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Sequence of Arrival and Spatial Distribution of Entomophagous and Associate Insects on Southern Pine Beetle-Infested Trees

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Summary

Sequence of arrival and spatial distribution of beneficial and associate insects on southern pine beetle-infested trees were investigated. Over 150 entomophagous and associate species were attracted to southern pine beetle-infested trees. Peak arrival of adult predators and parasites occurred when appropriate host life stages were most abundant. Associates responded in peak numbers during the later stages of southern pine beetle infestation, a period when necessary food and habitat seem to be present. Many of the insects trapped on the bark beetle-infested trees exhibited discrete spatial distributions.

parasits
predators

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Keywords: *Dendroctonus frontalis*/southern pine trees/[redacted]beneficial and associate insects.

Sequence of Arrival and Spatial Distribution of Entomophagous and Associate Insects on Southern Pine Beetle-Infested Trees

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The southern pine beetle, *Dendroctonus frontalis* Zimmerman (Coleoptera: Scolytidae), is the most destructive bark beetle species in the South. Pine trees from Pennsylvania to Virginia, southwards to Honduras, Central America, and as far west as Arizona are threatened by its devastating attacks (Thatcher, 1960).

Southern pine beetle outbreaks result in large volumes of pine destroyed in localized areas and at infrequent intervals. During an epidemic, trees of all age classes and stand densities are attacked. Healthy as well as weakened trees are susceptible to bark beetle attack (Thatcher, 1960).

The magnitude of the southern pine beetle problem is reflected in the fact that since 1976, infestations in the United States have occurred in over 30 million hectares of pine forests. In Texas alone, the volume of timber killed on state and private lands that year was estimated to be over 51 million cubic feet (Anonymous, 1978). This timber amounted to an estimated 16 thousand hectares at a stumpage value of $17 million. From 1958 to 1977, the period of the most recent epidemic of the beetle, Texas has suffered losses estimated at ca. 600 million board feet of salvage and 750 million cords — a total of over 150 million cubic feet of pine.

Efforts to control the beetle have ranged from mechanical methods such as burning infested bark and slabs, placing infested timber in soaking ponds, and salvage, to chemical methods such as insecticides and herbicides (Coulson et al., 1972). All of these methods have been criticized because of 1) expense, 2) potential impact on beneficial insects, 3) questionable effectiveness in managing extensive bark beetle populations, and 4) environmental hazards.

As an alternative to the inadequate unilateral control tactics, integrated pest management (IPM) has been proposed as an approach with the greatest promise for use in forest protection (Stark, 1977). IPM utilizes all tactics and more in an ecologically compatible manner. This systems approach to managing bark beetles has been described by Waters (1974) and is currently being used in the USDA Expanded Southern Pine Beetle Research and Applications Program (Leuschner et al., 1977). In general, both direct and indirect control tactics are considered (Coster, 1977) with a knowledge of beneficial and associated insects as an essential element.

Comprehensive lists of insects associated with the southern pine beetle have been compiled by Chamberlin (1939), Thatcher (1960), Dixon and Osgood (1961), Bushing (1965), Overgaard (1968), Franklin (1969), Moser et al. (1971), Moore (1972), Coulson et al. (1972), and Camors and Payne (1973). These biological tables include eight confirmed predators and 14 parasites.

The potential value of beneficial insects in the reduction of bark beetle populations has been recognized since the late 1800's. Hopkins (1893) observed that the clerid beetle *Thanasimus dubius* (F.) (Coleoptera: Cleridae) was highly predaceous on the southern pine beetle. Adult *T. dubius* killed an average of 2.2 southern pine beetle adults per day for 5 to 10 weeks, while actively feeding clerid larvae destroyed up to 100 immature bark beetles during their feeding period (Thatcher and Pickard, 1966).

Scolopscelis mississippensis Drake and Harris (Hemiptera: Anthocoridae) and *Temnochila virescens* (F.) (Coleoptera: Trogositidae) were important predators in studies conducted by Moore (1972). He estimated that immature *S. mississippensis* and *T. virescens* each consumed 0.9 southern pine beetle larvae/0.1m^2 bark. *Medetera* spp. (Diptera: Dolichopodidae) were observed by Fiske (1908) as being capable of reducing bark beetle populations.

Fronk (1947) reported that *Coeloides pissodis* (Ash.) (Hymenoptera: Braconidae) and *Cecidostiba*

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dendroctoni Ash. (Hymenoptera: Pteromalidae) were primary contributors to suppression of the southern pine beetle populations. Moore (1972) found southern pine beetle broods were destroyed 25-30 percent by parasites, especially when three or more species were present. Overall, 24 percent of southern pine beetle mortality was attributed to parasites and predators, with 80 percent brood destruction occurring.

Entomophagous insects were found important in reducing populations of other bark beetle species. Larval *Enoclerus sphegeus* Fab. (Coleoptera: Cleridae) killed 20 to 25 mountain pine beetles, *D. ponderosae* Hopk. (Schmid, 1970). *T. virescens* was recognized as important in limiting populations of the western pine beetle, *D. brevicomis* LeC. (Struble, 1942). *C dendroctoni* parasitized 90 percent of mountain pine beetle populations in western white and lodgepole pine (DeLeon, 1935). A 3-16 percent parasitism rate on seven consecutive generations of *Ips grandicollis* (Eich.) (Coleoptera: Scolytidae), a common associate of the southern pine beetle, was observed by Berisford et al. (1971).

A basic prerequisite to the development of any pest insect suppression program is the identification of not only what natural enemies and associate insects are present but when they are present and where they are found. However, only two investigations have been reported which relate to the sequence of arrival and spatial distribution of associates to standing southern pine beetle-infested trees. Camors and Payne (1973) reported on the sequence of arrival of five predators and six parasites of the southern pine beetle to bark beetle-infested trees. Monitoring was carried out only at ca. 1.4m (DBH). In a second investigation, Coster (1969) observed the sequence of arrival and spatial distribution of *Platypus flavicornis* (F.) (Coleoptera: Platypodidae) up to 12 feet on southern pine beetle-infested trees.

As a result of the scarcity of data in this area, the following research was conducted to provide needed information on the sequence of arrival and spatial distribution of beneficial and associated insects attracted to host trees infested by the southern pine beetle.

MATERIALS AND METHODS

Study Areas

Two southern pine beetle infestations (spots) were utilized in the investigation. In 1974, monitor trees were selected from a spot located within the Sam Houston National Forest. The following year, additional monitor trees were chosen from a spot situated within the area known as the Big Thicket of East Texas. Both stands were composed predominantly of the bark beetle host tree species loblolly pine (*Pinus taeda* L.) and short leaf pine (*P. echinata* Mill.). Other tree species present were hickories, oaks, magnolias, and sweetgum (SAF Type 80). Average height of the monitor trees was 18.1 ± SE$\bar{X}$ 1.2m, and average diameter at breast height was 31.7 ± 2.3cm.

Procedure

A total of seven southern pine beetle-attacked trees and seven unattacked trees were monitored for the two spots. Procedures for monitoring the trees were adapted from Stephen and Dahlsten (1976a) and Coster et al. (1977). Two lines of traps were attached to opposite sides of a monitor tree. Each trap was constructed of hardware cloth (15.2 × 30.5cm; 0.32cm mesh) coated with Stickem Special® (Figure 1).

The traps were replaced 3 days after the initial arrival of attacking southern pine beetles. Thereafter, the traps were removed and replaced with clean sticky traps every 3 days until 30 days after bark beetle mass attack. All traps removed were wrapped with plastic and placed in cold storage until cleaned. Heated kerosene was used to dissolve the stickem and plastic. The insects were preserved in kerosene filled vials. Insects were removed from the vials and allowed to dry ca. 24 hours to facilitate identification.

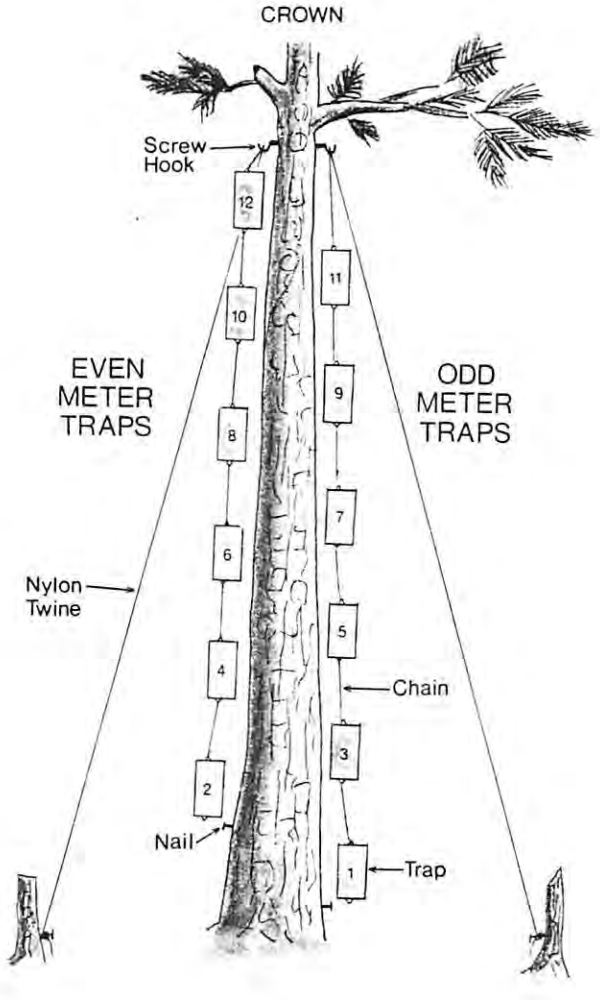


Figure 1. Arrangement of sticky traps for monitoring temporal and spatial distributions of beneficial and associate insects on bark beetle-infested trees.

Bark samples were taken from infested trees in order to correlate the sequence of arrival of beneficials and associates with the predominant life stages of the southern pine beetle within the trees. Procedures for taking bark samples followed those developed by Coulson et al. (1975). One $100cm^2$ bark sample per sample height per sampling time was taken on each tree (= 6 samples/sampling time). The sampling heights were 1.5m, 3.5m, 5.5m, 7.5m, 9.5m, and 11.5m. Tree climbing ladders were used to facilitate sampling at the upper heights. The sampling times were on the 3rd, 10th, 17th, 24th and 31st days after the start of southern pine beetle arrival. The bark discs were then refrigerated to curtail bark beetle development until they were radiographed. For each bark disc the numbers of parent adults, larvae, and pupae-callow adults when present were counted, thus giving an indication of the predominant bark beetle life stages within the trees. The Appendix Table lists all insects trapped on the bark beetle-infested trees, their probable biological roles, and relative abundance.

RESULTS AND DISCUSSION

Associated Bark and Ambrosia Beetles

Coleoptera: Scolytidae

Sixteen scolytid and one platypodid species were among the more than 150 species trapped on the southern pine beetle-infested trees. Each species exhibited a characteristic sequence of arrival and spatial distribution. Over the 30-day monitoring period ca. 97 percent of the southern pine beetles, *Dendroctonus frontalis* Zimm., were trapped within the first 9 days (Figure 2). Although trap catch of southern pine beetles did not increase after the rapid drop in numbers, the change in the male:female ratio suggested re-emergence of southern pine beetles occurred during days 10-12 (1:3.01 compared to 1:0.75 for the first 9 days). In the laboratory, Thatcher and Pickard (1964) found that re-emergence occurred in 10-14 days.

The predominant life stages of the southern pine beetle present during each sampling time were the following:

1) day 3 - parent adults
2) day 10 - parent adults and larvae
3) day 17 - larvae and pupae-callow adults
4) day 24 - larvae and pupae-callow adults
5) day 30 - pupae-callow adults

The increase in trap catch on day 30, although minimal, suggested the emergence of brood adults. Generally, those beetles on the traps at that time were light tan in color as are the tenerals before complete pigmentation occurs.

Ips avulsus (Eich.), *I. calligraphus* (Germar), and *I. grandicollis*, three food competitors of the southern pine beetle, were commonly trapped on the southern pine beetle-infested trees. Peak arrival of *I. avulsus* and *I. grandicollis* occurred ca. 12 and 18 days respectively after initial arrival of southern pine beetles

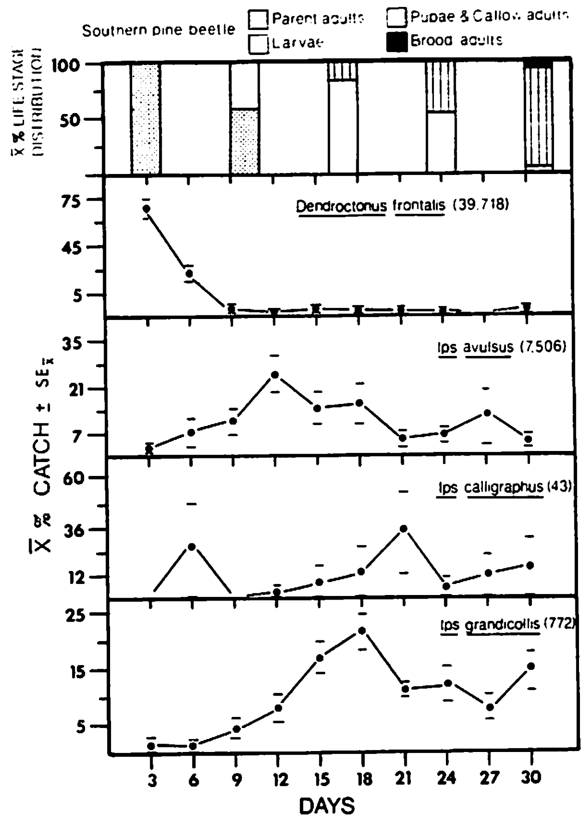


Figure 2. Sequence of arrival of *D. frontalis*, *I. avulsus*, *I. calligraphus*, and *I. grandicollis* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

(Figure 2). However, both *Ips* spp. were trapped during southern pine beetle mass attack. *I. calligraphus* was not trapped in large numbers until day 21. Several individuals were observed walking off the sticky traps, thus the trap catch of this bark beetle may have been unrepresentative of the actual response of *I. calligraphus* to the host trees. In addition, *D. terebrans* (Oliv.) was present on two of the monitored trees; however, none were caught on the traps. The large size and strength of black turpentine beetles may have enabled them to walk off of the sticky trap.

A sudden increase in trap catch characterized the arrival pattern of *Ips avulsus*, a behavior similar to the mass attack pattern of the southern pine beetle. On one of the trees monitored, ca. 1217 *I. avulsus* were trapped over a 3-day sample period. Male *I. avulsus* were most abundant during the initial arrival period; however, the male:female ratio became balanced by the day 16-18 interval (1:0.93). The overall sex ratio was 1:0.70 for the species.

I. grandicollis exhibited a similar rapid rise in trap catch followed by a quick decrease. During the first 9 days of arrival, the male:female ratio was ca. 1:1; thereafter, females predominated except on days 16-18 when the sexes were balanced again. The overall male:female ratio was 1:1.42. The sex ratio for *I. calligraphus* was 1:1.50. Similar sex ratios for *I. avulsus* and *I. calligraphus* were reported by Berisford and Franklin (1971).

Differences in spatial distribution were exhibited by the southern pine beetle and the three *Ips* spp. (Figure 3). Peak catch of the southern pine beetle occurred at the 3m and 4m traps with a low catch of 3 percent each at the 11m and 12m traps. This is in agreement with findings reported by Coster et al. (1977). In comparison, *I avulsus* was most abundant on the upper half of the tree bole. The male:female ratio of *I. avulsus* on the lower eight traps was 1:0.39, compared to 1:0.77 for the upper four traps, suggesting that those beetles on the lower two-thirds of the infested bole may not have constructed successful galleries to which female beetles were attracted. Hodges and Pickard (1971) reported that the lower limits of attack by *I. avulsus* was 8m and 15m on lightning-struck and nonstruck trees, respectively. The majority of the *I. grandicollis* and *I. calligraphus* were also trapped on the upper half of the tree bole (Figure 3).

The spatial distribution of niche breadth of the southern pine beetle and the three *Ips* species reported by Paine et al. (1979) is similar to the data presented here from landing trap catches. Birch and Svihra (1979) reported on the sequence of attack and distribution of these bark beetle species; however, their results are not comparable to those presented here in that they did not provide data on beetle densities.

Four other scolytid species present on the southern pine beetle-infested trees were *Crypturgus aluctaceus* Schwarz, *Pityophthorus annectans* LeC., *P. bisulcatus* (Eich.), and a *Hypothenemus* sp. (nr. *pubescens*). The first three species were reported as food competitors of the southern pine beetle (Moser et al., 1971). *C. aluctaceus*, a small scolytid whose galleries start from those of *Ips* spp. (Chamberlin, 1939), was trapped in greatest numbers ca. 12 and 18 days after peak catch of *I. grandicollis* and *I. avulsus*, respectively (Figure 4). Overall, *P. annectans* and *P. bisulcatus* were most abundant during the day 15-30 interval. The *Hypothenemus* sp. appeared to have three arrival peaks; however, one of the latter peaks may be indicative of brood emergence.

