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TRAP-NESTING BIOLOGY OF

# PASSALOECUS CUSPIDATUS SMITH (HYMENOPTERA: SPECIDAE)

#### AND SYMPATRIC SPECIES

presented by

John Morris Fricke

has been accepted towards fulfillment of the requirements for

Ph.D. degree in Entomology

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Date 16 February 1990

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### TRAP-NESTING BIOLOGY OF <u>PASSALOECUS</u> <u>CUSPIDATUS</u> SMITH (HYMENOPTERA: SPHECIDAE) AND SYMPATRIC SPECIES

By

John Morris Fricke

#### A DISSERTATION

#### Submitted to Michigan State University in partial fufiliment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Entomology

1990

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#### ABSTRACT

#### TRAP-NESTING BIOLOGY OF <u>PASSALOECUS CUSPIDATUS</u> SMITH (HYMENOPTERA: SPHECIDAE) AND SYMPATRIC SPECIES

By

#### John Morris Fricke

Trap-nesting studies of Passaloecus (Hymenoptera: Sphecidae) were carried out at Concordia College, Ann Arbor, Michigan, from 1984 through 1987. Variations in nest architecture and resource partitioning among sympatric Passaloecus spp. were studied. Trap nest bore diameter selections among <u>Passaloecus</u> spp. were: <u>P. annulatus</u> (Say) and P. areolatus Vincent, 1.6 - 2.4 mm; P. cuspidatus Smith, 2.0 - 6.4 mm, and P. monilicornis Dahlbom, 1.6 - 3.6 mm. P. cuspidatus preferred trap nests on <u>Pinus</u> and <u>P. areolatus</u> preferred trap nests on Juglans. P. areolatus nests were most frequent at heights of 3 to 9 m; <u>P. cuspidatus</u> nests were most frequent below 3 m. <u>Omalus aeneus</u> (Fabricius) (Chrysididae) parasitized nests of P. annulatus, P. areolatus, P. cuspidatus, and P. monilicornis; Omalus iridescens (Norton) parasitized P. annulatus; and Trichrysis doriae Gribodo parasitized <u>P. cuspidatus</u>. Pomenia thoracica (Cresson) (Ichneumonidae) parasitized <u>P. cuspidatus</u> and <u>Pomenia</u> <u>albipes</u> parasitized P. areolatus, P. cuspidatus, and P. monilicornis. Mean length of provisioned cells decreased as bore diameter increased, and volumes of provisioned cells increased with increasing bore diameter. Increased length of provisioned cells was associated with higher

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parasite activity but not with wasp senescence. Orientation of trapnest bore openings did not influence frequency of trap nest use by Passaloecus spp. Decreased bore depth resulted in significant decreases in basal cell lengths and slight decreases in provisioned cell lengths. A significant decrease in number of provisioned cells in trap nests with 60 mm bore depths was noted only for P. cuspidatus. In 1987, provisioning activity of P. cuspidatus extended from May 29 through August 6. Eighty trap nests contained 281 provisioned cells and 9618 aphids. The average number of aphids per cell was 34.2 and the average number of cells provisioned per day per trap nest was .73. P. cuspidatus used Cinaria sp., Dactynotus sp., Euceraphis sp., Macrosiphum euphorbiae (Thomas), Myzus sp., Myzus cerasi (Fabricius), Myzus monardae (Davis), and <u>Sitobium</u> avenae Fabricius. The number of aphids provisioned per cell was significantly different among three species of aphids and was inversely related to aphid size. Resin gathering activities of P. cuspidatus were also observed and described.

# DEDICATION

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This work is dedicated to Henry and Rose Muschick for their love and encouragement.

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The author expresses his appreciation to the following institutions and individuals that contributed to the initiation and development of this study: Concorida College, Ann Arbor, Michigan, which granted a sabbatical study leave for the academic year 1981-1982; Ald Associaton for Lutherans, which provided financial support during the study leave; Drs. Edward Grafius, Frederick Stehr, Gary Simmons, and Steve Stephenson, Guidance Committee members (Michigan State University); Dr. John Witter, advisor (University of Michigan; my wife Karen, and children Jeff and Jennifer for their long-suffering patience and word processing; Maryann Oester, word processing and deciphering of hand written manuscripts; the invertebrate zoology class of 1986 for trap nest construction; Dr. Manya Stoetzel, USDA, for the identification of prey; and finally, Dr. Roland L. Fischer, guidance committee chairman, and mentor.

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#### INTRODUCTION

Man and the insects have a long history of positive and negative inter-relationships. Many insects directly or indirectly are instrumental in providing food, fiber, shelter, and enjoyable recreational pursuits. Ecologically, insects have their place in food chains as biological concentrators (herbivores and carnivores), decomposers, reducers, or as benefactors to plants requiring biotic agents for pollination.

However, when man manages ecosystems for his own purposes, insects have opportunity to exploit concentrated resources and have negatively influenced man's objectives. Any product of interest to man (food, fiber, shelter, health, and recreation) is also a resource capable of being used by insects for their own purposes.

As human activity shifted from subsistance levels to commercial enterprizes, resources were concentrated, increasing the opportunity for their exploitation by insects. New technologies enabled larger scale operations and increased travel provided opportunity for distribution of potential insect pests. Energy investment, productivity, and profits increased. Monoculture replaced diverse ecosystems; and accidental introductions of potential pests into rich resource bases, lacking appropriate biological controls, often resulted in staggering losses.

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Efforts to combat competitors for products of interest predate Early control techniques included the agricultural revolution. compounds of sulfur, arsenic, and copper; plant derivatives such as nicotine, pyrethring, and rotenone; and other naturally derived materials such as chalk, wood ash, oil sprays, bitumen sticky bands, and predatory ant colonies. Åз the agricultural revolution progressed, pest control measures became more scientifically based and received a tremendous impetus from the field of medical entomology as many tropical diseases including Texas cattle fever. African sleeping sickness, malaria, and yellow fever were shown to have arthropod A multi-faceted approach, which might be considered vectors. primitive integrated pest management, emerged and included the development of resistant varieties, and the implimentation of cultural, biological, and chemical controls.

The search for improved chemical control received great impetus during World War II with the realization that dangers of tropical, insect-vectored diseases were surely as great as those of armed combat. Subsequent discovery of the insecticidal properties of DDT ushered in a new age of optimism regarding insect management, and "control" of pests was replaced with the attitude of eradication. Given this prospect, old pest management practices including crop rotation, sanitation, and encouragment of natural enemies declined.

