0	0	3
Anisodactylus furvis	0	1	0	1	0	1
Anisodactylus nigerrimus	2	1	2	1	0	3
Anisodactylus rusticus	2	3	2	3	0	5
Anisodactylus sanctaecrusis	81	43	109	15	0	124
Bembidion quadrimaculatum	26	13	2	2	35	39
Bembidion rapidum	7	9	15	1	0	16
Bradycellus rupestris	5	3	7	0	1	8
Calathus gregarius	40	44	9	5	70	84
Calathus opaculus	1	0	1	0	0	1
Calosoma sayi	1	0	1	0	0	1
Chlaenius laticollis	46	45	21	58	12	91
Chlaenius pusillus	45	42	65	15	7	87
Chlaenius sericeus	12	7	10	6	3	19
Chlaenius (s. st.) tricolor	10	12	10	6	6	22
Cicindela punctulata	22	9	29	1	1	31
Cicindela repanda	1	1	2	0	0	2
Clivina impressifrons	0	1	1	0	0	1
Colliuris pennsylvanicus	2	1	2	1	0	3
Crathacanthus dubis	4	3	4	2	1	7
Dicaelus dilatatus	3	0	0	1	2	3
Dicaelus elongatus	2	5	1	0	6	7
Dicaeus furvus	3	5	0	2	6	8
Dychirius haemorrhoidalis	0	1	1	0	0	1
Galerita bicolor	20	22	5	15	22	42
Galerita janus	2	1	0	2	1	3
Harpalus bicolor	36	32	20	15	33	68
Harpalus caligenosis	26	25	34	13	4	51
Harpalus erythropus	1	0	1	0	0	1
Harpalus faunus	60	43	81	17	5	103
Harpalus fulgens	8	14	6	16	0	22
Harpalus longicollis	58	47	10	17	78	105
Harpalus pennsylvanicus	373	332	587	45	73	705
Lebia abdominalis	1	0	1	0	0	1

Table 9. (Continued)

Species	No. Collected					
	Standard	Intercept Trap	Tobacco	Pasture	Woods	Total
Lebia spp.	2	0	2	0	0	2
Megacephala virginica	27	8	27	8	0	35
Notiobia nitidipennis	1	0	0	0	1	1
Notiophilus novemstriatus	2	2	3	0	1	4
Odontonyx sp.	0	1	0	0	1	1
Patrobus longicornis	53	43	76	12	8	96
Piesmus sp.	1	6	3	0	4	7
Pterostichus chalcites	41	48	83	6	0	89
Pterostichus coracinus	27	59	2	14	70	86
Pterostichus fatuus	1	2	0	0	3	3
Pterostichus lucublandus	31	37	2	3	63	68
Pterostichus rostratus	1	0	0	1	0	1
Scarites substriatus	104	130	141	77	16	234
Scarites subterraneus	24	35	25	24	10	59
Stenolophus comma	352	308	599	59	2	660
Stenolophus lecontei	24	21	44	1	0	45
Stenolophus rotundatus	2	3	2	2	1	5
Tachys spp.	11	7	15	3	0	18
Trichotichnus dichrous	1	2	3	0	0	3

Table 10. Number of Individuals of Less Common or Rare Species of Carabids Collected from June 15 through October 15, 1979, Greene Co., TN