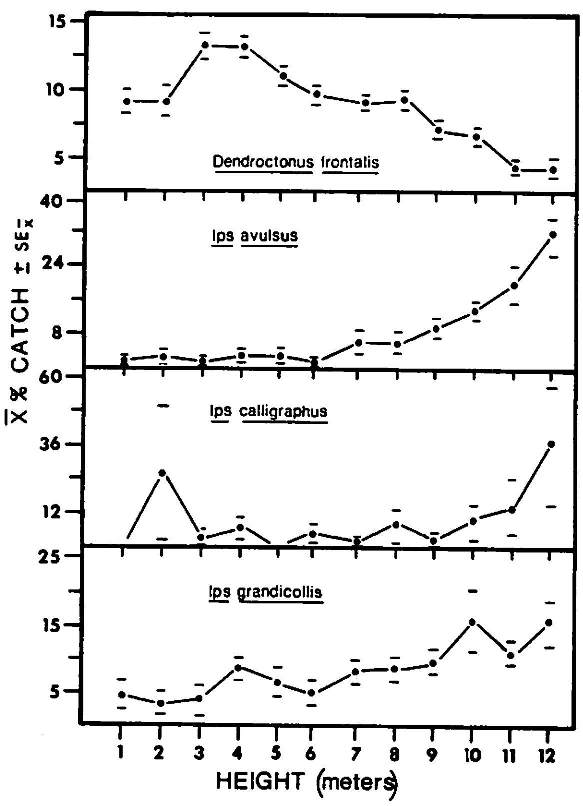


Figure 3. Height distribution of *D. frontalis*, *I. avulsus*, *I. calligraphus*, and *I. grandicollis* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

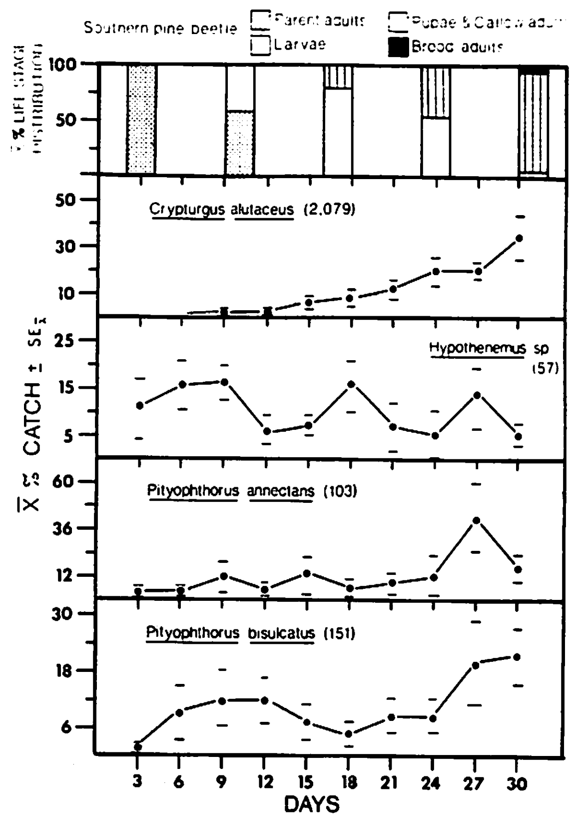


Figure 4. Sequence of arrival of *C. aluctaceus*, *Hypothenemus* sp., *P. annectans*, and *P. bisulcatus* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

Trap catch of *C. aluctaceus* was greatest at midbole (Figure 5). *P. annectans* was caught uniformly throughout the bole, although *P. bisulcatus* was trapped predominantly on the upper half of the tree bole. The upper limit of the *Hypothenemus* sp. was 11m.

Ambrosia beetles that typically breed in dead and dying pines include *Xyleborus ferrugineus* (F.), *X. pini* (Eich.), and *X. saxeseni* (Ratz.) (Coleoptera: Scolytidae) (Baker 1972). *X. ferrugineus* and *X. pini*, although present in low numbers during southern pine beetle mass attack, were not abundant until after the attacking southern pine beetle adults had re-emerged (Figure 6). Similarly, peak catch of *X. saxeseni* occurred after cessation of bark beetle mass attack. The three *Xyleborus* spp. were most abundant on the lower four traps with the 1m trap accounting

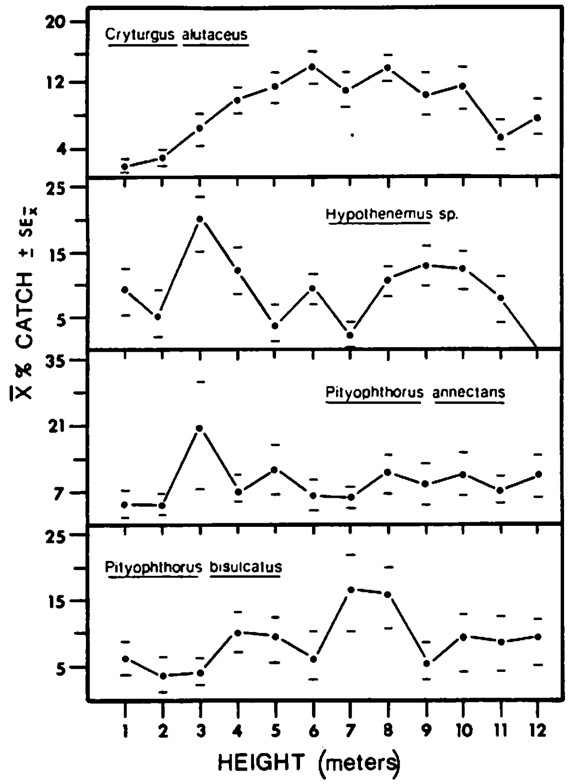


Figure 5. Height distribution of *C. aluctaceus, Hypothenemus* sp., *P. annectans*, and *P. bisulcatus* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

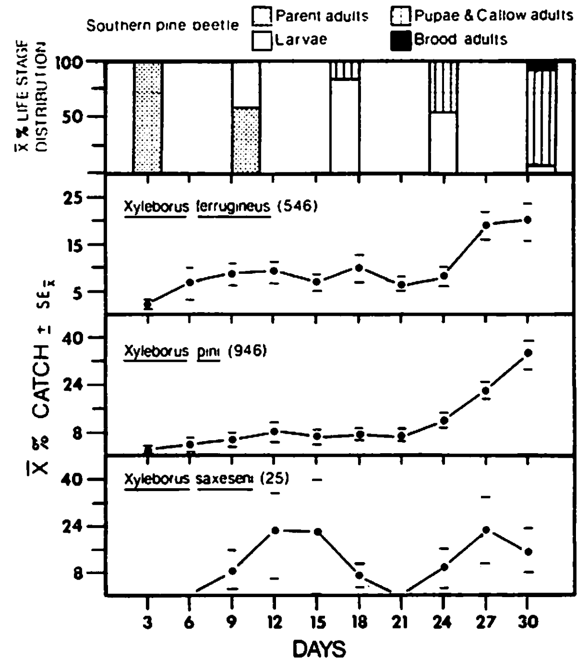


Figure 6. Sequence of arrival of *X. ferrugineus, X. pini*, and *X. saxeseni* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

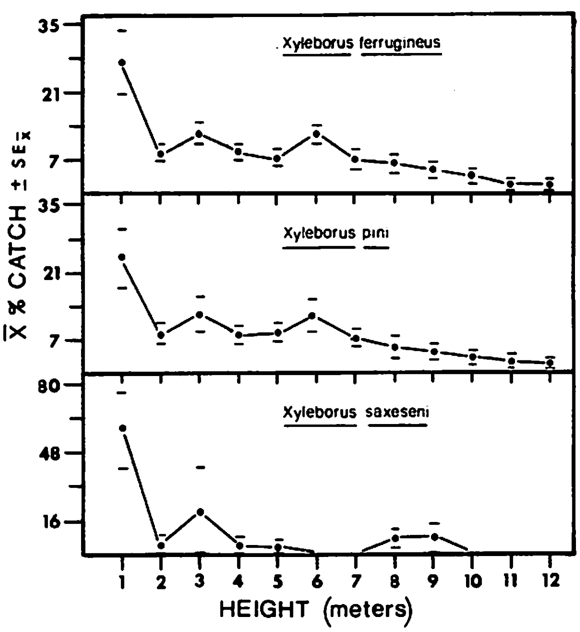


Figure 7. Height distribution of *X. ferrugineus, X. pini*, and *X. saxeseni* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

for the largest catch (Figure 7). A peculiar feature of the *Xyleborus* spp. was that all specimens were female. Male *Xyleborus* are unable to fly, spending their entire life cycle within the parental nest (Bright, 1968).

The ambrosia beetles *Gnathotrichus materiarius* (Fitch) (Scolytidae) and *Platypus flavicornis* (Fab.) (Platypodidae) typically breed in the above-ground, lower portions of dying pines. *Hylastes tenuis* (Eich.) (Scolytidae), however, generally inhabits the bases or roots of such pines (Baker, 1972). Peak catch of *G. materiarius* in this investigation occurred during the day 25-30 interval (Figure 8). Male *G. materiarius* were predominant (1:0.55) during the first 9 days of monitoring the bark beetle-infested trees. However, for the remaining 21 days, a period when the ambrosia beetle was increasing in numbers, the sex ratio was more balanced (1:1.00). Male *G. sulcatus* LeConte are reported to produce a pheromone which was subsequently identified as a population aggregating pheromone (Byrne et al., 1974). A similar aggregation system may occur in *G. materiarius* in that males were initially predominant on the bark beetle-infested trees followed by a balanced aggregation of the sexes.

Peak arrival of *P. flavicornis* occurred 6 to 9 days after the cessation of southern pine beetle mass attack (Figure 8). By comparison, Coster (1969) reported that the peak arrival of *P. flavicornis* occurred 10-14 days after the start of southern pine beetle mass attack. Based on laboratory bioassays, Madrid et al. (1972) suggested that a population aggregating pheromone is produced by the males. Renwick et al. (1977) later identified two pheromones in emergent males as 1-hexanol, 3-methyl-1-butanol and sulcatol.

The results of the present investigation appear to substantiate the earlier findings in that the sex ratio of initially arriving *P. flavicornis* favored males (1:0.32) with an apparent balancing of the sexes (1:1.49) for the remaining 27 days.

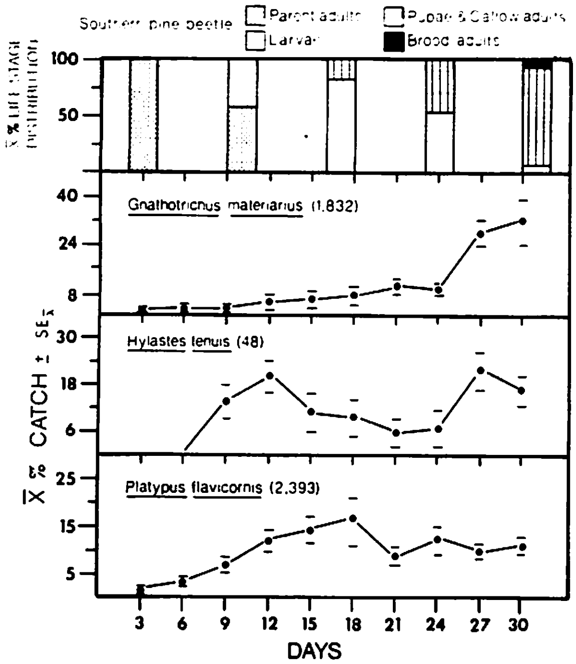


Figure 8. Sequence of arrival of *G. materiarius*, *H. tenuis*, and *P. flavicornis* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

Peak catch of *H. tenuis* occurred on days 10-12 and then on days 25-27 (Figure 8). The bimodal peaks of abundance for *H. tenuis* may have indicated brood emergence; however, the developmental rate of this beetle is not known.

The spatial distributions of *G. materiarius*, *H. tenuis*, and *P. flavicornis* were similar to the other previously discussed ambrosia beetles. The 1m trap accounted for the greatest number of all three species (Figure 9). *H. tenuis* differed slightly in that trap catch increased again near mid-bole. The attack limits for the beetles were not determined in this investigation but previous reports indicate an upper limit of 8m for *P. flavicornis* (Madrid et al., 1972). Coster (1969) observed that flight activity of *P. flavicornis* was usually higher on the infested bole than actual attacks and suggested that general movement downwards on the bole occurred after landing.

Predators

Cleridae

Seven clerid species were found to be attracted to the bark beetle-infested trees in this investigation. *T. dubius*, a known predator of the southern pine beetle, was the most abundant with peak numbers during days one to six (Figure 10), a period when the southern pine beetle was also trapped in greatest numbers (Figure 2). Dixon and Payne (1979) provide a detailed discussion of *T. dubius* aggregation on bark beetle-infested trees during southern pine beetle mass attack.

Peak catch of *Priocera castanea* (Newman), a predator of several scolytids (Knull, 1951; Baker, 1972), occurred during days 13-18 and then again in greater numbers during days 25-30. *Cregya oculata* (Say), a predator of cerambycid larvae and bark beetles (Knull, 1951), was most abundant during the last 6 days of trapping. *Tillus collaris* Spin., although trapped in low numbers (n=5), was caught only during the first 3 days of southern pine beetle arrival, which suggests it may prey on the bark beetle or other pioneer associates.

Trap catch of *T. dubius* was greatest on the lower half of the southern pine beetle-infested bole (Figure 11) as was the bark beetle catch (Figure 2) (62 percent and 64 percent, respectively). Trap catches on the upper half of the infested bole accounted for the greatest number of *P. castanea* and *C. oculata*. The lower limit of trap catch for *T. collaris* was 4m.

From these results it appears that the sequence of arrival and spatial distribution of the clerids depends to a large degree upon preferred prey. The temporal and spatial distributions of *T. dubius* were very similar to those of the southern pine beetle, a preferred prey[1]. The sequence of arrival and spatial distribution of *C. oculata* and *P. castanea* suggests similar responses to undetermined prey.

Clausen (1972) stated that clerids demonstrate an exceptional consistency in host preferences, most confining themselves to scolytid, buprestid, and cerambycid prey. A comparison of the sequences of arrival and height distributions of *P. castaneum* and two *Ips* spp. (*I. avulsus* and *I. calligraphus*) (Figures 2, 3, 10, and 11) reveals several similarities. These are 1) peak trap catches on days 12-18 and again on days

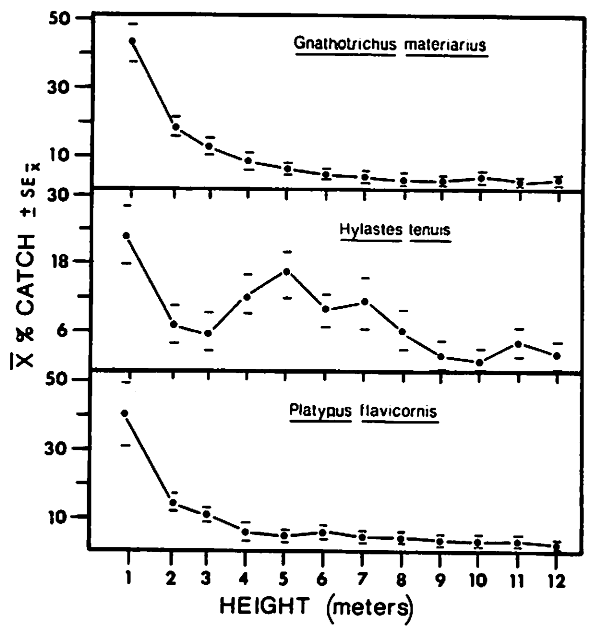


Figure 9. Height distribution of *G. materiarius*, *H. tenuis*, and *P. flavicornis* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

[1]Turnbow, R. H. 1975. Prey consumption, survivorship, and oviposition by adults of the bark beetle predator, *Thanasimus dubius* Fabricus (Coleoptera: Cleridae). M. S. Thesis. Oregon State University.

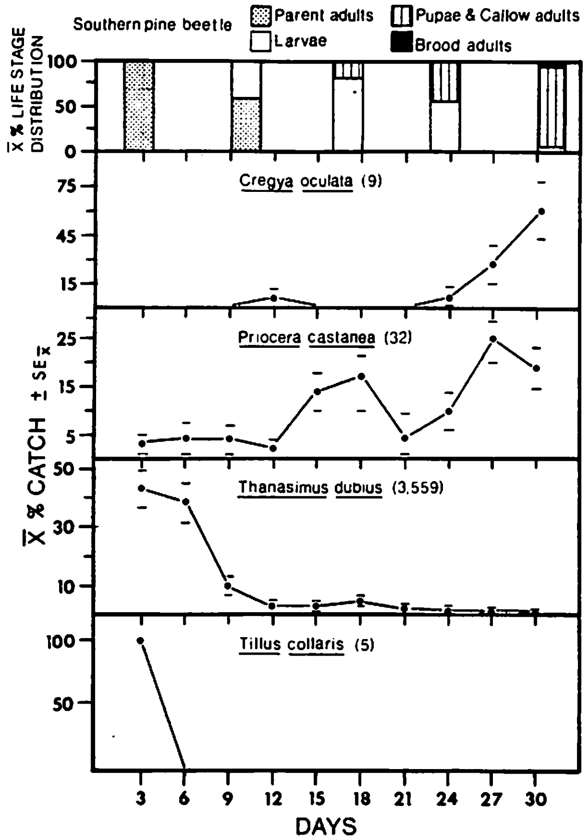


Figure 10. Sequence of arrival of *C. oculata*, *P. castanea*, *T. dubius*, and *T. collaris* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

27-30, and 2) a concentration of clerid and scolytid numbers above the 4m trap on the tree bole. In addition, *P. castaneum* has been observed on trees under attack by *Ips* beetles[2]. If in fact the *Ips* beetles are preferred prey of *P. castaneum*, then the predator may locate concentrations of prey in the same manner of *T. dubius* for southern pine beetles, i.e., by olfactory cues.

Histeridae

During this investigation six predaceous histerids were trapped on the bark beetle-infested trees. Peak catch of the *Abraeus* sp. occurred within the first 9 days of southern pine beetle mass attack, followed by a general decrease in numbers trapped (Figure 12). *Cylistix attenuata* LeC., a predator of bark beetles and other associates (Moser et al., 1971), was most abundant after the 18th day. *C. cylindrica* (Paykull) was trapped in greatest numbers from days 6-18, a period when its southern pine beetle adult and larval prey were prevalent. The total male:female ratio for this histerid was 1:1.20, similar to the 1:1.38 ratio reported by Camors and Payne (1973). *Plegaderus* spp., which typically prey on bark beetle eggs and larvae (Moser et al., 1971), were most abundant during the later stages of southern pine beetle brood development.