Pesticide use accelerated, without regard for ecological principles or consequences, and individual users applied chemical controls even in situations where pests were not economically harmful. The realization that something was amiss developed gradually. Smith,

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Hoskins, and Fullmer (1948) reported that dairy cows fed low residue hay (2 ppm DDT) produced butterfat with 65 ppm DDT, but little public attention was focused on the persistance and biological magnification of pesticides until the 1962 publication of Rachel Carson's Silent Spring. Subsequently, four significant observations were made: 1) target populations, especially those with short life cycles and high reproductive capacities developed resistance to pesticides; 2) target populations frequently rebounded to even higher population levels following pesticide applications, often due to the elimination of natural controls; 3) secondary pests became major pests due to the removal of natural control agents; and 4) significant numbers of non-target organisims were succumbing to pesticides as a result of direct application, food chain magnification of ingested pesticides. or the long term accumulation of hard pesticides with long half-lives.

In response to the development of resistance, application rates and frequency of applications increased. The pesticide industry responded with the development of alternative pesticides; but effective life spans of pesticides decreased, and development and testing costs contributed to increased cost of control, decreasing profit margins.

Smith and Michelbacher (1949) and Smith, Anderson, and Reynolds (1950) suggested that pest management should involve field evaluation of pest populations and their natural enemies. This is associated with the realization that pest populations can exist at levels too low to justify the cost of certain management practices. Gradually, control systems have been developed which involve a holistic ecosystem approach called Integrated Pest Management (IPM).

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IPM system success requires an accurate knowledge of the biology of crops, pests, natural controls, and the effects of climatic conditions on the population growth of each of these components. Classical success stories, such as the control of cottony cushion scale by the vedalla beetle, illustrate that comprehensive studies can identify effective agents of biological control.

It is interesting to note that research efforts to learn the general biology of insects and their biological control declined with increased pesticide production and testing. The very actions that precipitated greater need for such studies were mitigating against them. The basic biology and potential use of natural enemies has consequently been limited to those systems involving products of interest with the greatest economic impact and highest potential funding levels. Many predator-prey relationships await study and incorporation into the knowledge base of pure and applied entomology. One such relationship is that between the genus <u>Passaloecus</u> and aphids.

Field studies of <u>Passaloecus</u> show the correctness of describing these wasps as aphid hunters. However, these wasps have not been included in lists of aphid predators or parasites (parasitoids). This may be due to the peculiar biology of the aphid hunting wasps in general. These wasps provision nests located in the ground, twigs, beetle borings, reeds, grass culms, and bark. Nests may be located some distance from an aphid colony and time spent by provisioning wasps at these colonies may be minimal. This contrasts with the long term close contact with an aphid colony by predaceous larvae of coccinellids, chrysopids, syrphids, or hymenopterous parasitoids.

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Dixon (1973) notes the success of biological controls on aphids in man-managed ecosystems but indicates there is no evidence that natural enemies regulate aphid populations. Corbett and Backhouse (1975) suggest that aculeate Hymenoptera might be useful in IPM programs if more were known of their biology. They recognize difficulties (high temperature thresholds for activity, low fecundity, long generation time, slow response to prey density, high investment in rearing time, and availability of nest sites) but suggest that in greenhouses management of these wasps could prove successful.

Previous work on Passaloecus has been incidental and serendipitous. The most comprehensive studies have been reported on <u>P. cuspidatus</u> Smith (Fye, 1965b; Krombein, 1956, 1958, 1963, and 1967; and Vincent, 1978) and P. monilicornis Dahlbom (Fye, 1965b; Vincent, 1978). However, the scope of these studies was limited. Bore diameters used in these trap-nesting studies usually had lower limits of 3.2 mm and rather large scale increments of 1.6 mm. Bore diameters most commonly used have been 3.2, 4.8, 6.4, and 8.0 mm. Considering the small size of <u>Passaloecus</u> spp., smaller bore diameters are more appropriate for determining bore diameter preferences. Data from large bore trap nests suggest an inverse relationship between bore diameter and cell length or cell volume. The effectiveness of smaller bore diameters needs to be examined.

No biological studies have been reported on sympatric <u>Passaloecus</u>. If several <u>Passaloecus</u> spp. are present in a community, how are resources (aphids, nesting sites, closure materials, etc.) partitioned? An abundance of resources might make direct competition

or in sugge: exclu 1935; spp. i have activ annul and I repor in Ju stati Previ the Passa SURRE diame inves archi seiec or interference of no consequence, but competition theory would suggest that any advantage to one species would result in ultimate exclusion of others, if the same resources were required (Gause, 1934, 1935; Park, 1948). Can a partitioning of resources by <u>Passaloecus</u> spp. be demonstrated?

Corbet and Backhouse (1975) suggested that <u>Passaloecus</u> females have a hunting life of 50 days, but only one report confirms an activity period near that duration. Krombein (1963) reported <u>P</u>. <u>annulatus</u> as multivoltine and active from May 20 through October 13 and <u>P</u>. <u>cuspidatus</u> active 39 days (June 1 - July 9). Fye (1965b) reported on <u>P</u>. <u>monilcornis</u> with a spring generation provisioning nests in June and a summer generation provisioning nests in August.

Details on the nature of trap-nesting sites (exposures, heights, station species, and plant communities) have not been included in previous studies. Such information would be helpful in determining the factors influencing the local distribution of sympatric <u>Passaloecus</u>. The research reported below was carried out during the summers of 1984 - 1987. Preferences among <u>Passaloecus</u> spp. for bore diameters, stations, bore opening orientations, and heights were investigated. The influence of bore diameters and bore depth on cell architecture, the effects of parasitoid activity, and aphid prey selection were also investigated.

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#### METHODS AND MATERIALS

Many solitary bees and wasps construct brood cells in pre-existing natural cavities such as beetle borings or in excavations of pithy stems and twigs of Sambucus and Juglans. Artificial nesting materials are also acceptable and provide a convenient approach to study nest architecture, nesting activity, provisions and parasites. Various materials have been used as artificial nests and included bamboo, glass tubes, plastic straws, cuttings of twigs and stems, and trap nests. Condensation in glass tubes and plastic straws make these materials ineffective. Bamboo has a varying bore diameter and cuttings of twigs and stems are split with great difficulty. Trap nests used previously by various researchers consisted of small rectangular pieces of wood with holes drilled into their longitudinal axes. The longitudinal holes (bores) varied in depth and diameter and are analogous to natural cavities used as nesting sites. Trap nests of clear straight-grain pine were split in half lengthwise. exposing nest contents with relative ease, especially if bore diameters were greater than 3.2 mm.