Species	Collection Weeks																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Scarites subterraneus	38	18	22	13	12	13	8	14	6	7	1	3	4	4	8	8	6	9
Harpalus caligenosis		4	2		3	7	10	10	11	9	20	37	18	8	5	7	7	
Agonum punctiforme	3	7	1	5	1		3	2	1	1	1		6	2	5	7	28	76
Anisodactylus dulcicollis	62	14	21	17	19	19		4	1							1	3	
Harpalus longicollis	4	1	3	1	6	3	3	5	8	15	13	15	15	15	8	8	4	5
Harpalus faunus	1			1	2	5	2	6	2		2	17	28	34	12	9	3	5
Cratacanthus dubis		3	6	24	8	16	16	18	11	10	3	7	2					
Rhadine caudata			1	7	12	13	23	16	18		12			2	2	3		3
Agonum octopunctatum	12	9	5	7	4	4	7	22	2	7	4	10	1	1	2	2	6	3
Chlaenius laticollis		3	3	5	2	3	13	26	4	6	11	6	7	5	2	4	8	1
Patrobus longicornis						1						1	8	11	23	30	17	13
Chlaenius pusillus	5	3	5		1	3	3	20	10	13	9	7	4	3		1	2	1
Pterostichus crenicollis				1	1			1			3	1	8	2	7	12	10	6
Galerita janus			2	2	1	3		2			4	3	8	3	5	3	4	11
Stenolophus lecontei	6	9	16	11	2		2	1										
Bembidion quadrimaculatum	10		2	6	5		12	3	1	1		3	1					
Anisodactylus rusticus	14	8	8	1	3	6	1	1	2		2			1			1	
Notiophilus aeneus	1	5	4	8	5		5	7	3	2	1	1						
Stenolophus rotundatus	11	8	3	4		1	3	3	1	1								
Galerita lecontei		1	1	1					7	6	12	7	1		2			
Harpalus fulgens	8	7	10	3	4			1		1								
Sphaeroderus stenostomus	1	2	1	2	4	4	5	4		2	1	2	1	1	1			2
Evarthrus spp.		1	1				2	2	1	1	9	6	2	1	1	2		1

Table 10. (Continued)

Species	Collection Weeks																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Chlaenius emarginatus	2	1	3			7	3	5	2	3	1	1		1				
Chlaenius sericeus	1		1		2	2	2	5	2			1	2	2	3	1	1	1
Anisodactylus furvus	5	15	3		1		1										1	
Trichotichnus dichrous				1								2	1	2	9	7		
Tachys spp.	5			4	5	1	4	1										
Colliuris pennsylvanicus							2	4	1	2	1	1	6	1				1
Cymindis americana							1	1		7	3	2	3		1			
Bradycellus rupestris	7	1	6	1	1	4	1											
Dicaelus politus		6	5	1		1	1	1										
Dicaelus furvus	1	1	1	2	1		1	1	3	1								
Dicaelus elongatus	2	1		1	1	2				2			1	1				
Dicaelus dilatatus	2					2	1			1		1		1				1
Chlaenius (s. st.) tomentosus	2	1	1	1	1			1			1							
Piesmus mondalis															4	2	2	
Calosoma sayi					1		1		1	2		2	1					
Amara obesa																	5	2
Evarthrus sigillatus							1	2	1	1	1							
Apenes lucidula	2	2		1		1												
Lebia spp. - Microlestes pusio				2		1	1	1										
Amara pennsylvanica																2	2	2
Notiophilus novemstriatus									1							1		2
Amphasia interstitialis	1	3																

Table 10. (Continued)

Species	Collection Weeks																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Platynus decentis			1					1	1	1								
Agonum pallipes																	2	2
Pterostichus rostratus																	1	2
Anisodactylus nigerrimus			1		1				1									
Discoderus parallelus	1	1			1													
Anisotarsus terminatus										1					1			
Diplocheila sp.		1			1													
Selenophorus pedicularius		1				1												
Pterostichus fatuus										3								
Amara rubrica																	1	1
Calathus opaculus														1				
Amara exarata														1			1	
Tetragonoderus intersectus	1	1																
Lebia abdominalis												1						
Bembidion affine							1											
Pinacodera limbata																		
Clivina sp.				1														
Clivina impressifrons			1															
Anisodactylus ovularis						1												
Notiobia nitidipennis						1												
Calosoma externum										1								
Selenophorus ellipticus			1															
Brachinus sp.									1									
Scaphinotus (s. st.) unicolor																	1	

Table 10. (Continued)

Species	Collection Weeks																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Apenes sinuata								1										
Badister notatus							1											
Odontonyx sp.	1																	
Clivina bipustulata																		
Dyschirius haemorrhoidalis																		
Megacephala virginica					2	10	23	23	24	21	23	24	12		3			1
Cicindela repanda		2		1														
Cicindela sexguttata			1															

VITA

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Dayton Hylton is a member of the Tennessee Entomological Society, the Entomological Society of America, the honor societies of Phi Eta Sigma, Alpha Zeta, and Gamma Sigma Delta.