Trap catch for three of the histerid species (*Abraeus* sp., *C. cylindrica* and *Plegaderus* spp.) was

[2]Svihra, P. Personal communication.

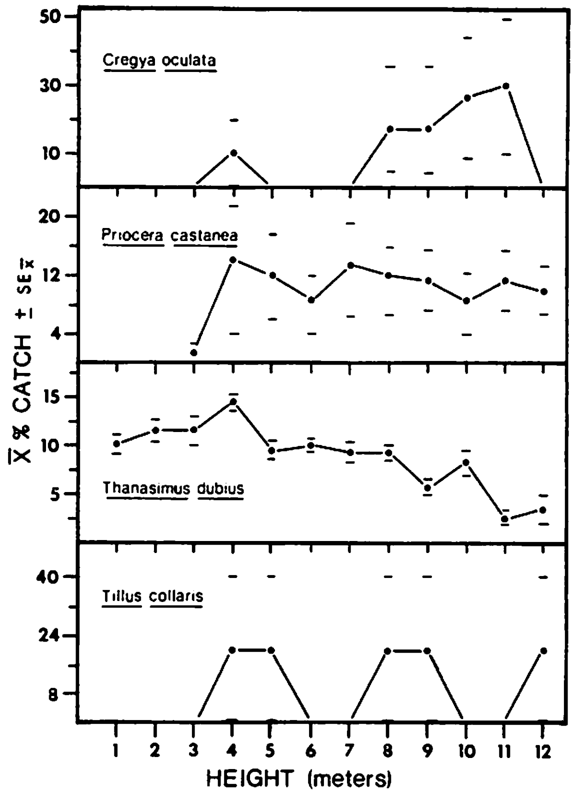


Figure 11. Height distribution of *C. oculata*, *P. castanea*, *T. dubius*, and *T. collaris* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

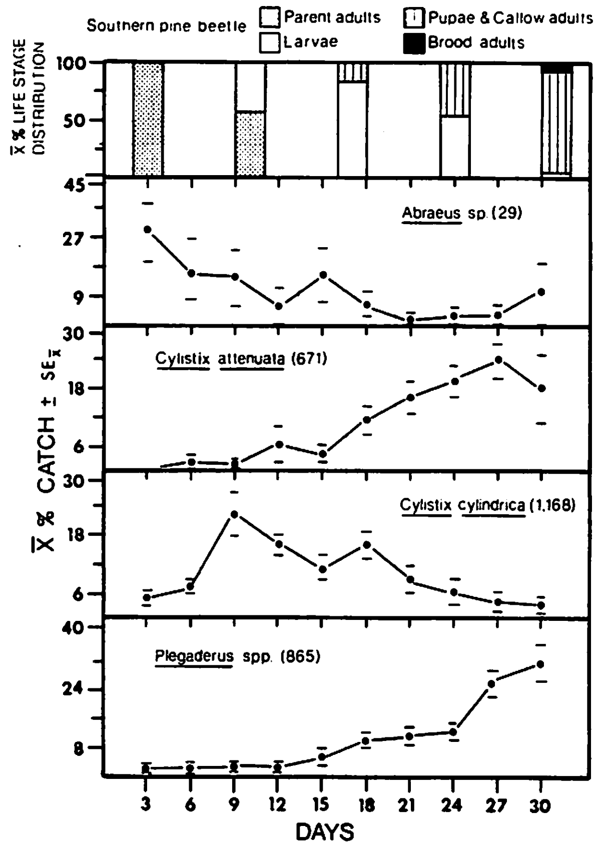


Figure 12. Sequence of arrival of *Abraeus* sp., *C. attenuata*, *C. cylindrica*, and *Plegaderus* spp. to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

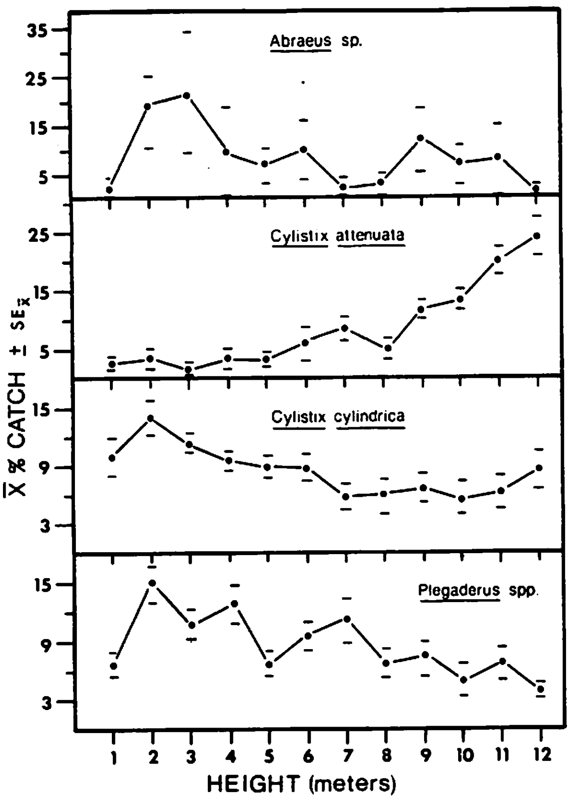


Figure 13. Height distribution of *Abraeus* sp., *C. attenuata*, *C. cylindrica*, and *Plegaderus* spp. on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

greatest on the lower half of the tree bole (Figure 13). Peak catch of *C. attenuata*, however, was on the upper half of the bark beetle-infested tree.

The remaining histerid species caught on the sticky traps were *Platysoma parallelum* LeC. and a *Hister* sp., both of which were reported to prey on bark beetles and other associates (Moore, 1972). Both histerids were most abundant ca. 2 weeks after southern pine beetle mass attack (Figure 14). Spatially, the two histerids differed in that *P. parallelum* was uniformly distributed on the 12 traps, while trap catch of the *Hister* sp. was greatest at mid-bole (Figure 15). Although common prey species probably exist, the variable arrival times and height distributions of the six histerid species suggests that unique prey and habitat requirements influence the distribution of each histerid to and on a bark beetle-infested tree.

Orthoperidae

Generally, members of Orthoperidae are found under decaying bark of trees or in rotting fungus-covered plant material and are carnivorous (Arnett, 1973). Moser et al. (1971) reported that a *Sacium* sp. was a common associate on southern pine beetle-infested trees. However, in this investigation, a *Molamba* sp. was the only orthoperid caught on the sticky traps. Peak catch of this orthoperid occurred ca. 2 weeks after the cessation of southern pine beetle attack (Figure 14). Spatially, the *Molamba* sp. was most abundant on the upper half of the bark beetle-infested bole (Figure 15).

Tenebrionidae

Corticeus glaber (LeC.) (Coleoptera: Tenebrionidae), a facultative predator of bark beetles (Moser et al., 1971), arrived in greatest numbers during days 15-27, a period when larval and pupal southern pine beetles were prevalent (Figure 14). Trap catch of *C. glaber* was slightly greater on the lower four traps (Figure 15), an area of similar concentration of southern pine beetles (Figure 3). The total male:female ratio was 1:0.95. *C. glaber* may function much like *C. substriatus* (LeC.), in that these tenebrionid adults and larvae consumed all life stages of the mountain pine beetle (Parker and Davis, 1971).

Trogositidae

Temnochila virescens (F.), *Tenebroides collaris* (Sturm), and *T. marginatus* (Palisot de Beauvois) (Coleoptera: Trogositidae) were found to be attracted to the bark beetle-infested trees. Moser et al. (1971) reported that adults and larvae of the trogositids were predators of bark beetle adults and larvae. *T. virescens*, in this investigation, appeared to exhibit two arrival peaks (Figure 16). The first was during days 7-12 followed by a second peak during days 22-30. The total male:female ratio was 1:1.36. *T. collaris* was most abundant during the day 10-21 interval. *T. marginatus* was trapped throughout the monitor period except during days 7-12. Spatially, all

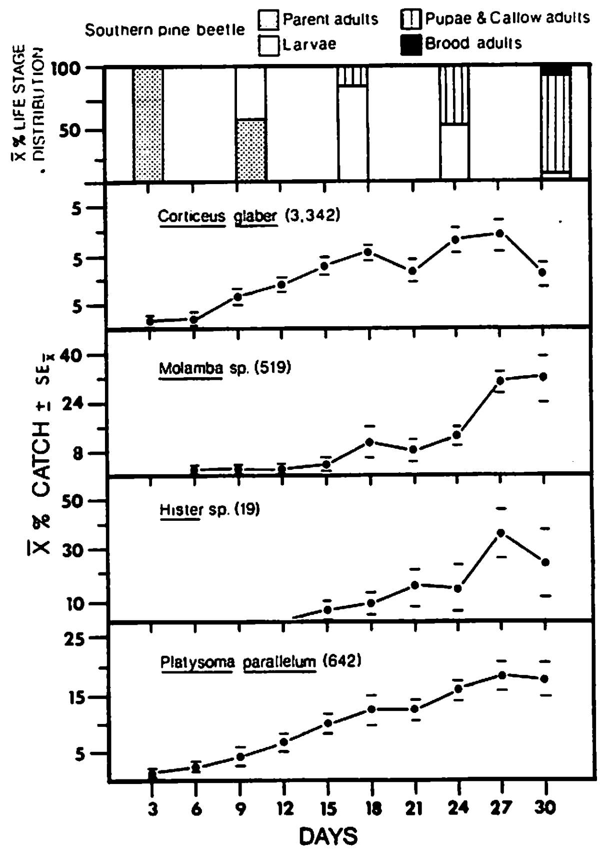


Figure 14. Sequence of arrival of *C. glaber*, *Molamba* sp., *Hister* sp., and *P. parallelum* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

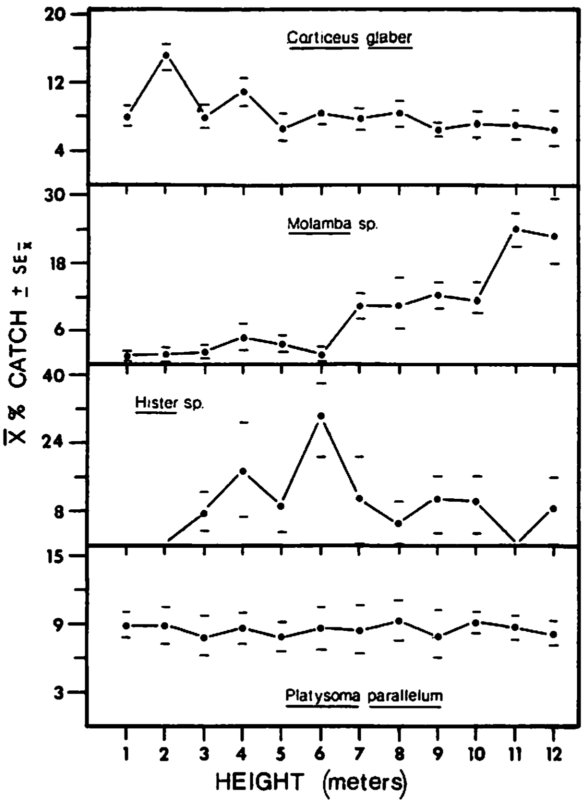


Figure 15. Height distribution of *C. glaber, Molamba* sp., *Hister* sp., and *P. parallelum* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

three trogositids were trapped at 2m and up on the bark beetle-infested bole (Figure 17).

Colyidiidae

Aulonium ferrugineum Zimm., *A. tuberculatum* LeC., *Colydium nigripenne* LeC., *Lasconotus pusillus* LeC., and *L. referendarius* Zimm. (Coleoptera: Colyidiidae) were also attracted to the bark beetle-infested trees. All five predators/scavengers were most abundant during the day 15-30 interval. The colyidiids were generally trapped in greatest numbers on the upper half of the tree bole (Figures 16-19). Sex determination was done only for *A. tuberculatum*, yielding a total male:female ratio of 1:1.37. During the day 1-2 interval, female *A. tuberculatum* were predominant (1:2.75); thereafter, as trap catch increased, the sex ratio became more balanced until days 25-30 when males were predominant (1:0.68).

Staphylinidae

Leptacinus paurumpunctatus (Gyllenhal) and an Aleocharinae sp. were the two most commonly encountered staphylinids on the bark beetle-infested trees. *L. paurumpunctatus*, a predator of bark beetles (Moore, 1972), and the aleocharine staphylinid were trapped in greatest numbers during the day 10-30 interval, a period when immature southern pine beetles predominated (Figure 20). Spatially, the two differed somewhat in that the aleocharine staphylinid was most abundant on the 4m-7m traps, but *L. paurumpunctatus* was trapped in greater numbers on the 1m-4m traps (Figure 21).

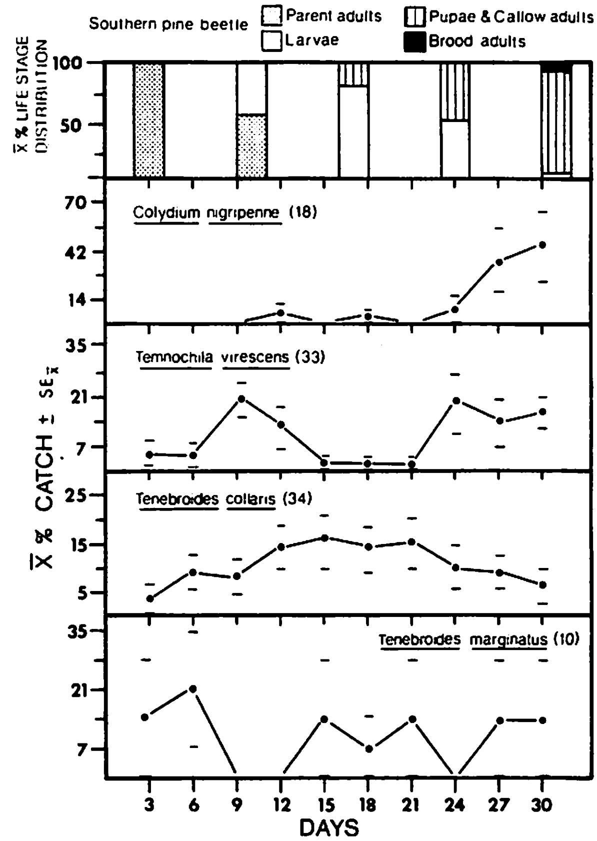


Figure 16. Sequence of arrival of *C. nigripenne, T. virescens, T. collaris*, and *T. marginatus* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

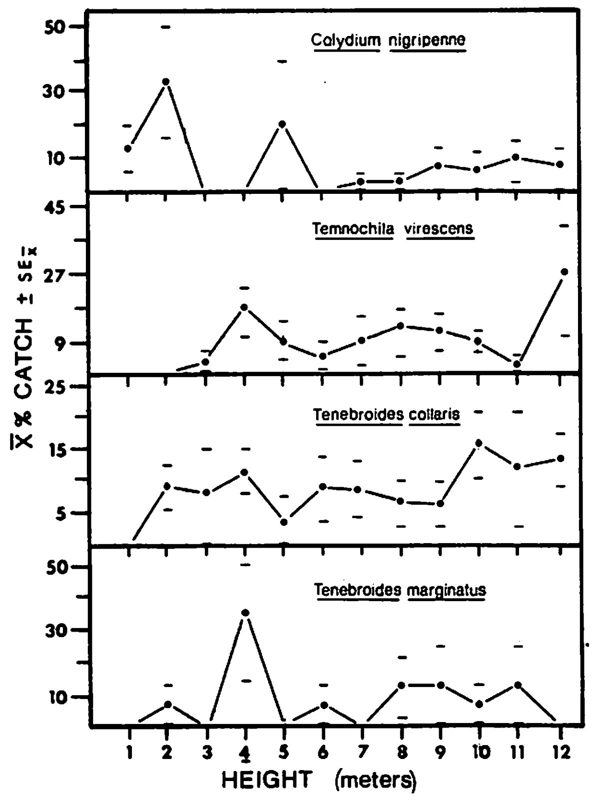


Figure 17. Height distribution of *C. nigripenne, T. virescens, T. collaris*, and *T. marginatus* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

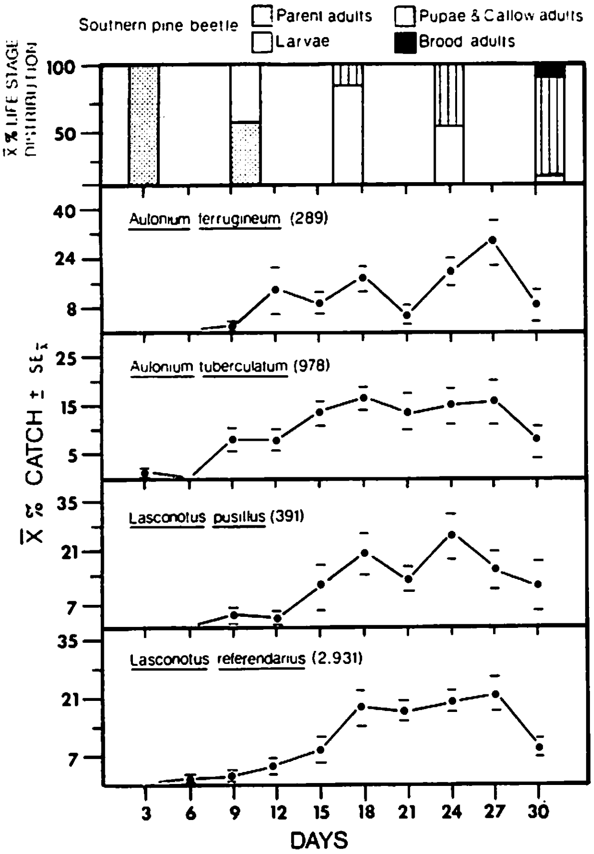


Figure 18. Sequence of arrival of *A. ferrugineum, A. tuberculatum, L. pusillus,* and *L. referendarius* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