Trap nest construction techniques for this study were similar to those described by Fye (1965a) and Krombein (1967). Pine boards were cut into trap nests (19 x 19 x 140 mm) with holes drilled longitudinally to depths of 60 and 120 mm. Bore diameters and bore depths varied seasonally, dependent upon prior experience and current study focus.

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Bore diameters used in these studies ranged from 1.6 to 9.6 mm with increments of 0.4 or 0.8 mm. Trap nests were usually placed at heights convienient for making field observations. Heights above ground level usually ranged from 50 cm to 200 cm with 25 cm increments. In one experiment, trap nests were distributed at heights of 1 to 9 m with one meter intervals. Bore depths of 120 mm were used in all studies with the exception of investigations carried out in 1986 when 60 and 120 mm bore depths were used with equal frequency.

Several problems encountered in early studies were resolved with modifications of trap nest construction techniques. Small bore trap nests (1.6 mm - 3.2 mm) were split with some difficulty. The splitting plane frequently did not intercept the bore, since it was seldom parallel to the long axis of the trap nest. These problems were solved by the use of <u>pre-split</u> trap nests. Several steps were required for their construction. A band saw was used to cut trap nest blocks length-wise into two sections with dimensions nominally 6.4 x 19 x 140 mm and 12.6 x 19 x 140 mm. A drill-guide channel was routed in a longitudinal face of the larger section. Trap nest sections were bound together with masking tape and drilled to appropriate depths and diameters with high speed twist-steel bits.

Pre-split trap nest sections did not fit well together. Irregularities across split surfaces admitted light and excess molsture, both detrimental to trap nest use. These difficulties were eliminated by modifying a technique from Krombein (1967). Pre-split trap nests were coated with melted paraffin and then re-drilled to

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their appropriate bore diameter and depths. Re-drilling removed paraffin that blocked the bore and produced exceptionally smooth bore surfaces. Steps in construction of pre-split trap nests are illustrated in Figure 1. Completed trap nests were bound together into <u>bundles</u> of nine  $(3 \times 3)$ , twelve  $(3 \times 4)$ , or twenty  $(4 \times 5)$  trap nests. Cotton cord, rubber bands and plastic strapping were used to secure individual trap nests in bundles. Fye's (1965a) design for a bundle carrier was used to place bundles in the field and fence staples were used to attach bundles to the trunks of trees in the study area. A typical trap nest bundle is illustrated in Figure 2. An individual tree with attached trap nest bundles is called a station.





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Figure 2. A 3 x 3 bundle of trap nests ready for distribution into the field.

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Trap nest stations were established in a mixed hardwood forest edge between a small red pine plantation and an old field. The long axis of the edge runs from north-west to south-east. Bundles of trap nests were positioned so that bore openings faced north-west, north-east, south-east, and south-west. Trap nests were arranged in bundles (Figure 3) with bore openings of adjacent trap nests facing opposite directions, presenting either regular or randomized patterns of drilled and blank trap nest faces.



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Figure 3. Distribution of bore openings in 3 x 3 and 4 x 5 trap nest bundles illustrating opposite ends of representative bundles.

COI nes N. of 19 and deg COI m stu nes anc re VI (b) the tra anc Pro guc Leg ide deg <u>SUD</u>O The distribution of bore sizes in trap nest bundles varied considerably from year to year. Bundles for 1984 contained nine trap nest of a single bore diameter. Diameters were 3.2, 4.0, and 4.8 mm. A 1985 bundle consisted of twenty trap nests with two trap nests each of bore diameters 1.6 - 8.8 mm (0.8mm increments). Bundles for the 1986 season were 3 x 4 units of three bore diamter classes (1.6, 2.0, and 2.4mm; 2.8, 3.2, and 3.6 mm, and 4.0, 4.4 and 4.8 mm) and two bore depth classes (60 and 120mm). Bundles for 1987 were 3 x 4 units consisting of trap nests with bore diameters of 2.4 to 7.2 mm with 0.8 mm increments. The number of trap nests set out for trap-nesting studies from 1984 through 1987 was <u>4877</u>.

Several techniques were used to rear adult material: (1) trap nests were placed individually into 200 ml polycarbonate rearing tubes and stored in an unheated garage over winter, (2) pre-pupae were removed from their cells and transfered to 2 or 4 dram vials lined with lens paper and (a) stored over winter in an unheated garage or (b) stored in a refrigerator at 3.5 degrees C for 60 to 90 days.

To gather data on aphid provisions, trap nests were removed from the field within one to two days of closure and were replaced with trap nests of similar bore diameter. Closed trap nests were opened and data taken on number of cells, cell types, cell lengths, and cell provisions. The contents of each cell were removed, aphids counted and the food stores with the wasp egg or larva were transferred to a rearing vial. Two aphids from each provisioned cell were removed for identification. Wasp prepupae were placed in a cold box at 3.5 degrees Centigrade for 90 days. These materials were removed to ambient lab conditions for rearing of adults.

an The fa 1. 01 **5**0 in pla Th rej PC CO 60 th de di đu Agi Pi Pla gCi (1, The study area is a mixed forest edge between a pine plantation and an old pasture on the most northern portion of Concordia's campus. The area is bordered on the east by highway U.S. 23 and on the west by faculty housing. The plant cover of the study area is given in Table 1. An intermittent stream lies within the edge and an old fence row roughly parallels the northern side of the stream. The edge faces south-southwest and receives maximum sunlight in mid-afternoon. Trees in the area have reached maturity and some are senescent. The plantation consists of red pine with white pine scattered at the edge. The edge consists primarily of walnut and ash, with other hardwoods represented occasionally. A variety of shrubs and herbs are also present.

Malaise trap collections during the summers of 1982-1983 confirmed the presence of <u>Passaloecus</u> on the campus of Concordia College, Ann Arbor, Michigan. Preliminary studies were conducted at this time to identify an area for intensive <u>Passaloecus</u> studies and to develop acceptable trap-nesting material. Pine trap nests with bore diameters of 3.2, 4.8, 6.4, 8.0, and 9.6 mm were placed in three areas during the summer of 1982, but no <u>Passaloecus</u> were reared out. The variety of nesting materials was expanded for summer 1983 and included pine trap nests, <u>Fraxinus</u> stems, cuttings of <u>Rhus</u>, and <u>Rubus</u>; and plastic straws. Five areas were surveyed and presumed <u>Passaloecus</u> activity was noted in each one. Three areas showed minimal activity (1, 1, and 4 <u>Passaloecus</u> trap nests respectively); a fourth had 12

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<u>Passaloecus</u> trap nests and a fifth (area II) produced 27 <u>Passaloecus</u> trap nests. Due to these results area II was selected as the location for more intensive studies of <u>Passaloecus</u> trap-nesting biology.

Trap nests were placed in the field in late May and early June. Observations of <u>Passaloecus</u> activity were made throughout the summer. For the 1984-1986 seasons trap nests were removed from the field following the cessation of provisioning activities. Trap nests were opened and data were gathered on nest architecture including cell types, number of cells and cell dimensions. Materials were reared whenever possible. For the 1987 season trap nests were removed upon closure and data were taken on nest architecture and aphid provisions. Food stores and wasp eggs or larvae were transferred to small glass vials and adults were reared the following spring. Species identifications were based upon reared materials or unique features of a wasp's trap-nesting biology. Table 1.

Plant cover of trap-nesting study area.

# Trees

Acer negundo L.	<u>Populus deltoides</u> Marsh
Acer saccharum Marsh	<u>Prunus serotina</u> Ehrh
Betula papyrifera Marsh	Quercus spp.
Fagus grandifolia Ehrh	Robina pseudoacacia L.
Fraxinus americana L.	Salix interior Rowlee
Juglans nigra L.	<u>Salix</u> sp.
Juniperus virginana L.	<u>Thuia occidentalis</u> L.
Pinus resinosa Alton	Tsuga canadensis L.
Pinus strobis L.	Ulmus americana L.
Pinus sylvestris L.	<u>Ulmus rubra</u> Muhl

## Shrubs

Cornus spp.	<u>Ribes</u> sp.
<u>Blaeagnus augustilolla</u> L.	Rosa spp.
Lonicera	<u>Rubus</u> spp.
Potentilla	Viburnum sp.
Rhamnus	<u>Viburnum trilobum</u> Marsh
Rhus radicans L.	<u>Vitis</u> spp.

## Herbs

Achillea millifolium L. Capsella bursa-pastoris (L.)	<u>Plantago</u> sp. <u>Polvgonatum</u> sp.
<u>Cirsium</u> sp.	
<u>Gailum aparine</u> L.	KUBEX CLIEDIE L
<u>Hleracium</u> sp.	<u>Sanguinaria canadensis</u> L. <u>Smilacina</u> sp.
<u>Impatiens</u> sp.	<u>Solanum</u> sp.
<u>Medicago lupulina</u> L.	<u>Solidago</u> spp.
Oxalis sp.	<u>Stellaria</u> sp.
Parthenocissus	Taraxicum officinale L.
guinguefolla (L.)	Tragopogon pratensis L.
Phleum pratense L.	Trifolium repens L.

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### RESULTS AND DISCUSSION

Bore Diameter Preferences Among Sympatric Passaloecus spp.

Fye (1965b), Krombein (1967), and Vincent (1978) reported on a number of <u>Passaloecus</u> spp. and gave data on bore diameters selected. Vincent (1978) noted <u>P. annulatus</u> (Say) reared from a 1.5 mm bore trap nest and <u>P. areolatus</u> Vincent from two 1.5 mm bore trap nests. All of these authors reported trap nest bores used by <u>P. cuspidatus</u> and their pooled data are summarized as follows: 20 trap nests - 3.2 mm bore; 83 trap nests - 4.0 mm bore; and 3 trap nests - 6.4 mm bore. Fye (1965b) reported that <u>P. monilicornis</u> preferred 6.4 mm bores and Krombein (1967) noted <u>P. monilicornis</u> from four 3.2 mm borings, and two 4.8 mm borings.

It is questionable whether these reports are truly indicative of bore diameter preferences of <u>Passaloecus</u> spp. or represent artifacts due to the bore diameters selected by the investigators. Bore diameters most commonly made available by these authors were 4.8 mm or greater, with increments of 1.6 mm. Fye used 6.4 and 8.0 mm drillings; Krombein also used these sizes and included a few 3.2 mm bores. Ratios or actual frequencies were not reported. Vincent is the only author to report use of bores as small as 1.5 mm. <u>Passaloecus</u> are small wasps (4 - 9 mm long) and bore diameters used in general trap-nesting survey studies may be inappropriate for studies focused on this genus, because bore sizes have been too large to be used effectively by the majority of these small wasps.

Bore diameter preferences among <u>Passaloecus</u> spp. were investigated from 1984 through 1987. In 1984, 432 trap nests with bore diameters of 3.2, 4.0, and 4.8 mm were available. Diameters were represented with equal frequencies - 144 trap nests of each bore diameter. Trap nests were bundled into 3 x 3 units and distributed at 16 stations, 3 bundles per station. The following frequencies of trap nest use by <u>Passaloecus cuspidatus</u> were confirmed with reared materials: 3.2 mm bore - 19 nests; 4.0 mm bore - 9 nests; 4.8 mm bore - 13 nests. An additional 153 trap nests were distributed at a <u>supplemental</u> site about 100 yards distant from the primary study area. Bore diameters were 3.2, 4.0, 4.8, 6.4, and 8.0 mm. <u>Passaloecus</u> <u>cuspidatus</u> was confirmed in 13 of these trap nests: 3.2 mm bore - 4 nests, 4.0 mm bore - 3 nests, 4.8 mm bore - 5 nests, and 6.4 mm bore -1 nest.

Since all available bore sizes were used in the 1984 study, the number of bore sizes for 1985 was increased and ranged from 1.6 to 8.8 mm with increments of 0.8 mm. One hundred twenty-eight trap nests of each bore size were used. Two trap nests from each of these 10 bore classes were bound together producing bundles of 20 trap nests each. Sixty-four bundles were distributed, 4 at each of 16 stations.

<u>Passaloecus</u> spp. were confirmed in trap nests with bore diameters ranging from 1.6 to 4.8 mm in the following frequencies: <u>P. annulatus</u> (Say), 1.6 mm bore - 2, 2.4 mm bore - 3; <u>P. cuspidatus</u> Smith, 3.2 mm

bore - 2, 4.0 mm bore - 2, 4.8 mm bore - 3; <u>P. monilicornis</u> Dahlbom, 1.6 mm bore - 1, 2.4 mm bore - 5; and <u>P. singularis</u> Dahlbom, 2.4 mm bore - 1.