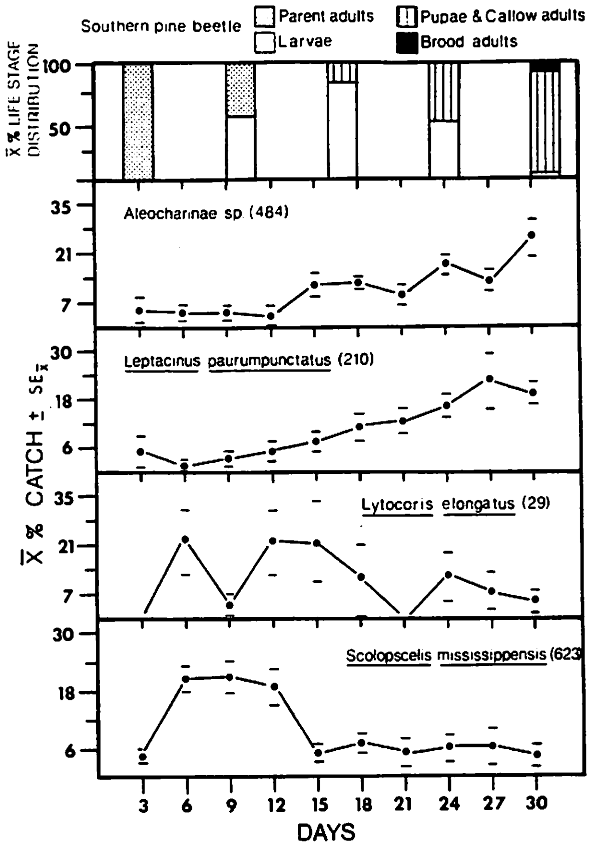


Figure 20. Sequence of arrival of Aleocharinae sp., *L. paurumpunctatus, Lyctocoris* sp., and *S. mississippensis* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

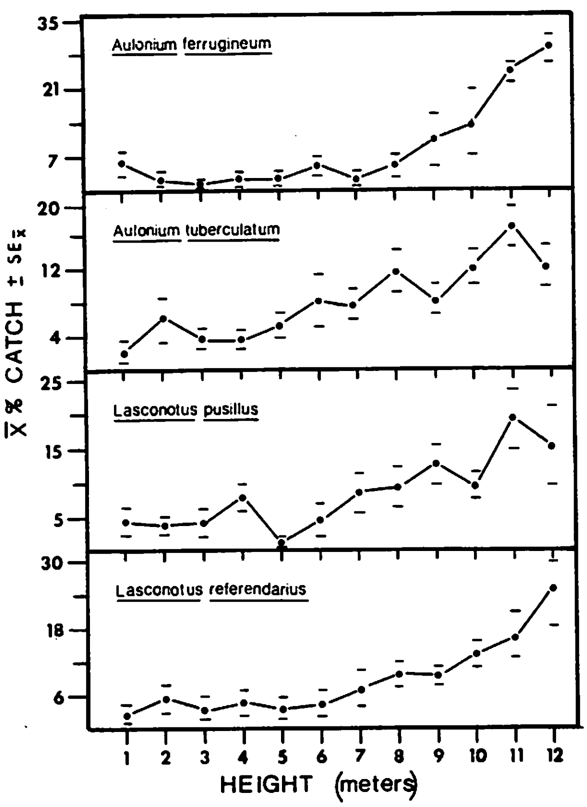


Figure 19. Height distribution of *A. ferrugineum, A. tuberculatum, L. pusilius,* and *L. referendarius* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

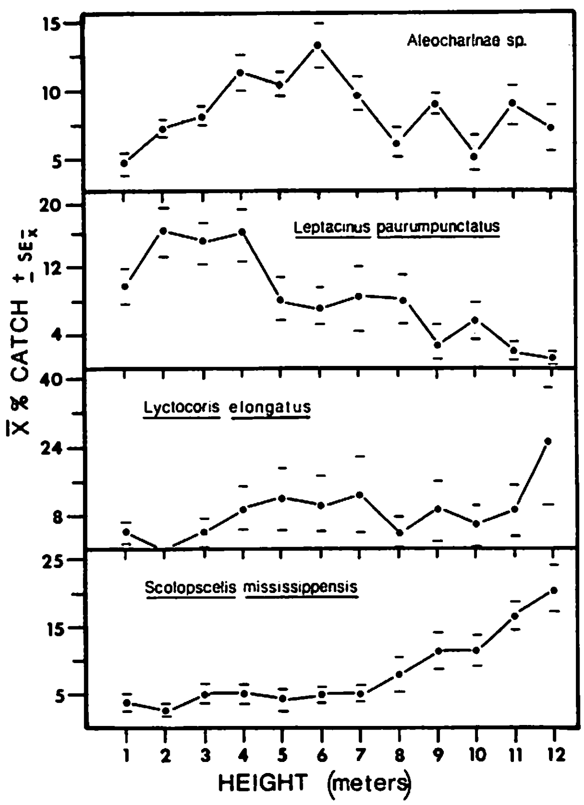


Figure 21. Height distribution of Aleocharinae sp., *L. paurumpunctatus, Lyctocoris* sp., and *S. mississippensis* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

Hemiptera: Anthocoridae

Scolopscelis mississippensis (Drake and Harris) and *Lyctocoris elongatus* (Reuter) (Hemiptera: Anthocoridae), predators of bark beetle eggs and larvae (Fronk, 1947; Moore, 1972), were similar in their spatial distribution but differed in sequence of arrival. Peak catch of *S. mississippensis* occurred during the day 4-12 interval; thereafter, trap catch remained at a low but constant level (Figure 20). The total male:female ratio was 1:0.71; however, within the 30 days of trapping there were changes in the predominance of one sex or the other. During the first 12 days males were most abundant (1:0.53) followed by a predominance of females for the next 12 days (1:4.29), then another switch for the last 6 days (1:0.55). Peak catch of *L. elongatus* occurred during southern pine beetle mass attack, days 10-18, and days 25-30. The total male:female ratio was 1:1.23. Also, only females were trapped during the first peak, a 1:2.50 ratio for the second, and only females again for the third. Both anthocorids were most abundant on the middle to upper traps (Figure 21).

Camors and Payne (1973) reported *S. mississippensis* was most abundant on the fourth day with none trapped after the eighth day. The male:female ratio was 1:0.55. The apparent difference in the results presented here and those of Camors and Payne (1973) may be explained in part by the numbers trapped (623 vs. 20, respectively) as well as the fact that their data was collected only at a 1.4m height.

Diptera: Dolichopodidae

Peak catch of the *Medetera* spp. (Dolichopodidae), dipteran bark beetle predators (Moser et al., 1971), occurred during the first 6 days of southern pine beetle mass attack, a period when adult bark beetles were predominant. Thereafter, trap catch declined and remained at a low constant level (Figure 22). The total male:female ratio was 1:10.40. However, through the 30-day trapping period the predominance of females declined such that the male:female ratio was 1:5.37 for days 28-30. Spatially, the *Medetera* spp. also exhibited differences in sex ratio. On the lower bole females were predominant (1:20.83) but much less so on the upper bole (1:7.83). Overall, the dolichopodid flies were most abundant on the lower and upper traps with the least number caught at mid-bole (Figure 23).

Lonchaeidae

The *Lonchaea* sp. (Diptera: Lonchaeidae) was most abundant during days 13-21, a period when immature southern pine beetles were prevalent (Figure 22). Peak catch of the lonchaeid fly was greatest on the 1m and 2m traps (Figure 23). Reid (1957) observed that *L. corticeus* Taylor was a predator of *Ips* spp. and Moser et al. (1971) reported a *Lonchaea* sp. as a probable predator, which suggests the lonchaeid fly in this investigation may prey upon scolytids, particularly ambrosia beetles, which were also concentrated on the lower bole.

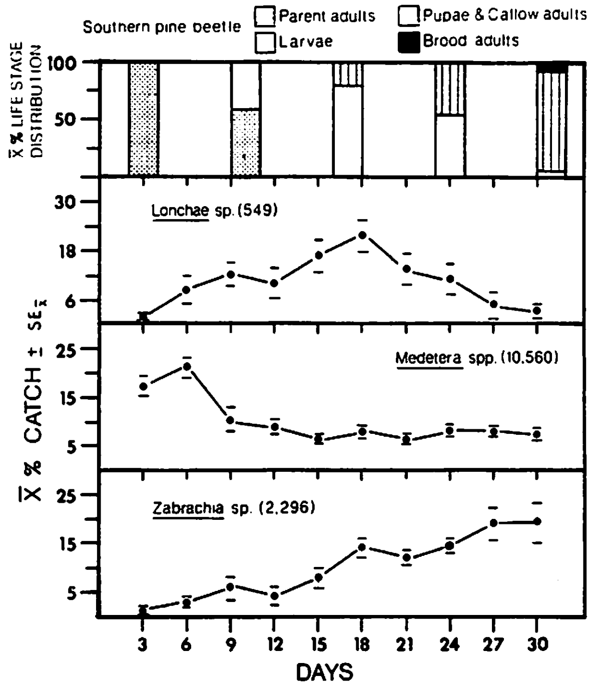


Figure 22. Sequence of arrival of *Lonchaea* sp., *Medetera* spp., and *Zabrachia* sp. to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

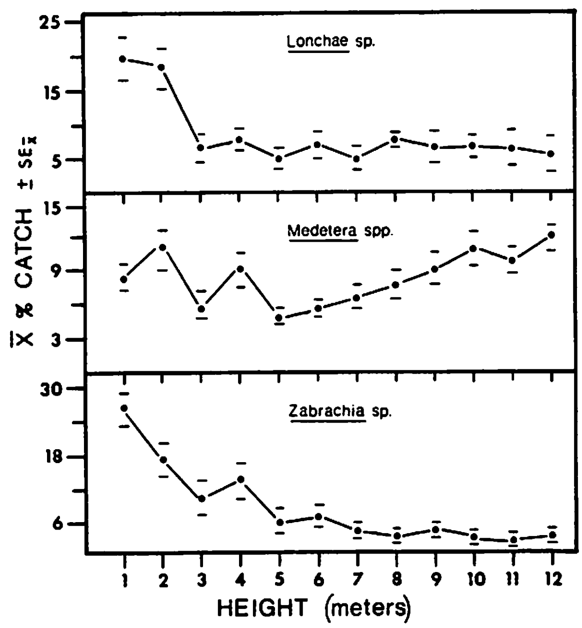


Figure 23. Height distribution of *Lonchaea* sp., *Medetera* spp., and *Zabrachia* sp. on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

Stratiomyidae

A *Zabrachia* sp. (Diptera: Stratiomyidae) was most abundant during days 15-30 (Figure 22). The 1m-4m traps accounted for over half of the trapped stratiomyids (Figure 23). Other stratiomyid flies have been reported as scavengers feeding on insect larvae under bark or parasitic on southern pine beetle larvae (Clausen, 1972; Dixon and Osgood, 1961) which suggests the *Zabrachia* sp. may function in a similar manner.

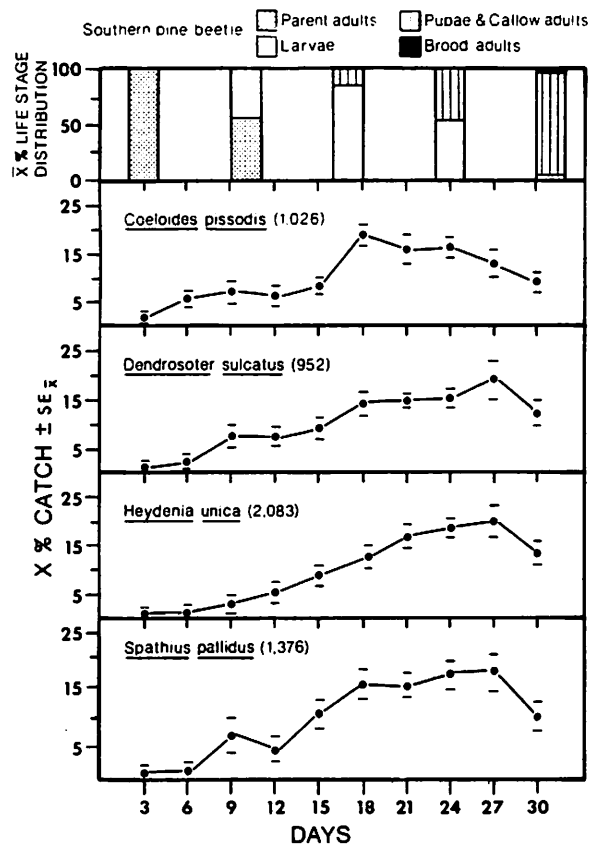


Figure 24. Sequence of arrival of *C. pissodis, D. sulcatus, H. unica,* and *S. pallidus* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

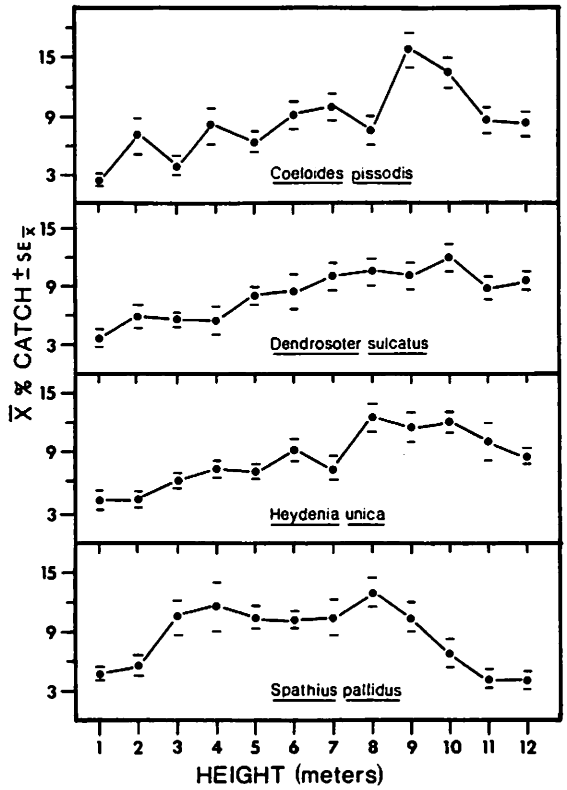


Figure 25. Height distribution of *C. pissodis, D. sulcatus, H. unica,* and *S. pallidus* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

Parasites

Hymenoptera: Braconidae and Pteromalidae

In this investigation, several hymenopterous parasites were attracted to the bark beetle-infested trees and, with a few minor differences, were found to exhibit similar aggregation and spatial distribution.

Peak catch of *Coeloides pissodis* Ashmead (Braconidae) was during days 16-18, a period when larval southern pine beetles were most abundant (Figure 24). *Heydenia unica* Cook and Davis (Pteromalidae), *Dendrosoter sulcatus* Ashmead, and *Spathius pallidus* Ashmead (Braconidae) were trapped in greatest numbers when late larval and pupal bark beetles were abundant. Similar results were reported by Berisford et al. (1971) on the earlier arrival of *C. pissodis* on bark beetle-infested trees in comparison to other scolytid parasites.

The total male:female ratios for the parasites trapped were 1:3.19 (*C. pissodis*), 1:85.50 (*D. sulcatus*), 1:85.00 (*S. pallidus*), and 1:21.16 (*H. unica*). It was also found that males, although distinctly trapped in lesser numbers, increased in numbers shortly before peak trap catch of each parasite. The male:female ratios were 1:1.83 for *C. pissodis*, 1:74.28 for *D. sulcatus*, 1:71.00 for *S. pallidus*, and 1:15.25 for *H. unica* when based on trap catches ca. 1 week before peak arrival occurred. Camors and Payne (1973) reported sex ratios of 1:9.05, only females, 1:617.00, and 1:385.00 for the four parasites respectively.

C. pissodis, D. sulcatus, and *H. unica* were trapped in greatest numbers on the upper half of the tree bole while *S. pallidus* was most abundant at mid-bole (Figure 25). Several reports have suggested that bark thickness may determine the distribution of parasites (Ryan and Rudinsky, 1962; Ashraf and Berryman, 1969) in that bark beetle parasites typically drill through the bark and deposit their eggs in or next to the immature hosts; thus, parasitism in thick-barked regions would be restricted to bark crevices. In this investigation, the apparent capability of the parasites to utilize bark crevices rather than being restricted to the higher, thin-barked regions, due to relatively short ovipositors, may have accounted for the large numbers trapped on the lower bole of the beetle-infested trees.