These data suggested that <u>Passaloecus</u> spp. partition nesting sites on the basis of bore diameter and that preferred bore diameters were less than 6.4 mm. To increase the frequency of acceptable nesting material and bore categories, the maximum bore diameter used in 1986 was 4.8 mm. Nine bore diameters were used, ranging from 1.6 mm to 4.8 mm with 0.4 mm increments. One hundred twenty-eight coated, pre-split trap nests of each bore diameter were prepared and assembled into 96 3 x 3 bundles. Bundles were of 3 classes: class I, 1.6 - 2.4 mm bores; class II, 2.8 - 3.6 mm bores; and class III, 4.0 - 4.8 mm bores. Each bore diameter was represented 3 times in their respective bundles. Bundles were distributed to 24 stations, 4 per station.

One hundred forty-seven trap nests were provisioned by <u>Passaloecus</u> spp. and species confirmations were made for 104 trap nests by reared materials or trap nest biology. Four species of <u>Passaloecus</u> were reared: <u>P. annulatus</u> (Say), 6 trap nests - 8 males and 3 females; <u>P. areolatus</u> Vincent, 47 trap nests - 17 males and 42 females; <u>P. cuspidatus</u> Smith, 33 trap nests - 58 males and 13 females; and <u>P. monilicornis</u> Dahlbom, 18 trap nests - 17 males and 22 females. Forty-five trap nests, presumed to contain <u>Passaloecus</u>, suffered cell failure or rearing losses and no adults were reared. These trap nests were initially classified as provisioned by unknown <u>Passaloecus</u> spp.

Hc us <u>P</u>. di Pa tr ar = di th is fc P. << However, subsequent examination of trap nest closure materials were used to identify thirteen unknown trap nests as being provisioned by <u>P. areolatus</u> Vincent.

Table 2 summarizes data for 1984-1986 on frequency of bore diameter availability and selection as nesting sites by five <u>Passaloecus</u> spp. The Kruskal-Wallis test for differences in ranks of trap nest bore selection by four of these species (<u>P. annulatus</u>, <u>P. areolatus</u>, <u>P. cuspidatus</u>, and <u>P. monilicornis</u>) is very significant (H = 120.9749, df = 3, p <<.0005). The chi-square (I) test for differences of bore diameter selection by <u>P. cuspidatus</u> (based upon three bore diameter classes: 2.0 - 2.8, 3.2 - 4.0, and 4.4 - 6.4 mm) is very significant ( $X^2$  = 15.2583, df = 2, p <.0005) The t(II) test for differences of bore diameter preferences between <u>P. cuspidatus</u> and <u>P. monilicornis</u> is also very significant (t = 7.4316, df = 116, p <<.0005).

Tab	e	2.
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	Bore diameters (mm)										
	1.6	2.0	2.4	2.8 Bore	3.2 diane	3.6 ter fi	4.0 requent	4.4 cies	4.8	5.6	6.4
Species	256	128	256	128	430	1 <b>28</b>	430	128	430	128	158
<u>annu i atus</u>	3	1	7	0	0	0	0	0	0	0	0
areolatus	18	20	9	0	0	0	0	0	0	0	0
<u>cuspidatus</u>	0	1	4	6	32	7	19	3	21	0	1
monilicornis	2	3	13	2	2	2	0	0	0	0	0
singularis	0	0	1	0	0	0	0	0	0	0	0

Bore diameter selections for five Passaloecus spp., 1984-1986.

Pa 7. si 11 11 11 1 ft Г In 1987 the focus of these studies was narrowed to P. <u>cuspidatus</u>. Paraffin coated, pre-split trap nests of seven bore diameters (2.4 -7.2 mm, with 0.8 mm increments) were used. The frequencies of bore sizes made available as potential nesting sites were as follows: 2.4 mm - 211; 3.2 mm - 307; 4.0 mm - 307; 4.8 mm - 307; 5.6 mm - 211; 6.4 mm - 211 and 7.2 mm - 211. P. <u>cuspidatus</u> used bores in the following frequencies: 2.4 mm - 9; 3.2 mm - 37; 4.0 mm - 28; 4.8 mm - 8; 5.6 mm - 1, and 6.4 mm - 1.

<u>P. cuspidatus</u> trap nest selection data from 1984-1987 were pooled for analysis and are given in Table 3. Due to insufficient data in a few bore diameter classes, bore diameter selection data were recombined into five classes. The expected frequencies of trap nest selection were based upon relative frequencies of trap nests in each bore class and the expectancy that the ratio of trap nest use would be equal in all classes. The expected frequencies of trap nest use in respective bore classes were: 27.17, 39.50, 39.50, 39.50, and 32.33. The observed frequencies of selection in these respective bore diameter classes were 14, 75, 54, 32, and 3. Expected and observed frequencies of bore selection are significantly different (Figure 4,  $X^2 = 71.6456$ , df = 4, p <<.0005) indicating that <u>P. cuspidatus</u> prefers trap nests with bore diameters from 2.0 - 4.8 mm.

Table	3.
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Bore diameter class (mm)	Diameter frequency	Selection frequency
2.0 - 2.4	595	14
2.8 - 3.2	865	75
3.6 - 4.0	865	54
4.4 - 4.8	865	32
5.6 - 6.4	708	3

P. cuspidatus bore diameter selections, 1984-1987.



Figure 4. Expected and observed frequencies of bore diameter selection by <u>Passaloecus cuspidatus</u>, 1984-1987.

A possible factor influencing bore diameter selections among <u>Passaloecus</u> spp. is wasp size. A relatively simple index to wasp size is head width. Head width measurements, to the nearest 0.1 mm, were taken from samples of ten females of <u>P. cuspidatus</u>, <u>P. monilicornis</u>, and <u>P. areolatus</u>. The respective mean head widths for these samples were 1.46, 1.19, and 1.0 mm. <u>Passaloecus</u> spp. partition nesting sites on the basis of bore diameter and the size of the wasp may limit the minimum acceptable bore diameter. An additional factor in this regard may be the size of aphids selected as prey. Aphids are usually carried in the mandibles with the prey's body lying below the wasp's head. Under these circumstances the dorsal-ventral dimension of the wasp's head plus an aphid will be greater than head width and will certainly influence acceptable bore diameters. Trap Nest Height Selection in Passaloecus spp.

Trap nests were distributed at several heights to determine those acceptable to <u>Passaloecus</u> spp. and to determine if height was a significant factor in the partitioning of nesting sites. Trap nest bundles were distributed at heights of 0.5 to 9.0 meters. Intervals below 2.0 m were 0.25 m. One meter intervals were used at heights above 2 m. <u>Passaloecus</u> spp. used trap nests at all available heights. Pooled data for 1984-1987 are given in Table 4. The frequency of trap nests used by four <u>Passaloecus</u> spp. at various heights is given along with the number of trap nests of acceptable bore diameters distributed at those heights.