Eurytomidae and Torymidae

The remaining, most commonly trapped scolytid parasites were *Cecidostiba dendroctoni* Ashmead and *Rhopalicus pulchripennis* (Crawford) (Pteromalidae), a *Eurytoma* sp. (Eurytomidae), and *Roptrocerus eccoptogastri* (Torymidae). All four parasites were trapped in greatest numbers during the late larval and pupal stages of the southern pine beetle (Figure 26). Female parasites predominated as with the previously discussed parasites. The total male:female ratios were 1:60.33 (*C. dendroctoni*), all females (*Eurytoma* sp.), all females (*R. pulchripennis*), and 1:2.84 (*R. eccoptogastri*). Male *C. dendroctoni* were most abundant (1:43.50)

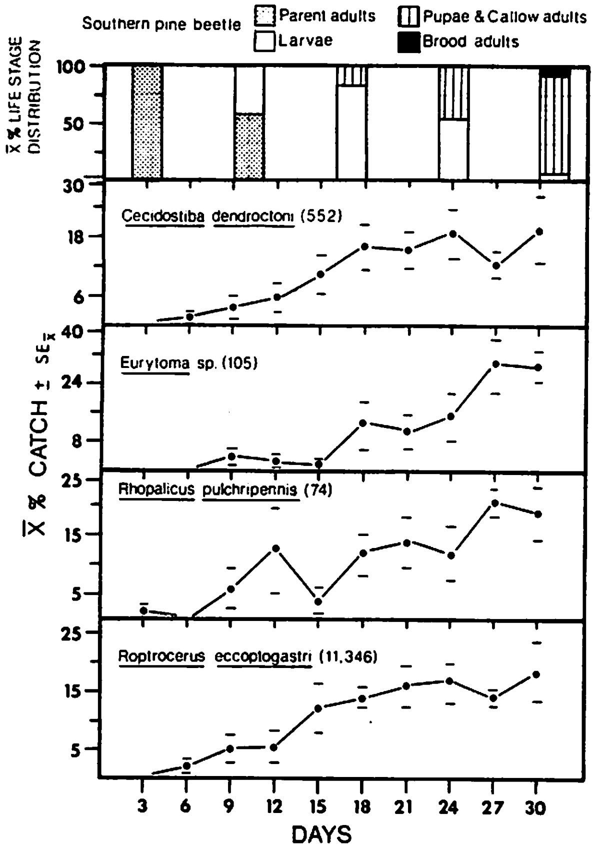


Figure 26. Sequence of arrival of *C. dendroctoni, Eurytoma* sp., *R. pulchripennis*, and *R. eccoptogastri* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

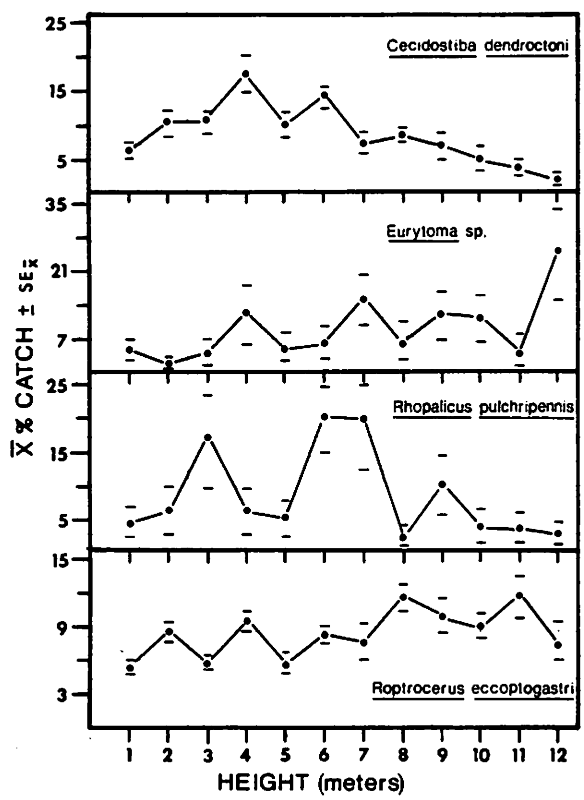


Figure 27. Height distribution of *C. dendroctoni, Eurytoma* sp., *R. pulchripennis*, and *R. eccoptogastri* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

during peak arrival rather than shortly before. Female *R. eccoptogastri* were predominant during days 1-15 (1:37.75); thereafter, males increased until on days 28-30 they were predominant (1:0.40). Camors and Payne (1973) reported only females for *C. dendroctoni* and a 1:3.66 ratio for *R. eccoptogastri*. A similar switching of male and female abundancy of *R. eccoptogastri* during arrival on bark beetle-infested trees was also noted by Camors and Payne (1973).

C. dendroctoni and *R. pulchripennis* were most abundant at mid-bole as was the *Eurytoma* sp., except for a sudden increase in trap catch on the 12m trap (Figure 27). Again, utilization of bark crevices to get sufficiently close to host bark beetles may have accounted for the considerable numbers trapped on the thick-barked regions. *R. eccoptogastri* was not so limited by bark crevice utilization, in that it enters bark beetle galleries to parasitize its hosts. *R. eccoptogastri* were caught on all traps but there was a slight increase on the upper traps.

Associates

Coleoptera: Nitidulidae

Colopterus niger (Say) and *C. unicolor* (Say) (Coleoptera: Nitidulidae) were attracted to the bark beetle-infested trees. The *Colopterus* spp. exhibited similar spatial distributions but were distinctly different in their sequence of arrival (Figures 28 and 29).

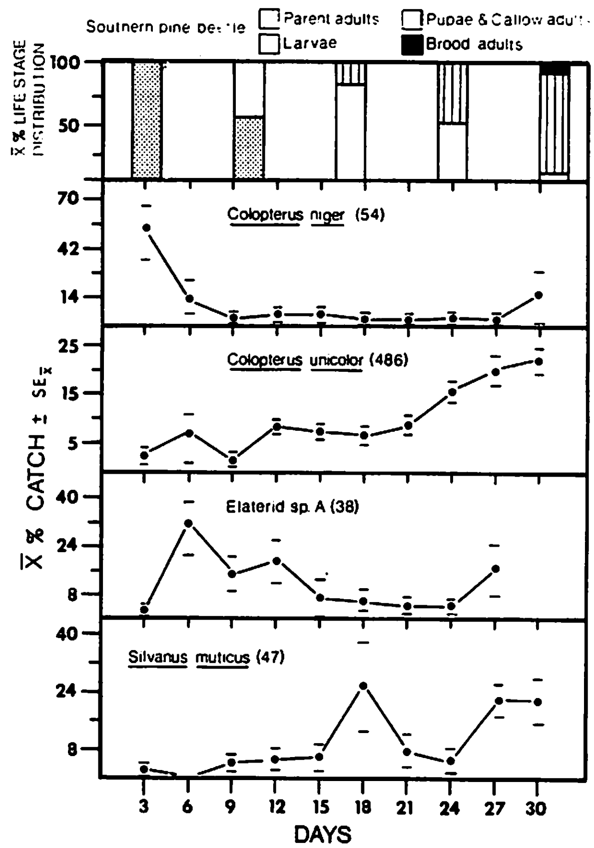


Figure 28. Sequence of arrival of *C. niger, C. unicolor*, Elaterid sp. (A), and *S. muticus* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

Peak catch of C. *niger* was during days 1-6, while C. *unicolor* was trapped in greater numbers during days 22-30. The 1m-5m traps accounted for the greatest numbers of both nitidulids. Nitidulids typically live under bark, as well as other habitats, feeding on fermenting juices and sap (Hatch, 1962; Arnett, 1973).

Elateridae

Several elaterid beetles were caught on the sticky traps of bark beetle-infested trees. Peak arrival of an unidentified elaterid sp. (A) was during the 4-12 day interval and again 12 days later (Figure 28). It was trapped predominantly on the upper half of the tree boles (Figure 29). Overgaard (1968) reported that two elaterid species, which were also trapped in this investigation but at very low numbers, were probable bark beetle predators, although a scavenger nature is more likely. Elaterid sp. (A) and the other click beetles identified in this investigation may function in a similar manner.

Cucujidae

One of the six cucujids trapped was *Silvanus muticus* Sharp. The cucujid was trapped in greatest numbers during the latter 15 days, a period when immature bark beetles were prevalent (Figure 28). Spatially, S. *muticus* was most abundant on the 1m-3m traps, 6m-7m traps, and 10m-11m traps, and none were caught on the 4m and 9m traps (Figure 29). Other identified cucujid species (Appendix Table) were reported as parasites of cerambycids and braconids or predators of woodborers and bark beetles (Chamberlin, 1939; Moser et al., 1971; Arnett, 1973).

Cerambycidae

Acanthocinus obsoletus Oliv. (Coleoptera: Cerambycidae) was trapped in greatest numbers after the cessation of southern pine beetle mass attack and was trapped predominantly at lower to mid-bole (Figures 30 and 31). Recently killed trees were found to be the most suitable hosts for the cerambycid (Baker, 1972).

Curculionidae

Cossonus corticola Say (Coleoptera: Curculionidae), a scavenger under the bark of bark beetle-killed trees (Baker, 1972), was not trapped during the first 3 days, but thereafter it was caught in increasing numbers (Figure 30). Spatially, the curculionid was most abundant on the lower half of the tree bole with the 3m trap catching the greatest number (Figure 31).

Anobiidae

Petalium spp. (Coleoptera: Anobiidae) typically live in the bark or corky tissues of pines and hardwoods (Ford, 1973). Although no arrival peak was apparent (Figure 30), P. *bistriatum* (Say) was trapped in greater numbers (66) on the bark beetle-infested trees compared to the control trees (8) which suggests dead and dying pines provide optimal habitat. The 6m-12m traps caught the majority of the arriving anobiids (Figure 31).

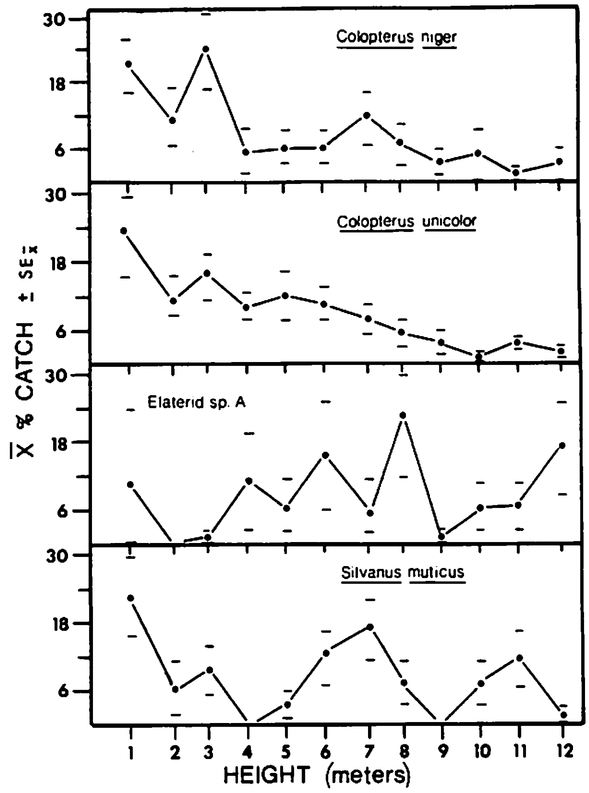


Figure 29. Height distribution of *C. niger*, *C. unicolor*, Elaterid sp. (A), and *S. muticus* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

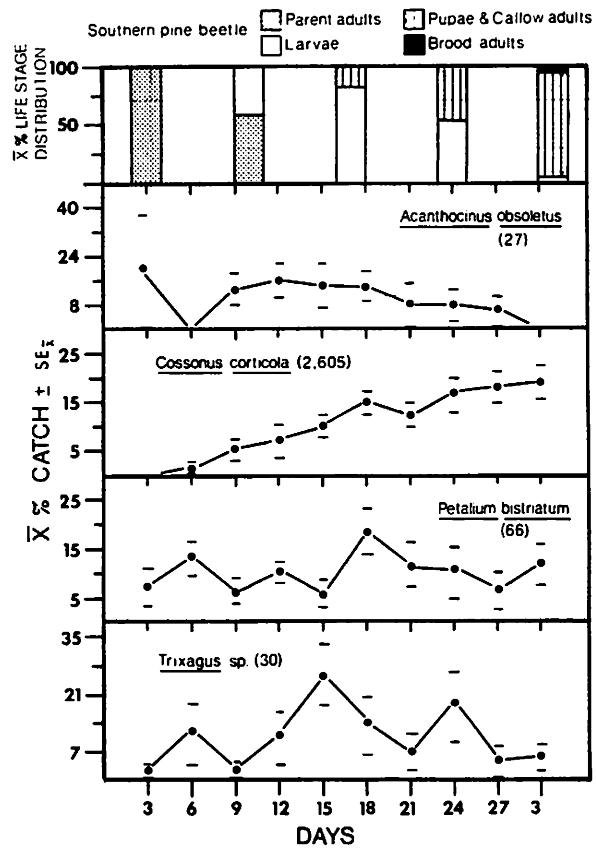


Figure 30. Sequence of arrival of *A. obsoletus*, *C. corticola*, *P. bistriatum*, and *Trixagus* sp. to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

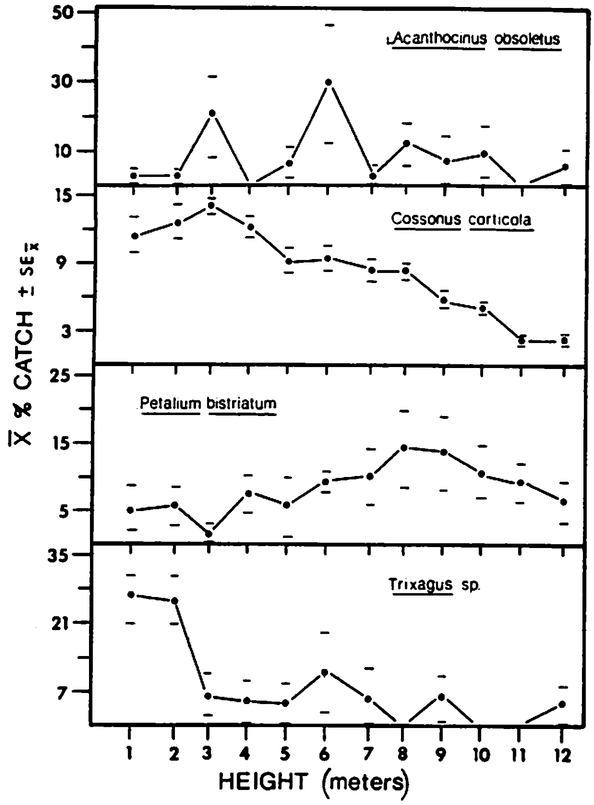


Figure 31. Height distribution of *A. obsoletus, C. corticola, P. bistriatum*, and *Trixagus* sp. on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

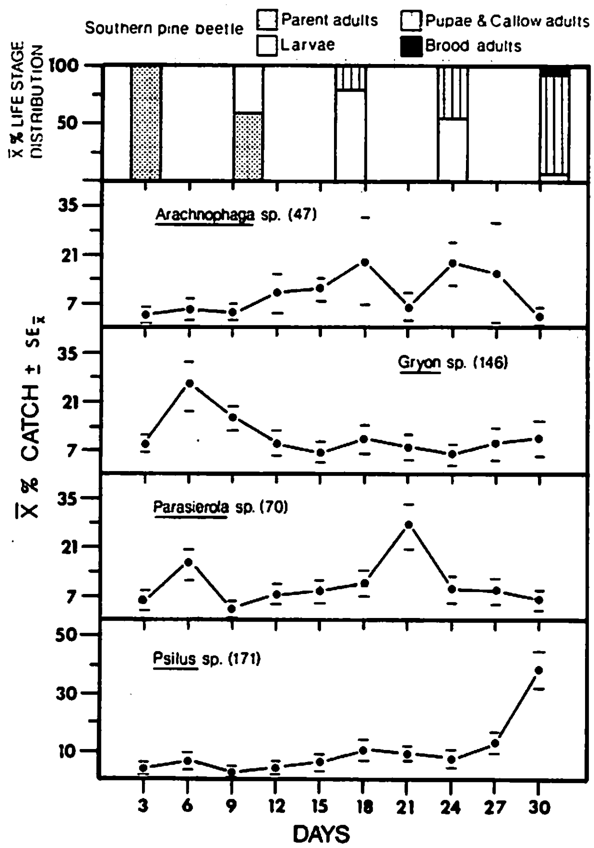


Figure 32. Sequence of arrival of *Arachnophaga* sp., *Gyron* sp., *Parasierola* sp., and *Psilus* sp. to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

Throscidae

Peak catch of a *Trixagus* sp. (Coleoptera: Throscidae) was during the day 13-24 interval, a period when immature bark beetles predominated (Figure 30). Spatially, greatest trap catch for the throscid was on the 1m and 2m traps (Figure 31). Generally, throscids live in soil litter and under the bark of dead and dying trees (Yensen, 1975). The larvae are probably carnivorous (Arnett, 1973).

Hymenoptera: Eupelmidae

In this investigation, an undescribed *Arachnophaga* sp. (Hymenoptera: Eupelmidae)[3] was found to be attracted to the bark beetle-infested trees. The eupelmid was most abundant during the day 16-27 interval (Figure 32). Known hosts of other *Arachnophaga* spp. include braconids, several lepidopteran families, and chrysopids (Allen, 1962; Muesebeck et al., 1951).