P. annulatus and P. monilicornis were restricted to heights below 3 meters. P. areolatus and P. cuspidatus used trap nests from a wide range of heights, 1 - 9 m and 0.5 - 7 m respectively. However, these data do not indicate upper limits of heights that might be used by these two species. The data are particularly interesting in the case of P. areolatus and P. cuspidatus, the first preferring heights above three meters and the second heights below three meters. Chi-square (I) was used to test for differences in height distribution of trap nests selected by P. cuspidatus and P. areolatus. Data were pooled into three height classes for each species and expected frequencies of trap nest selection were based upon frequencies of acceptable bore diameters. For P. cuspidatus height classes were 0.5 - 1.0, 1.25 - 1.75, and 2.00 - 9.00 m; observed frequencies of trap nest selection

for these height classes were 63, 84, and 17; and respective expected frequencies of trap nest selection were 71.70, 63.23 and 29.06. The chi-square (I) statistic for these data is significant ( $X^2 = 12.8819$ , df = 2, p < .005). For <u>P. areolatus</u> height classes were 0.5 - 3, 4 -6, and 7 - 9 meters; observed frequencies of trap nest selection were 22, 12, and 15; and respective expected frequencies of trap nest selection were 43.49, 2.75, and 2.75. The chi-square (I) statistic for these data is very significant ( $X^2 = 96.1107$ , df = 2, p <<.0005). These results have implications for future trap-nesting studies, supporting the notion that height should be considered in distribution of nesting materials, and suggest that height may be a factor in partitioning nesting material.

Table	4.

Trap nest heights and frequency of use by four <u>Passaloecus</u> spp., 1984-1987.

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	Total # of	# of trap i	nests used (# a	offered)* to <u>P</u>	assaloecus spp
Heights (m)	trap nests	annulatus	areolatus	cuspidatus	monilicornis
9.00	48	0 (48)	15 (48)		0 (48)
8.00	48			0 (48)	0 (48)
7.00	48			3 (48)	
6.00	48	0 (48)	12 (48)		0 (48)
5.00	48			0 (48)	0 (48)
4.00	48			2 (48)	
3.00	48	0 (48)	13 (48)		0 (48)
2.00	764	1 (160)	5 (160)	12 (604)	4 (372)
1.75	5 <b>86</b>		0 (70)	34 (516)	0 (204)
1.50	860	4 (160)	1 (160)	9 (700)	5 (372)
1.25	586			41 (516)	0 (204)
1.00	908	4 (160)	3 (160)	17 (748)	9 (372)
0.75	586			25 (516)	0 (204)
0.50	860	2 (160)	0 (160)	21 (700)	5 (372)

\* Numbers in parentheses indicate the number of trap nests at given heights that are of acceptable bore diameter for a species.
## Parasites of Passaloecus spp.

Parasites of <u>Passaloecus cuspidatus</u> have been reported by Krombein (1967) and Vincent (1978) and included the chrysidids <u>Omalus aeneus</u> (Fabricius), <u>Omalus pupuratus</u> (Provancher), and ichneumons <u>Poemenia</u> <u>americana americana</u> (Cresson), and <u>Poemenia thoracica</u> (Cresson). Of nine hundred twenty-eight <u>Passaloecus</u> spp. cells provisioned, 88 were parasitized and 70 parasites were reared. Parasites included <u>Omalus</u> <u>aeneus</u> (Fabricius), <u>O. iridescens</u> (Norton), <u>Trichrysis doriae</u> Gribodo, and <u>Poemenia albipes</u> (Cresson) and <u>P. thoracica</u> (Cresson).

Table 5 summarizes data on <u>Omalus aeneus</u> parasitism of <u>P</u>. <u>cuspidatus</u> for 1984. Of 25 trap-nesting stations, 21 were used by <u>P</u>. <u>cuspidatus</u> and 14 had trap nests parasitized by <u>O</u>. <u>aeneus</u>. <u>O</u>. <u>aeneus</u> parasitized 35.19% (19 of 54) of all <u>P</u>. <u>cuspidatus</u> trap nests and 17.06% (29 of 170) of all <u>P</u>. <u>cuspidatus</u> cells. Stations with high frequencies of <u>Passaloecus</u> activity (3 or more trap nests per station) showed a wide range of parasite activity. Station 3 produced four <u>Passaloecus</u> nests with 21 cells and no cells were parasitized. Station 11 produced 3 nests and 6 cells, with 100% nest parasities and 66.66% of the cells parasitized. Station 8A generated 5 <u>P</u>. <u>cuspidatus</u> nests with 26 cells. Three of these nests and 9 cells were parasitized.

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Distribution of <u>Omalus aeneus</u> (Fabricius) among <u>Passaloecus cuspidatus</u> trap nest stations, 1984.

Station	Passaloe trap nests	cus cells	Parasi nests	tized cells
1	4	19	1	2
2	2	5	0	0
3	4	21	0	0
4	0	0	0	0
5	1	2	0	0
б	2	4	1	1
7	4	9	2	2
8	3	5	1	1
9	3	9	1	2
10	3	10	1	1
11	3	6	3	4
12	4	13	1	1
13	2	5	1	1
14	1	2	1	1
15	4	14	1	1
16	1	2	0	0
17	2	3	1	1
27	0	0	0	0
3 <b>a</b>	0	0	0	0
4 <b>λ</b>	2	10	0	0
5 <b>A</b>	1	1	0	0
6 <b>λ</b>	2	3	1	2
7እ	1	1	0	0
<b>8</b> A	5	26	3	9
9 <b>λ</b>	Ō	0	0	0

Data from 1984 were also examined for bore diameter preferences of <u>Q</u>. <u>aeneus</u> and are summarized in Table 6. These data show no significant difference in frequency of parasitism based upon bore diameter differences.

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Parasitism of <u>Passaloecus cuspidatus</u> trap nests and cells by <u>Omalus</u> <u>aeneus</u> (Fabricius) by Bore Diameter, 1984.

	Bore diameter (mm)			
	3.2	4.0	4.8	6.4
Number of <u>P. cuspidatus</u> trap nests	23	12	18	1
Number of <u>P. cuspidatus</u> cells	78	29	52	10
% trap nests parasitized	26.09	33.33	27.78	100.0
<pre>% cells parasitized</pre>	12.82	17.24	44.44	20.0

In 1985, two of 25 <u>Passaloecus</u> nests produced parasites: one <u>Omalus iridescens</u> from a trap nest of <u>P</u>. <u>annulatus</u> and two <u>Trichrysis</u> <u>doriae</u> Gribodo from a single <u>P</u>. <u>cuspidatus</u> trap nest.