Scelionidae, Bethyliidae, Diapriidae

Other hymenopterans found to be attracted to bark beetle-infested trees were *Gyron* (Scelionidae), *Parasierola* (Bethyliidae), and *Psilus* (Diapriidae) species. Peak arrival of the scelionid was during the first 9 days of bark beetle infestation (Figure 32). Spatially, it was most abundant at mid- to upper bole (Figure 33). Hosts that have been recorded for *Gyron* spp. were predominantly hemipterans (Muesebeck

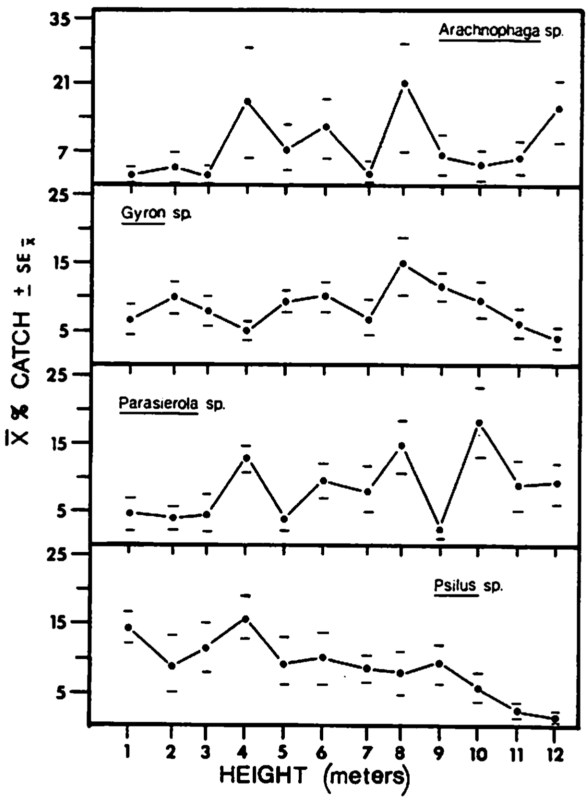


Figure 33. Height distribution of *Arachnophaga* sp., *Gyron* sp., *Parasierola* sp., and *Psilus* sp. on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

[3]Gordh, G. Personal Communication.

et al., 1951). The *Parasierola* sp. arrived in peak numbers during the day 4-6 interval and again during days 19-21. Trap catch of the bethyliid was greatest on the upper half of the tree bole. *Parasierola* spp. parasitize immature Diptera, Lepidoptera, and Coleoptera (Clausen, 1972). The *Psilus* sp. was trapped predominantly during the day 27-30 interval and was most abundant on the lower half of the tree bole. Generally, immature Diptera are hosts of diapriids

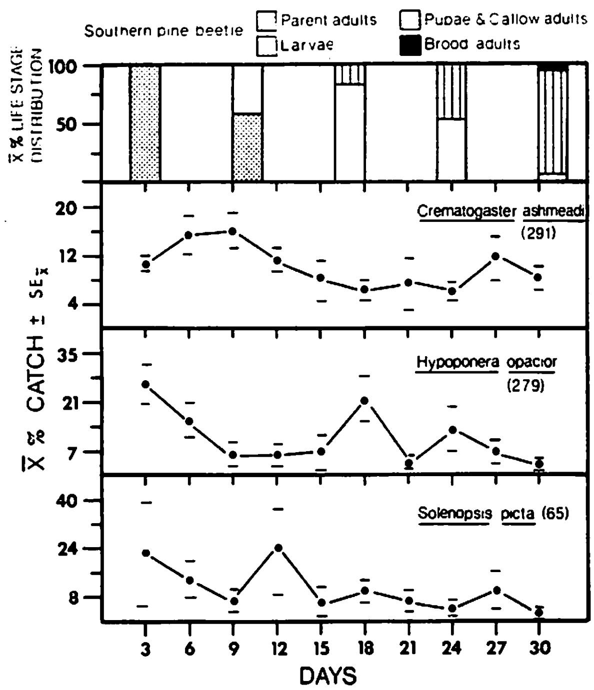


Figure 34. Sequence of arrival of *C. ashmeadi, H. opacior,* and *S. picta* to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

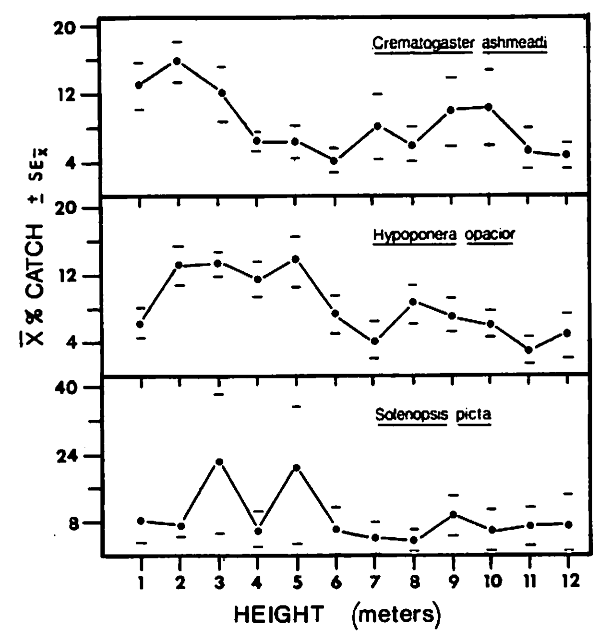


Figure 35. Height distribution of *C. ashmeadi, H. opacior,* and *S. picta* on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

(Clausen, 1972). In addition, a *Psilus* sp. was reported parasitic on a lonchaeid fly (Bedard, 1938).

Formicidae

Several ant species (Hymenoptera: Formicidae) were commonly associated with the monitored trees. Most abundant were *Crematogaster ashmeadi* Mayer, *Hypoponera opacior* (Forel), and *Solenopsis picta* Emery. Chamberlin (1939) observed that ants were probably the only predaceous Hymenoptera of importance so far as bark beetles were concerned. One of the most efficient groups of predaceous ants is the genus *Solenopsis* (Clausen, 1972). In this investigation, *S. picta* was most abundant during the day 1-12 interval, a period when southern pine beetle adults predominated (Figure 34). Similarly, *C. ashmeadi* and *H. opacior* were trapped in the greatest numbers during this period, although trap catch of *H. opacior* increased again during days 18-24. All three formicids were predominantly trapped from lower to mid-bole (Figure 35).

Chrysididae

Peak catch of a *Ceratochrysis* sp. (Hymenoptera: Chrysididae) was during the first 9 days of trapping (Figure 36) and was most abundant on the lower to mid-bole traps (Figure 37). Overgaard (1968) reported a chrysidid was commonly associated with the southern pine beetle-attacked trees. Chrysidids typically parasitize vespoid and sphecoid Hymenoptera (Clausen, 1972).

Platygasteridae

A *Platygaster* sp. and *Leptacis* sp. (Hymenoptera: Platygasteridae) were trapped on the bark beetle-infested trees. The two parasites, although distributed similarly on the tree boles, differed in their sequence of arrivals (Figures 36 and 37). The first was trapped predominantly during the day 7-15 interval, while peak catch for the latter was on days 25-30. Both parasites were trapped in greatest numbers on the upper six traps. *Leptacis* spp. parasitize larval cecidomyiids but nymphal Hemiptera are hosts of *Platygaster* spp. (Askew, 1971).

Sphecidae

Peak arrival of a *Nitela* sp. (Hymenoptera: Sphecidae) was during the last 15 days of trapping (Figure 36). Most of the wasps were trapped on the lower tree bole (Figure 37). Members of Nitelini typically provision their nests with small Hemiptera or spiders (Borror and Delong, 1973). Generally, these wasps construct burrows in trees, although they often construct their nests in the deserted galleries of woodboring insects (Pate, 1934).

Braconidae and Ichneumonidae

Peak catch of *Atanycolus ulmicola* (Hymenoptera: Braconidae) was during days 25-30 (Figure 38). Spatially, the parasite appeared to be trapped primarily at mid-bole (Figure 39). The total male:female ratio was 1:2.21. However, the parasite was trapped in greatest numbers on nearby control trees (125 versus 48 on the infested trees), and these

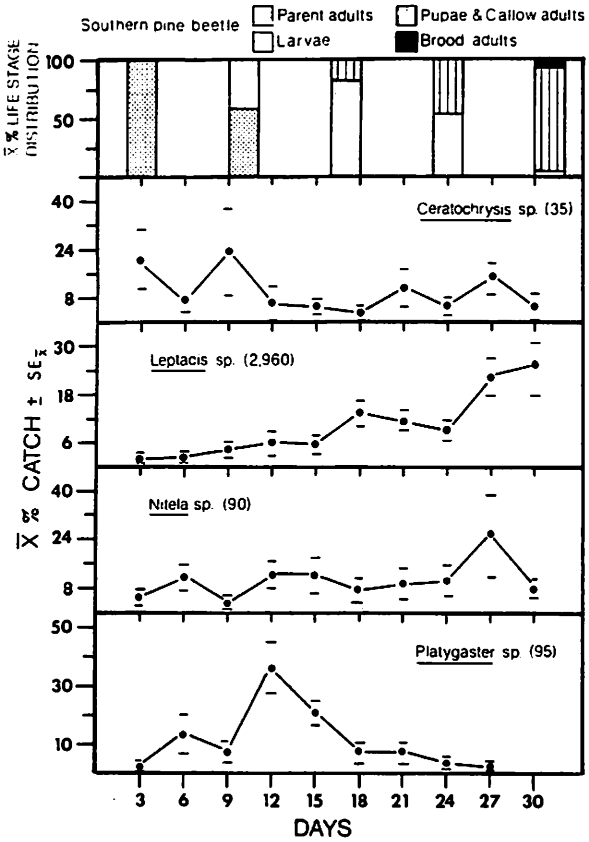


Figure 36. Sequence of arrival of *Ceratochrysis* sp., *Leptacis* sp., *Nitela* sp., and *Platygaster* sp. to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

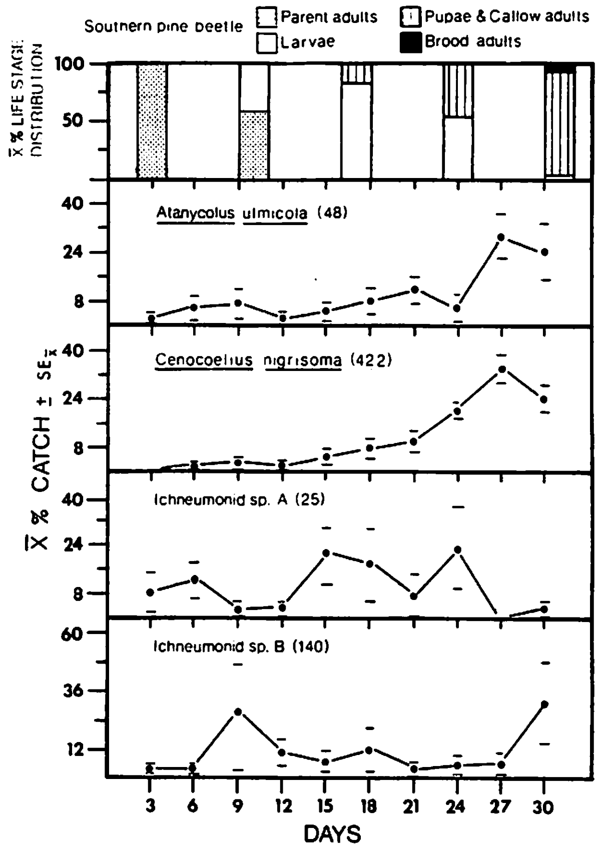


Figure 38. Sequence of arrival of *A. ulmicola, C. nigrisoma,* Ichneumonid sp. (A), and Ichneumonid sp. (B) to bark beetle-infested trees during southern pine beetle development. Total number trapped on 7 trees ( ).

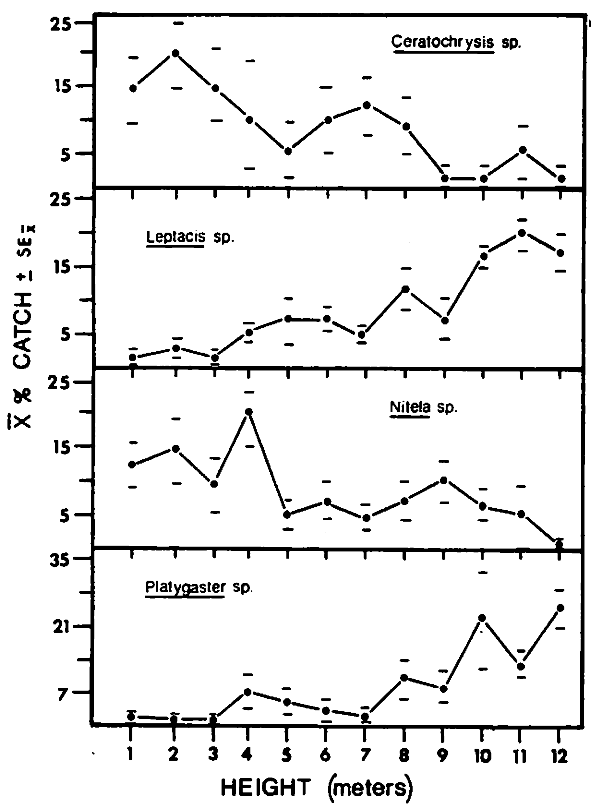


Figure 37. Height distribution of *Ceratochrysis* sp., *Leptacis* sp., *Nitela* sp., and *Platygaster* sp. on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

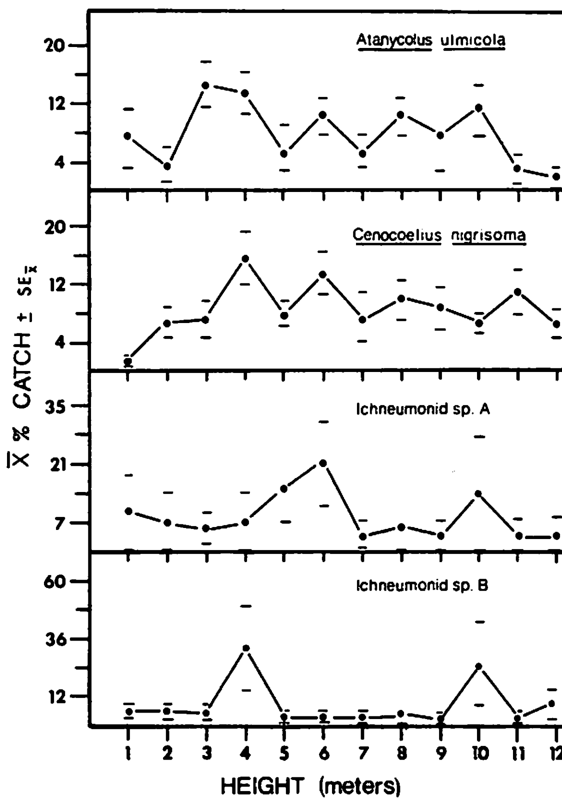


Figure 39. Height distribution of *A. ulmicola, C. nigrisoma,* Ichneumonid sp. (A), and Ichneumonid sp. (B) on bark beetle-infested trees during southern pine beetle development. Data from 7 trees.

were predominantly males (1:0.07). *Atanycolus* spp. parasitize cerambycids and buprestids usually, although some scolytids serve as hosts (Bushing, 1965).

Two unidentified ichneumonid spp. (A & B) and *Cenocoelius nigrisoma* (Rohwer) (Braconidae) were also trapped on the bark beetle-infested trees (Figures 38 and 39). *C. nigrisoma* was most abundant during the day 22-30 interval, and greatest trap catch was at mid-bole. Peak arrival of ichneumonid (A) was during the 13-25 day period, while ichneumonid (B) was most abundant after day 7. Both ichneumonids were caught in peak numbers on the 4m-6m and 10m traps. Braconids and ichneumonids exhibit a wide host range including Lepidoptera, Coleoptera, and Hymenoptera (Clausen, 1972).

Control Trees

The importance of recognizing the dynamic community structure of a bark beetle-infested tree is emphasized by the control tree trap catches. Species diversity of bark beetle-infested trees was >2.6 × that of the control trees. Average total catch of species *n* per control tree was ca. 20 percent of the bark beetle-infested tree. Overall, ca. 81 percent of the species were caught on control trees at levels ≤0.10 the beetle-infested tree numbers (Table 1).

Most of the species utilize resources under tree bark as immature and mature life stages which suggests that control tree trap catches were indicative of adult insects searching for potential hosts-habitats. Further research is necessary to clarify the role trees uninfested by the southern pine beetle may have in the distribution of associate insects.

CONCLUSION

The sequence of arrival and spatial distribution of insects attracted to trees infested initially by the southern pine beetle were monitored for a period of 30 days. Total number of species was large (>150), and thus the potential of a multitude of temporal and spatial patterns existed; however, this was not found to be the case. Overall, several trends were evident for the sequence of arrivals and spatial distributions of the many insects attracted to bark beetle-infested trees (Figures 40 and 41).

Temporal Patterns

Predaceous insects aggregated on the trees during one of two intervals. Adult predators commonly associated with the southern pine beetle (e.g., *T. dubius*, *Medetera* spp., and *S. mississippensis*) arrived during the first 15 days, the period of peak adult southern pine beetle abundancy. Other predators, preying on immature bark beetles and other prey, aggregated primarily during days 15-30, the second interval. Many of these insects are small and of an elongated cylindrical or flattened body shape and are thus well suited for entering and foraging within

TABLE 1. RELATIONSHIP OF INSECT SPECIES AND NUMBERS CAUGHT ON CONTROL TREE STICKY TRAPS TO INSECTAN CATCHES ON BARK BEETLE-INFESTED TREES[1]

HEMIPTERA

Factor[2]	Species
0.41	*Lyctocoris elongatus*
.09	*Scolopscelis mississippensis*

COLEOPTERA

Factor	Species
.09	*Aulonium ferrugineum*
.01	*A. tuberculatum*
.52	*Colopterus niger*
.02	*C. unicolor*
.12	*Colydium nigripenne*
.01	*Corticeus glaber*
.09	*Cossonus corticola*
.01	*Crypturgus aluctaceus*
.11	*Cylistix attenuata*
.02	*C. cylindrica*
.01	*Dendroctonus frontalis*
.19	*Gnathotrichus materiarius*
.25	*Hylastes tenuis*
.24	*Hypothenemus (pubescens)*
.06	*Ips avulsus*
2.65	*I. calligraphus*
.01	*I. grandicollis*
.04	*Lasconotus pusillus*
.08	*L. referendarius*

DIPTERA

Factor	Species
0.10	*Medetera* spp.
.02	*Zabrachia* sp.