Table 7 gives data on the distribution of parasitism among <u>Passaloecus</u> trap nests for the 1986 season. Twenty-four of 28 stations produced <u>Passaloecus</u> nests and 11 stations had parasitized nests. <u>Omalus aeneus</u> was reared from two <u>P. annulatus</u> nests, four <u>P. areolatus</u> nests, two <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, two <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests, six <u>P. cuspidatus</u> nests, and one nest of <u>P. areolatus</u> nests.

Table 7	•
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Distribution of <u>Qmalus aeneus</u> and <u>Poemenia</u> among <u>Passaloecus</u> trap nests, 1986.

	Pass	loecus	0. <u>aeneus</u>	Poemenia
Station	nests	cells	cells	cells
	-			
1	6	17	0	0
2	8	26	7	1
3	2	5	0	1
4	3	7	1	0
5	1	1	0	0
6	2	4	0	0
7	3	6	0	0
8	1	3	0	0
9	0		-	-
10	7	23	0	2
11	4	10	1	0
12	3	9	0	0
13	4	8	0	1
14	5	14	0	0
15	3	4	0	0
16	10	24	1	2
17	5	13	0	0
18	0		-	-
19	2	5	0	0
20	0		-	-
21	1	6	0	0
22	2	6	0	1
23	7	29	5	0
24	5	17	0	0
25	19	40	2	2
26	27	70	4	7
27	10	28	Ō	2
28	Ō		-	-
	Totals 140	375	21	19

Data from 1986 were also examined for the height distribution of nests parasitized by <u>Omalus aeneus</u> and <u>Poememia albipes</u>. <u>O. aeneus</u> parasitized nests at heights of 1 to 7 m, while <u>P. albipes</u> parasitized nests at heights of 0.5 to 9 m.

The distribution of <u>Passaloecus</u> parasites according to station for 1987 may be noted in Table 8. Twenty-two of 49 stations were used as nesting sites by <u>P. cuspidatus</u>. Nests at six stations were parasitized by <u>Omalus</u> aeneus and one station produced <u>Poemenia</u> thoracica. Of special note are stations 36, and 47 through 49. Station 36, established on May 30, produced seventeen P. cuspidatus trap nests and sixty-five provisioned cells. As of June 15 four nests were parasitized. On July 1 three additional stations (47 - 49) were established nearby, each within 5 meters of station 36. These stations generated an additional 17 P. cuspidatus nests, and 59 provisioned cells, but none were parasitized. Trap nests at all of these stations were distributed at the same heights and with similar orientations. At station 36, P. cuspidatus used eight trap nests at a height of 1.75 m, another eight at 1.25 m, and one at .75 m. Among stations 47 - 49 P. cuspidatus used seven trap nests at a height of 1.75 m and ten trap nests at 1.25 m.

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It is questionable whether the unevenness of  $\underline{0}$ . <u>aeneus</u> distribution at <u>Passaloecus</u> stations is due to host switching behavior or to seasonal changes in host availability. Data from 1984 studies show that  $\underline{0}$ . <u>aeneus</u> parasitized <u>P. cuspidatus</u> nests as early as June 12 and as late as July 24. These data suggest that  $\underline{0}$ . <u>aeneus</u> could prey on <u>P. cuspidatus</u> as long as it is active and that the searching behavior of <u>Q</u>. <u>aeneus</u> is limited to an area where host activity is first observed. However, other site factors may influence the activity of this parasitoid.

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	Passaloec	us		
Station	trap nests	cells		parasitoids
1	5	13	2	<u>Poemenia thoracica</u>
2	1	2	1	<u>Omalus aeneus</u>
3	3	8	0	
· <b>4</b>	1	1	0	
10	2	15	0	
14	2	8	0	
15	9	41	2	Omalus aeneus
16	1	3	Ō	
7	ī	4	Ō	
	ī	1	Ó	
3	1	5	0	
	3	9	3	<u>Omalus aeneus</u>
1	2	8	1	Omalus aeneus
5	4	14	0	
5	17	65	5	<u>Omalus aeneus</u>
9	1	1	0	
0	7	28	2	<u>Omalus aeneus</u>
2	2	5	0	
3	1	2	0	
5	1	3	Ō	
17	10	30	Ō	
3	4	22	0	
49	3	7	0	

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Distribution of Parasitism among <u>Passaloecus</u> <u>cuspidatus</u> trap nests, 1987.

## Provisioned Trap Nest Architecture

A general discussion of provisioned trap nest architecture, as illustrated in Figure 5, follows. The innermost portion of a trap nest is sometimes left empty and walled off by a <u>preliminary plug</u>. This portion of a nest is called the <u>basal cell</u>. <u>Provisioned cells</u> consist of a food-stores space and partition materials. The length of the food-stores space and thickness of the partition comprise the length of the cell. Infrequently, empty (<u>intercalary</u>) cells are found between provisioned cells. The outermost portion of the nest is usually empty and closed by a partition at the nest opening. This final cell is the <u>vestibular cell</u> and its partition is the <u>closure</u>.



Figure 5. Nest architecture illustrating basal cell, provisioned cells, vestibular cell, preliminary plug, resin partitions and closure.

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Factors Influencing Cell Length and Volume

The raw data for provisioned cell lengths for these three Passaloecus spp. were guite varied and This should be skewed. expected since one tail of the possible distribution of provisioned cell lengths is closed (no cell can have a length shorter than 0.00 mm) and the open end of the distribution is limited by the actual length of the trap nest bore (60 or 120 mm). P. areolatus provisioned trap nests of three bore diameters - 1.6, 2.0, and 2.4 mm. Data for provisioned cells from these three bore diameters are respectively: number of cells (49, 73, and 30); range of cell lengths (9 to 70, 7.5 to 41, and 7 to 36 mm); median cell lengths (16.25, 13.19, and 13.19);and mean cell lengths (19.79  $\pm$  12.79, 14.33  $\pm$  5.31, and 15.57  $\pm$  7.27). <u>P. cuspidatus</u> provisioned trap nests in 10 bore diameters ranging from 2.0 to 6.4 mm. Four bore diameter classes (2.4, 3.2, 4.0, and 4.8 mm) produced significant numbers of cells. Data for these four bore diameters are respectively: numbers of cells (40, 210, 180, and 95); range of cell lengths (8 to 39, 6 to 82, 5 to 101, and 5 to 116 mm); median cell lengths (12.96, 12.73, 10.03, and 10.23 mm); and mean cell lengths (14.34  $\pm$  5.29, 14.17  $\pm$  8.30, 15.09  $\pm$  17.00, and 20.58  $\pm$ 26.33).