COLEOPTERA

Factor	Species
.20	*Leptacinus paurumpunctatus*
.01	*Molamba* sp.
.35	*Petalium bistriata*
.25	*Pityophthorus annectans*
.32	*P. bisulcatus*
.02	*Platypus flavicornis*
.10	*Platysoma parallelum*
.01	*Plegaderus* spp.
.22	*Priocera castaneum*
.26	*Temnochila virescens*
.20	*Tenebroides collaris*
.21	*T. marginatus*
.02	*Thanasimus dubius*
.50	*Triplex festiva*
.30	*Trixagus* sp.
.16	*Xyleborus ferrugineus*
.34	*X. pini*
.36	*X. saxeseni*

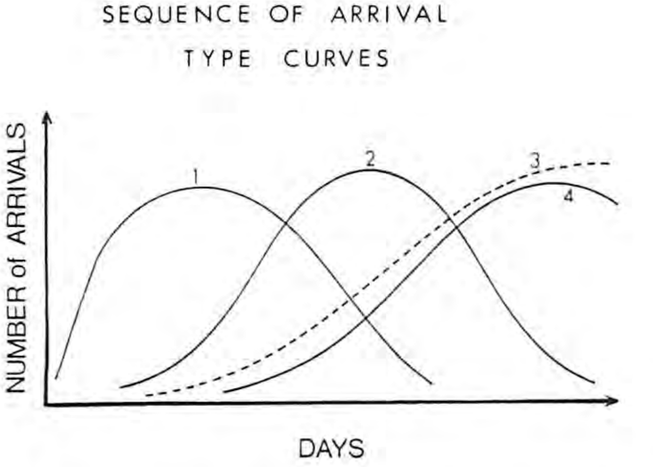
HYMENOPTERA

Factor	Species
0.98	*Atanycolus ulmicola*
.01	*Cecidostiba dendroctoni*
.06	*Ceratochrysis* sp.
.36	*Coeloides pissodis*
.06	*Crematogaster ashmeadi*
.09	*Dendrosoter sulcatus*
.07	*Eurytoma* sp.
.18	*Heydenia unica*
.10	*Hypoponera opacior*
.08	*Leptacis* sp.
.33	*Lutnes* sp.
.29	*Nitela* sp.
.05	*Platygaster* sp.
.51	*Psilus* sp.
.03	*Roptrocerus eccoptogastri*
.14	*Solenopsis picta*
.01	*Spathius pallidus*

Total No. spp. = 58
$\overline{X}$ FACTOR = 0.21

[1]Control trees (n = 5) were not bark beetle-infested.

[2]$\dfrac{\overline{X}\text{ No. of a species/control tree}}{\overline{X}\text{ No. of a species/bark beetle-infested tree}}$ = factor value.



CURVE	REPRESENTATIVES
1	*Dendroctonus frontalis, Thanasimus dubius, Medetera spp.*
2	*Ips spp., Lonchae sp., Coeloides pissodis, Hister sp.*
3	*Zabrachia sp., Colopterus unicolor, Plegaderus spp.*
4	*Dendrosoter sulcatus, Heydenia unica, Lasconotus spp*

Figure 40. General sequence of arrival patterns of insects aggregating on southern pine beetle-infested trees.

bark beetle or woodborer galleries. Representative types would include *Plegaderus* spp., *Aulonium* spp., *Lasconotus* spp., and *Dirhagus* spp. It is during this time period when bark beetle galleries are quite extensive that the food and habitat requirements should be at optimal levels.

Parasitic insects aggregated on the bark beetle-infested trees when appropriate life stages of their respective hosts were most abundant. Peak arrival of southern pine beetle parasites (e.g., *C. pissodis, H. unica,* and *S. pallidus*) coincided with optimum numbers of larval and pupal bark beetles within the trees. Several parasites were trapped during the first 10 days of bark beetle infestation which suggests that beetle pheromones and host tree volatiles, in conjunction with other environmental stimuli, may serve to initially aggregate the parasites on appropriate host-infested trees. Such a system may also operate as well for the predaceous species. Overall, parasites arrived on the trees either 1) during the first 2 weeks and thereafter in decreasing numbers, or 2) initially in low numbers with a substantial increase during the last 2 weeks.

Insects that utilized the same food source as the southern pine beetle (e.g., *Ips* spp., *Acanthocinus* sp.) arrived shortly after mass attack by the beetle. Nutritional quality of the food supply and its availability would appear to be important in the arrival time of these associates, especially since the southern pine beetle was the most abundant co-competitor for the limited food source and was the first species to occupy feeding sites along the tree bole.

Scavengers and fungus feeders (e.g., *Xyleborus* spp., *C. cossonus,* and *C. unicolor*) aggregated on the trees during the last 10 days. Many were caught in still increasing numbers at termination of tree monitoring. Tens of insect species actively occupied and utilized tree resources during the first 20 days, thus presumably a period of increasing degradation of the tree. Odors associated with tree decay may have attracted the scavengers and fungus feeders.

The sequence of arrival of associate insects to southern pine beetle-infested trees was very similar to that reported for the associates of mountain pine[4] and western pine beetles. Stephen and Dahlsten (1976b) characterized the general progression of arrival to trees attacked initially by the western pine beetle. First associates were those predaceous on the adult bark beetles. Next to arrive were scavengers, woodborers, fungus feeders, and more general predators. Parasites of primary and secondary invaders increased in numbers as the various host broods developed into suitable life stages. A succeeding wave of associates, as it can be likened, included additional scavengers, woodborers, and predators.

Species common to both studies were few (e.g., *H. unica, R. eccoptogastri,* and *C. lineola*). The number of genera common to both studies (n=42) was considerably greater. In both studies, the patterns of arrival of the genera trapped were similar on a relative time scale comparison. This is to be expected if general requirements such as food and habitat are kept in mind.

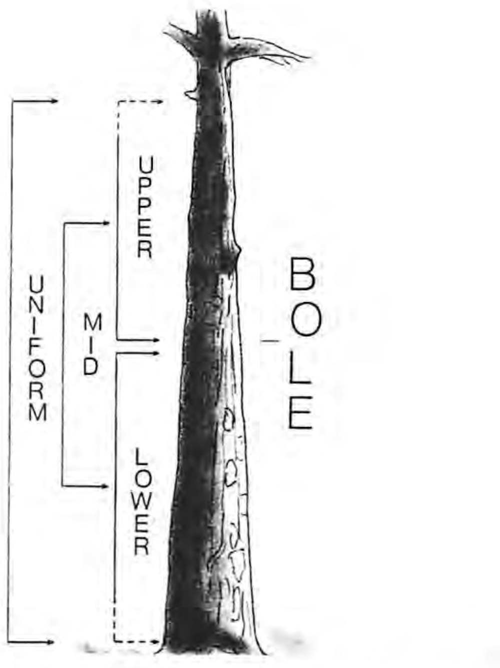


Figure 41. General spatial distributions of insect associates aggregating on southern pine beetle-infested trees.

[4]Edson, L. J. 1978. Host colonization and the arrival sequence of the mountain pine beetle and its insectan associates. Ph.D. Dissertation. University of California, Berkeley.

Spatial Patterns

Spatial distributions of associate insects arriving on bark beetle-infested trees are characterized by four patterns: 1) lower bole, 2) mid-bole 3) upper bole, and 4) uniform. Ambrosia beetles (e.g., *Xyleborus* spp., *P. flavicornis*) were trapped on the lower bole, an area advantageous for fungus gardens due to proximity of root systems and soil water. Parasites (e.g., *C. pissodis, D. sulcatus*) were most abundant at upper bole. Others aggregated at mid-bole (e.g., *S. pallidus, C. dendroctoni*). Bark characteristics and host abundance, as well as other factors, may bear on these distributions, particularly in that at the upper bole several host ranges overlap (e.g., southern pine beetles and *Ips* spp.). Predators appeared to congregate in a similar manner as the parasites, i.e., preferred prey abundance and habitat requirements may have affected their spatial distribution. Various species dominated at the lower bole (e.g., *C. cylindrica*), mid-bole (e.g., *T. virescens*), upper bole (e.g., *A. ferrugineum*), and uniformly (e.g., *P. parallelum*).

The colonization of a southern pine tree by southern pine beetles initiates a dynamic interaction of associate insects and tree resources in a remarkably short period of time. In less than 30 days after the first southern pine beetle landed on a tree, over 150 species of insects were also intimately involved in the utilization and ultimate degradation of the resources of the tree and its inhabitants (Figure 42). The complexity of this ecosystem is worthy of future in-depth investigation.

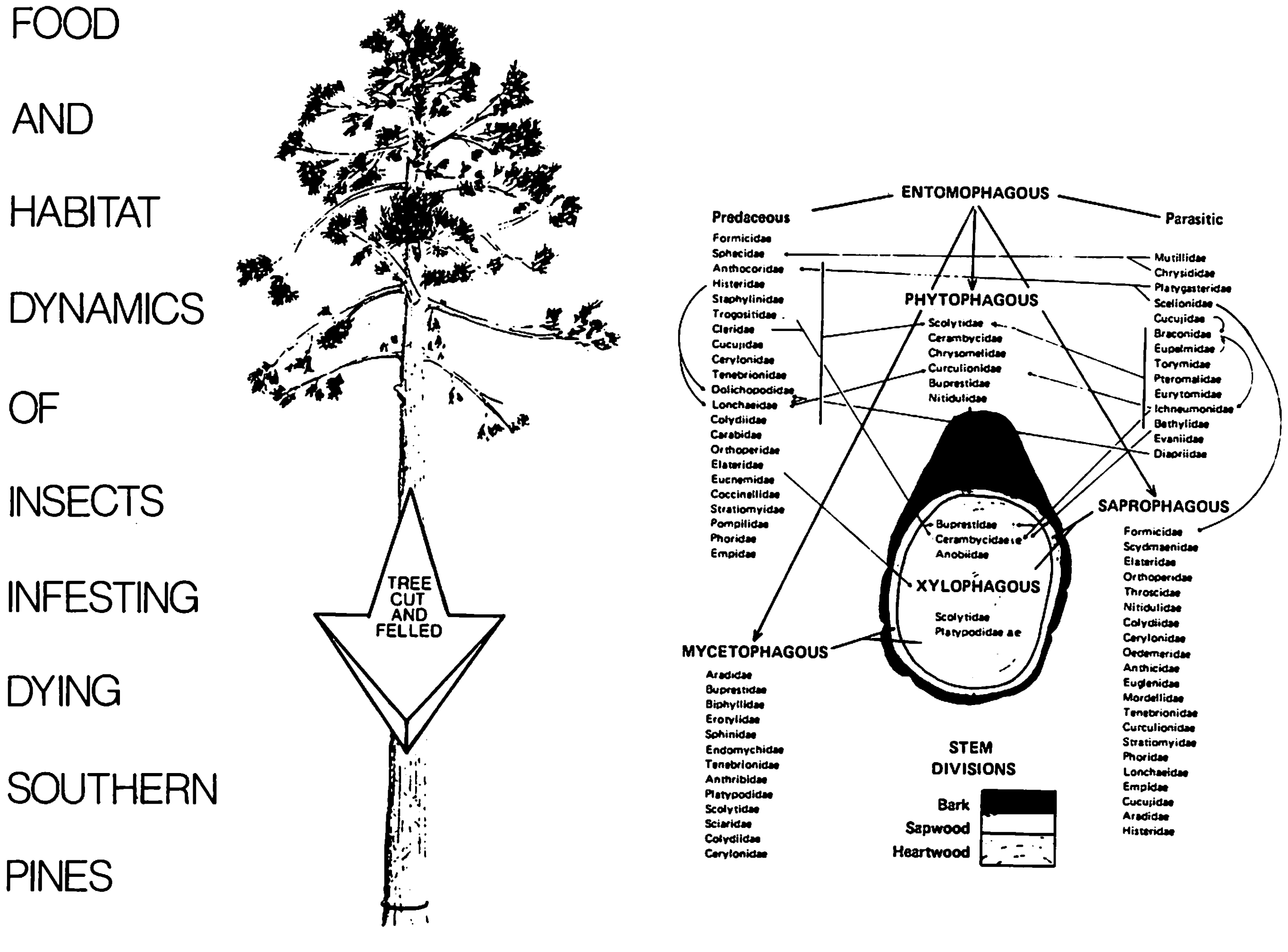


Figure 42. Interrelationship of food and habitat requirements of insects attracted to bark beetle-infested trees. Hosts as indicated in literature; others specified only as entomophagous on other arthropods.

REFERENCES CITED

Allen, H. W. 1962. Parasites of the oriental fruit moth in the eastern U. S. USDA Tech. Bull. 1265.

Anonymous. 1978. Texas Forest Pest 1976-1977 and Forest Pest Control Section Biennial Report. Texas Forest Service Pub. 117.

Arnett, R. H. 1973. The Beetles of the United States. Ann Arbor, Michigan: Amer. Entomol. Inst.

Ashraf, H. and A. A. Berryman. 1969. Biology of *Scolytus ventralis* (Coleoptera: Scolytidae) attacking *Abies grandis* in northern Idaho. Melandria 2:1-23.

Askew, R. R. 1971. Parasitic Insects. New York: American Elsevier Publ. Co., Inc.

Baker, W. L. 1972. Eastern forest insects. USDA-FS Miscellaneous Pub. 1175.

Balduf, W. V. 1935. The Bionomics of Entomophagous Coleoptera. New York: J. S. Swift and Co., Inc.

Bedard, W. D. 1938. An annotated list of the insect fauna of Douglas fir (*Pseudotsuga micronota* Rafinsque) in the northern Rocky Mountain Region. Can. Entomol. 70:188-197.

Berisford, C. W. 1969. Attack sequence of *Ips grandicollis* (Coleoptera: Scolytidae) and some associated hymenopterous parasites. J. Ga. Entomol. Soc. 4:93-96.

Berisford, C. W. and R. T. Franklin. 1971. Attack patterns of *Ips avulsus* and *Ips grandicollis* (Coleoptera: Scolytidae) on four species of southern pines. Ann. Entomol. Soc. Amer. 64:894-897.

Berisford, C. W., H. M. Kulman, R. L. Pienkowski and H. J. Heikkenen. 1971. Factors affecting distribution and abundance of hymenopterous parasites of spp. bark beetles in Virginia (Coleoptera: Scolytidae). Can. Entomol. 103:235-239.

Birch, M. C. and P. Svihra. 1979. Exploiting olfactory interactions between species of Scolytidae. In Current Topics in Forest Entomology, W. E. Waters (ed.). Selected Papers from the XVth International Congress of Entomology, Wash. DC, Aug., 1976. 135-138 pp.

Borror, D. J. and D. M. DeLong. 1973. An Introduction to the Study of Insects. 3rd ed. New York: Holt, Rinehart and Winston Publ. Co.

Bright, D. W., Jr. 1968. Review of the tribe Xyleborini in America north of Mexico (Coleoptera: Scolytidae). Can. Entomol. 100:1288-1323.

Bushing, R. W. 1965. A synoptic list of the parasites of Scolytidae (Coleoptera) in North America north of Mexico. Can. Entomol. 97:449-492.

Byrne, K. J., A. A. Swigar, R. M. Silverstein, J. H. Borden, and E. Stokkink. 1974. Sulcatol: Population aggregation pheromone in the scolytid beetle, *Gnathotrichus sulcatus*. J. Insect Physiol. 20:1895-1900.

Camors, F. B., Jr. and T. L. Payne. 1973. Sequence of arrival of entomophagous insects to trees infested with the southern pine beetle. Environ. Entomol. 2:267-270.

Chamberlin, W. J. 1939. The Bark and Timber Beetles of North America. Corvallis, Oregon: OSC Cooperative Association.

Clausen, C. P. 1972. Entomophagous Insects. New York: Hafner Publ. Co.

Coster, J. E. 1969. Observations on *Platypus flavicornis* (Coleoptera: Platypodidae) in southern pine beetle infestations. Ann. Entomol. Soc. Amer. 62:100-111.

Coster, J. E. 1977. Towards integrated protection from the southern pine beetle. J. Forestry 75:481-484.

Coster, J. E., T. L. Payne, E. R. Hart, and L. J. Edson. 1977. Aggregation of the southern pine beetle in response to attractive host trees. Environ. Entomol. 6:725-731.

Coulson, R. N., T. L. Payne, J. E. Coster, and M. W. Houseweart. 1972. The southern pine beetle, *Dendroctonus frontalis* Zimm. (Coleoptera: Scolytidae), 1961-1971. Texas Forest Service Pub. 108.

Coulson, R. N., F. P. Hain, J. L. Foltz, and A. M. Mayyasi. 1975. Techniques for sampling the dynamics of southern pine beetle populations. Texas Agricultural Experiment Station Misc. Pub. 1185.

Craighead, F. C. 1950. Insect enemies of eastern forests. USDA Misc. Pub. 657.

DeLeon, D. 1935. The biology of *Coeloides dendroctoni* Cushman (Hymenoptera: Braconidae) an important parasite of the mountain pine beetle (*Dendroctonus monticolae* Hopk.). Ann. Entomol. Soc. Amer. 38:423-441.

Deyrup, M. A. 1975. The Insect Community of Dead and Dying Douglas-fir. I. The Hymenoptera. Bull. 6 - Coniferous Forest Biome Ecosystem Analysis Studies. Seattle: Univ. of Wash. Press.

Dixon, J. C. and E. A. Osgood. 1961. Southern pine beetle, a review of current knowledge. USDA Forest Service Paper 128.

Dixon, W. N. and T. L. Payne. 1979. Aggregation of *Thanasimus dubius* (F.) on trees under mass attack by the southern pine beetle. Environ. Entomol. 8:178-181.

Edwards, J. C. 1949. Coleoptera or Beetles East of the Great Plains. Ann Arbor, Michigan: Edwards Brothers.

Fiske, W. F. 1908. Notes on insect enemies of wood-boring Coleoptera. Proc. Entomol. Soc. Wash. 9:23-27.

Ford, E. J. 1973. A revision of the genus *Petalium* LeConte in the United States, Greater Antilles, and the Bahamas (Coleoptera: Anobiidae). USDA Tech. Bull. 1467.

Franklin, R. T. 1969. Hymenopterous parasites of the southern pine beetle in Georgia. J. Ga. Entomol. Soc. 4:119-122.

Fronk, W. D. 1947. The southern pine beetle — its life history. Virginia Agricultural Experiment Station Tech. Bull. 108.

Hatch, M. H. 1957. The Beetles of the Pacific Northwest. Vol. 16, Part II: Staphyliniforma. Seattle: Univ. of Wash. Press.

Hatch, M. H. 1962. The Beetles of the Pacific Northwest. Vol. 16, Part III: Pselaphidae and Diversicornia I. Seattle: Univ. of Wash. Press.

Hatch, M. H. 1965. The Beetles of the Pacific Northwest. Vol. 16, Part IV: Macrodactyles, Palpicornes, and Heteroma. Seattle: Univ. of Wash. Press.

Hatch, M. H. 1971. The Beetles of the Pacific Northwest. Vol. 16, Part V: Rhypiceroidea, Sternoxi, Phytophaga, Rhynchophora, and Lamellicornia. Seattle: Univ. of Wash. Press.

Hodges, J. D. and L. S. Pickard. 1971. Lightning in the ecology of the southern pine beetle, *Dendroctonus frontalis* (Coleoptera: Scolytidae). Can. Entomol. 103:44-51.

Hopkins, A. D. 1893. Catalogue of West Virginia Scolytidae and their enemies: with a list of trees and shrubs attacked. West Virginia Agricultural Experiment Station Bull. 31:121-168.

Knull, J. N. 1951. The checkered beetles of Ohio (Coleoptera: Cleridae). Ohio Biol. Surv. Bull. 42, vol. 8, no. 2.

Krombein, K. V. 1958. Hymenoptera of America north of Mexico. Synoptic Catalogue. USDA Agr. Monogr. 2, 1st suppl.

Krombein, K. V. and B. D. Burks. 1967. Hymenoptera of America north of Mexico. Synoptic Catalogue. USDA Agr. Monogr. 2, 2nd suppl.

Leuschner, W. A., R. C. Thatcher, T. L. Payne, and P. E. Buffam. 1977. SPBRAP — An integrated research and applications program. J. Forestry 75:478-480.

Madrid, F., J. P. Vité and J. A. A. Renwick. 1972. Evidence of aggregation pheromones in the ambrosia beetle *Platypus flavicornis* (F.). Z. Angew. Entomol. 72:73-79.

Moore, G. E. 1972. Southern pine beetle mortality in North Carolina caused by parasites and predators. Environ. Entomol. 1:58-65.

Moser, J. E., R. C. Thatcher, and L. S. Pickard. 1971. Relative abundance of southern pine beetle associates in East Texas. Ann. Entomol. Soc. Amer. 64:72-77.

Muesebeck, C. F. W., K. V. Krombein, and H. K. Townes. 1951. Hymenoptera of America north of Mexico. Synoptic Catalogue. USDA Agr. Monogr. 2.

Overgaard, N. A. 1968. Insects associated with the southern pine beetle in Texas, Louisiana, and Mississippi. J. Econ. Entomol. 61:1197-1201.

Paine, T. D., M. C. Birch, and P. Svihra. 1979. Niche breadth and resource partitioning by four sympatric species of bark beetles (Coleoptera: Scolytidae). J. Chem. Ecol.. In press.

Parker, D. L. and D. W. Davis. 1971. Feeding habits of *Corticeus substriatus* (Coleoptera: Tenebrionidae) associated with the mountain pine beetle in lodgepole pine. Ann. Entomol. Soc. Amer. 64:293-294.

Pate, V. S. L. 1934. The nearctic species of *Nitela* with a description of a new species of *Solierella* (Hymenoptera: Sphecidae). Entomol. News 45:241-244.

Reid, R. W. 1957. The bark beetle complex associated with lodgepole pine slash in Alberta. Part III. Notes on biologies of several predators with special reference to *Enoclerus sphegeus* Fab. (Coleoptera: Cleridae) and two species of mites. Can. Entomol. 89:111-120.

Renwick, J. A. A., J. P. Vité, and R. F. Billings. 1977. Aggregation pheromones in the ambrosia beetle *Platypus flavicornis*. Naturwissenschaften 64:226.

Ryan, R. B. and J. A. Rudinsky. 1962. Biology and habits of the Douglas-fir beetle parasite *Coeloides brunneri* Viereck (Hymenoptera: Braconidae) in western Oregon. Can. Entomol. 94:748-763.

Schmid, J. M. 1970. *Enoclerus sphegeus* (Coleoptera: Cleridae), a predator of *Dendroctonus ponderosae* (Coleoptera: Scolytidae) in the Black Hills. Can. Entomol. 102:969-977.

Stark, R. W. 1977. Integrated pest management in forest practice. J. Forestry 75:251-254.

Stephen, F. M. and D. L. Dahlsten. 1976a. The temporal and spatial arrival pattern of *Dendroctonus brevicomis* in ponderosa pine. Can. Entomol. 108:271-282.

Stephen, F. M. and D. L. Dahlsten. 1976b. The arrival sequence of the arthropod complex following attack by *Dendroctonus brevicomis* (Coleoptera: Scolytidae) in ponderosa pine. Can. Entomol. 108:283-304.

Stone, A., C. W. Sabrosky, W. W. Wirth, R. H. Foote and J. R. Coulson. 1965. A Catalogue of the Diptera of America north of Mexico. USDA Agr. Handbk. 276.

Struble, G. R. 1942. Biology of two native coleopterous predators of the mountain pine beetle in sugar pine. Pan-Pac. Entomol. 18:96-97.

Thatcher, R. C. 1960. Bark beetles affecting southern pines: A review of current knowledge. USDA Forest Service Occasional Paper 180.

Thatcher, R. C. and L. S. Pickard. 1964. Seasonal variations in activity of the southern pine beetle in east Texas. J. Econ. Entomol. 57:840-842.

Thatcher, R. C. and L. S. Pickard. 1966. The clerid beetle, *Thanasimus dubius*, as a predator of the southern pine beetle. J. Econ. Entomol. 60:656-658.

Waters, W. E. 1974. Systems approach to managing pine bark beetles. Proc. Southern Pine Beetle Symposium, T. L. Payne, R. N. Coulson, and R. C. Thatcher, eds. 12-14 pp. Texas Agricultural Experiment Station, Texas A&M University System.

Yensen, E. 1975. A revision of the North American species of *Trixagus* Kugelan (Coleoptera: Throscidae). Trans. Am. Entomol. Soc. 101:125-166.

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IDENTIFICATION CREDIT

Identifications of the listed insect species were provided by the following specialists of the Systematic Entomology Laboratory, Insect Identification and Beneficial Insect Introduction Institute, USDA-ARS Beltsville Agricultural Research Center, Maryland: D. M. Anderson, R. H. Arnett (SEL Coop. Sci.), W. A. Connell (SEL Coop. Sci.), R. J. Gagne, G. Gordh, R. D. Gordon, J. M. Kingsolver, P. M. Marsh, A. S. Menke, D. R. Smith, T. J. Spilman, G. Stekyskal, R. White, and W. W. Wirth.

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Appendix

APPENDIX TABLE. IDENTIFIED AND TABULATED INSECT ASSOCIATES OF BARK BEETLE-INFESTED TREES

ORDER, FAMILY, SPECIES	ROLE[a]	ABUNDANCE[bc]
HEMIPTERA		
Aradidae		
Aradus sp.	Sap/fungus feeder in decaying pine	1
Anthocoridae		
Lyctocoris elongatus (Reuter)	Predator of bark beetles	1
Scolopscelis mississippensis Drake and Harris	Adults and nymphs predator of immature and mature bark beetle under bark	3
COLEOPTERA		
Carabidae		
Pinacodera limbata Dejean	Predator under bark	1
Stenolophus lineola Fab.	Predator under vegetational detritus	1
Tachyta pavicornis Notman	Predator under bark	1
Histeridae		
Abraeus sp.	Do.	1
Cylistix attenuata LeC.	Adult and larva predator of immature and mature bark beetles under bark//scavenger.	3
C. cylindrica (Paykull)	Do.	4
Hister sp.	Do.	1
Platysoma parallelum LeC.	Do.	3
Plegaderus spp. (2?)	Do.	3
Staphylinidae		
Aleocharinae sp.	Predator (parasite) of coleopterans and dipterans under bark//scavenger.	2
Leptacinus paurumpunctatus (Gyllenhal)	Predator of bark beetles under bark//scavenger.	2
Nacaeus tenellus Erichson	Do.?	1
7801[d] (Unidentified)	Do.	1
7802 (Unidentified)	Do.	1
Scydmaenidae		
Euconnus sp.	Scavenger under bark and leaf litter	1
Orthoperidae		
Molamba sp.	Predator under bark// scavenger	3
Trogositidae		
Corticotomus parallelus Melsh.	Adult and larva predator of immature and mature bark beetles and woodborers	1
Temnochila virescens (F.)	Do.	1
Tenebroides collaris (Sturm)	Do.	1
T. marginatus (Palisot de Beauvois)	Do.	1
T. nanus (Melsh.)	Do.	1
Cleridae		
Chariessa pilosa (Forst.)	Adult and larva predator of immature and mature bark beetles, woodborers, and others over-under bark	1
Cregya oculata (Say)	Do.	1
Cymtodera undulata (Say)	Do.	1
Phyllobaenus pallipennis Dejean	Do.	1
Priocera castanea (Newman)	Do.	1
Thanasimus dubius (F.)	Do.	4
Tillus collaris Spin.	Do.	1
Elateridae		
Anchastus signaticollis (Germar)	Adult and larva predator of arthropods under bark// scavenger	1
Athos sp.	Do.	1
7803 Elaterid sp. (A)	Do.	1
Glyphonyx sp.	Do.	1
Lacon impressicollis (Say)	Do.	1
Menalotus ignobilis Melsh.	Do.	1
Melanotus sp.	Do.	1
Eucnemidae		
Dirhagus triangularis (Say)	Predator of arthropods under bark	1
Dirhagus sp.	Do.	1
Throscidae		
Trixagus sp.	Scavenger under bark and leaf litter//predator	1

[a]Information from: Hopkins (1893); Balduf (1935); Chamberlin (1939); Edwards (1949); Craighead (1950); Knull (1951); Muesebeck *et al.* (1951); Hatch (1957, 1962, 1965, 1971); Krombein (1958); Thatcher (1960); Bushing (1965); Stone *et al.* (1965); Krombein and Burks (1967); Bright (1968); Overgaard (1968); Franklin (1969); Askew (1971); Moser *et al.* (1971); Baker (1972) Clausen (1972); Moore (1972); Arnett (1973); Deyrup (1975); Yensen (1975); Craighead (1950).

[b]Relative Abundance: 1 = 1 - 100
2 = 101 - 500
3 = 501 - 1,000
4 = 1,001 - 5,000
5 = 5,001 - 10,000
6 ≥ 10,001

[c]Total Number = 110,022.

[d]Call number of voucher specimens.

APPENDIX TABLE. (Continued)

ORDER, FAMILY, SPECIES	ROLE	ABUNDANCE
Buprestidae		
Chrysobothris floricola Gory	Woodborer/fungus feeder under bark	1
Biphyllidae		
Diplocoelus rudis LeC.	Fungus feeder under bark	1
Erotylidae		
Triplax festiva LaCordaire	Fungus feeder under bark	1
T. flavicornis (LeC.)	Do.	1
T. frontalis Horn	Do.	1
Sphinidae		
Sphindus sp. prob. *americanus*	Do.	1
Cucujidae		
Carthartosilvanus imbellis (LeC.)	Predator of arthropods under bark	1
Catogenus rufus (F.)	Parasite of cerambycids and braconids under bark	1
Nausibus clavicornis (Kug.)	Predator of bark beetles under bark//scavenger	1
Silvanus muticus Sharp	Do.	1
7804 (Unidentified)	Do.?	1
7805 (Unidentified)	Do.	1
Nitidulidae		
Colopterus niger (Say)	Sapfeeder//scavenger under bark	1
C. unicolor (Say)	Do.	2
Colydiidae		
Aulonium ferrugineum Zimm.	Predator of bark beetles and woodborers under bark// scavenger/fungus feeder	2
A. tuberculatum LeC.	Do.	3
Colydium lineola Say	Do.	1
C. nigripenne LeC.	Do.	1
Lasconotus pusillus LeC.	Do.	2
L. referendarius Zimm.	Do.	4
Pycnomerus sulcicollis LeC.	Do.	1
Cerylonidae		
Cerylon castaneum Say	Do.	1
Endomychidae		
Danae testaceae Zieglar	Fungus feeder under bark	1
Coccinellidae		
Diomus amabilis (LeC.)	Predator of scale insects on conifers	1
Chilocorus sp.	Do.	1
Cycloneda sanguinea L.	Do.	1
Oedemeridae		
Oxycopis notoxoides (F).	Scavenger under bark, leaf litter	1
Anthicidae		
Anthicus sp.	Scavenger under bark// predator?	1
Euglenidae		
Cnopus impressus (LeC.)	Do.	1
Mordellidae		
7806 (Unidentified)	Scavenger under bark// predator?	1
7807 (Unidentified)	Do.	1
Tenebrionidae		
Corticeus glaber (LeC.)	Predator of bark beetles under bark//scavenger/fungus feeder	4
Anobiidae		
Petalium bistriatum (Say)	Bark and woodborer	1
Bostrichidae		
7808 (Unidentified)	Woodborer	1
7809 (Unidentified)	Do.	1
Cerambycidae		
Acanthocinus obsoletus (Oliv.)	Woodborer	1
Monochamus titillator (F.)	Do.	1
Xylotrechus undulatus (Say)	Do.	1
Xylotrechus sp.	Do.	1
Chrysomelidae		
Metachroma luridum (Oliv.)	Root feeder	1
Pachybrachys alticola Fall	Plant feeder	1
Anthribidae		
Euparius marmoreus (Oliv.)	Fungus and bark feeder	1
Piesocorynus sp.	Do.	1
Curculionidae		
Auletobius cassandrae (LeC.)	Scavenger under bark/ woodborer	1
Cossonus corticola (Say)	Do.	4
Pissoides nemorensis Genmar	Consumer of phloem food supply	1
Pachylobius picivorus (Germ.)	Bark and root feeder	1
Platypodidae		
Platypus flavicornis (F.)	Fungus feeder under bark (ambrosia)	4
Scolytidae		
Crypturgus aluctaceus Schwarz	Consumer of phloem food supply	4
Dendroctonus frontalis Zimm.	Do.	6
Dendroctonus terebrans (Oliv.)	Do.	1
Gnathotrichus materiarius (Fitch)	Fungus feeder under bark (ambrosia)	4
Hylastes tenuis Eich.	Consumer of phloem food supply	1
Hypothenemus sp. near *pubescens*	Do.	1
Ips avulsus (Eich.)	Do.	5
I. calligraphus (Germ.)	Do.	1
I. grandicollis (Eich.)	Do.	3
Pityophthorus annectans (LeC.)	Do.	1

APPENDIX TABLE. (Continued)

ORDER, FAMILY, SPECIES	ROLE	ABUNDANCE
P. bisulcatus (Eich.)	Do.	1
P. pulicarius Zimm.	Do.	1
Xyleborus ferrugineus (F.)	Fungus feeder under bark (ambrosia)	2
X. pini Eich.	Do.	2
X. saxeseni (Ratz.)	Do.	1
Xyleborus sp.	Do.	1
DIPTERA		
Sciaridae		
Bradysia sp.	Fungus feeder under bark	1
Stratiomyidae		
Zabrachia sp.	Scavenger under bark// predator	4
Empidae		
Euhybus sp. near *gentivus* Melander (undescribed)	Do.	1
Syndas polita (Loew)	Do.	1
Dolichopodidae		
Medetera sp.	Predator of immature and mature bark beetles over-under bark	6
Phoridae		
Dorniphora sp.	Scavenger under bark// predator?	1
Lonchaeidae		
Lonchaea sp.	Scavenger under bark// predator	3
HYMENOPTERA		
Braconidae		
Atanycolus ulmicola (Vier.)	Parasite of woodborers	1
Cenocoelius nigrisoma (Rohwer)	Parasite of bark beetles and woodborers	2
Coeloides pissodis (Ash.)	Parasite of bark beetles	4
Dendrosoter sulcatus Mues.	Do.	3
Doryctes sp.	Parasite of bark beetles and woodborers	1
Spathius pallidus Ash.	Do.	4
Syntretus sp.	Parasite on adult ichneumonids?	1
Ichneumonidae		
7808 (Unidentified) (A)	Parasite of bark beetles, woodborers and lepidopterans	2
7809 (Unidentified) (B)	Do.	1
Eupelmidae		
Arachnophaga sp.	Parasite of bark beetles, braconids?	1
Lutnes sp.	Do.	1
Torymidae		
Roptrocerus eccoptogastri (Ratz.)	Parasite of bark beetles	6
Pteromalidae		
Cecidostiba dendroctoni Ash.	Do.	3
Heydenia unica Cook & Davis	Do.	4
Rhopalicus pulchripennis (Crawford)	Do.	1
Eurytomidae		
Eurytoma sp.	Do.	2
Evaniidae		
Hyptia sp.	Parasite of cockroaches	1
Diapriidae		
Psilus sp.	Parasite of lonchaeid and dolichopodid flies	2
Scelionidae		
Calotela sp.	Parasite of formicids	1
Gyron sp.	Parasite of hemipterans	2
Macrotelia sp.	Parasite of orthopterans	1
Platygasteridae		
Amitus sp.	Parasite of hemipterans and dipterans	1
Leptacis sp.	Parasite of dipterans	4
Platygaster sp.	Do.	
Chrysididae		
Ceratochrysis sp.	Parasite of vespoid and sphecoid hymenopterans	1
Bethylidae		
Parasierola sp.	Parasite of scolytids, cerambycids, lepidopterans	1
Formicidae		
Camponotus sayi Emery	Scavenger over-under bark// predator	1
Crematogaster ashmeadi Mayer	Do.	2
Crematogaster sp.	Do.	1
Cryptopone gilva (Roger)	Do.	1
Hypoponera opacior (Forel)	Do.	2
Pheidole sp.	Do.	1
Proceratium croceum (Rover)	Do.	1
Solenopsis picta Emery	Do.	1
Mutillidae		
Lomachaeta sp.	Parasite on hymenopterans, coleopterans, dipterans	1
Pompilidae		
Ageniella sp.	Prey on spiders	1
Sphecidae		
Ampulex ferruginea Braley	Prey on hemipterans, coleopterans, dipterans, hymenopterans, spiders	1
Nitela sp.	Do.	1
Trypoxylon carinatum (Say)	Do.	1
T. sp. in *rufidens* group	Do.	1

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