Examination of ranges and medians for these respective species and bore diameter classes show median cell lengths much shorter than cell lengths at mid-points of respective ranges. In normal distributions we would expect equal proportions of measurements above and below the mean. However, the percentage of cell lengths shorter than respective mean cell lengths for <u>P. areolatus</u> were 71.4, 68.5, and 73.3%. For <u>P. cuspidatus</u> these values were respectively 72.5, 61, 80, and 81.5%.

In each of the above cases mean cell lengths are longer than median cell lengths and variances are exceptionally high. These data reflect the statistical effects of a small number of provisioned cells of extraordinary length. These cells were usually found to be, but not limited to, the last provisioned cell in a trap nest. Frequently such a nest did not have a vestibular cell, although in a few cases an extraordinarily long cell was followed by a vestibular cell. To eliminate the statistical effects of cells of extraordinary length, I arbitrarily applied a 10% exclusion role in the analysis of cell length data. For each species, 10% of the pooled cell length values from the open end of the distributions were excluded in subsequent analysis.

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Based upon the 10% exlusion rule, P. areolatus cell length data, respectively for 1.6, 2.0, and 2.4 mm bore diameter trap nests, are: number of cells (41, 71, and 25); range of cell lengths (8 to 25.5, 7 to 25, and 7 to 21 mm); median cell lengths (14.17, 13.06, and 12.81 mm); and mean cell lengths (15.13  $\pm$  3.81, 13.51  $\pm$  3.79, 12.68  $\pm$  3.26). Similarly, data for P. <u>cuspidatus</u> provisioned cells from bore diameters 2.4, 3.2, 4.0, and 4.8 mm are respectively: number of cells (38, 195, 164, and 79); range of cell lengths (8 to 22, 6 to 23, 5 to 23, and 5 to 23); median cell lengths (12.89, 11.93, 9.90, and 9.825 mm), and mean cell lengths (13.43  $\pm$  3.19, 12.39  $\pm$  3.45, 10.33  $\pm$  2.38, and 9.47  $\pm$  2.72 mm).

One way analysis of variance for differences in cell lengths associated with differences in bore diameter were significant for P. areolatus ( $\mathbf{F} = 3.30337$ , df = 134, p <.01) and for P. cuspidatus ( $\mathbf{F} =$ 19.51697, df = 472, p <.001). In the case of P. monilicornis, data were too scanty for the application of normal based statistics, but the Kruskal-Wallis rank order test for differences in cell length data was significant ( $\mathbf{H} = 25.7153$ , df = 4, p <.0005). These results indicate that for each of these <u>Passaloecus</u> spp. an inverse relationship exists between bore diameter and cell length. A summary of these analyses are given in Table 9.

Tab	1.	0
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Hean provisioned cell lengths for three <u>Passaloecus</u> spp. from pooled samples, 1984-1987.

Passal	<u>oecus</u> s	pp. provisioned cell	oned cell lengths# (mm)		
areolatus	(N)	cuspidatus (N)	monilicornis	(N)	
15.13 <u>+</u> 3.81	(41)				
13.51 <u>+</u> 3.79	(71)		14.17 <u>+</u> 2.72	(3)	
12.68 ± 3.26	(25)	13.43 <u>+</u> 3.19 (38)	12.47 ± 2.95	(38)	
			9.81 <u>+</u> 2.09	(8)	
		12.50 ± 3.59 (195)	9.93 ± 1.27	(7)	
			7.42 ± .61	(6)	
		10.47 <u>+</u> 3.11 (164)	)		
		10.07 ± 3.37 (79)			
	Passali areolatus 15.13 ± 3.81 13.51 ± 3.79 12.68 ± 3.26   	Passaloecus s areolatus (N) 15.13 ± 3.81 (41) 13.51 ± 3.79 (71) 12.68 ± 3.26 (25)   	Rassaloecus spp. provisioned cell   areolatus (N) cuspidatus (N)   15.13 $\pm$ 3.81 (41)    13.51 $\pm$ 3.79 (71)    12.68 $\pm$ 3.26 (25) 13.43 $\pm$ 3.19 (38)     12.50 $\pm$ 3.59 (195)    10.47 $\pm$ 3.11 (164)    10.07 $\pm$ 3.37 (79)	Passaloecus spp. provisioned cell lengths# (mm)areolatus(N)cuspidatus(N)monilicornis $15.13 \pm 3.81$ (41) $13.51 \pm 3.79$ (71) $14.17 \pm 2.72$ $12.68 \pm 3.26$ (25) $13.43 \pm 3.19$ (38) $12.47 \pm 2.95$ 9.81 \pm 2.0912.50 \pm 3.59(195) $9.93 \pm 1.27$ 7.42 \pm .6110.47 \pm 3.11(164)10.07 \pm 3.37(79)	

\* Ten percent of pooled sample values from skewed end of distribution were excluded in analysis.

With the application of the 10% exclusion rule mean values are clearly more representative cell length measurements and demonstrate an inverse relationship between bore diameter and cell lengths. However, they do not reflect the extreme variation observed in provisioned cell length and we can only speculate on possible causes for such variation. For example, one possible cause could be a declining prey population. As the prey numbers decrease, additional time and energy are expended during provisioning. In this case an optimal closure or partition construction strategy would be the

red to clo ler fot in , le SI th P. P P reduction of the time required to move from the trap nest bore opening to the partition or closure. A partition or closure established closer to the bore opening will produce a cell of disproportionate length and volume.

Results of regression analysis of bore diameter and cell length for three <u>Passalaoecus</u> species are given in Table 10. These analyses indicate that larger bore diameters result in shorter provisioned cell lengths.

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Species	Regression	line	Co-efficient of correlation	Significance		
<u>P. areolatus</u>	Y = -3.06X +	19.90	98	P = .10		
<u>P. cuspidatus</u>	Y = -1.51X +	17.07	97	P < .05		
P. monilicornis	Y = -4.01X +	21.99	97	P < .01		

Simple linear regression of bore diameters and mean cell lengths for three <u>Passaloecus</u> spp.

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Danks (1971c) suggested that the availability of nesting sites was one of the factors limiting populations of aculeate Hymenoptera. If this is true, it should be possible to identify strategies used to optimize available nesting materials. One of these strategies could be the decrease of cell length as bore diameter increases. Fye (1965b), Krombein (1967) and Vincent (1978) gave bore diameter and cell length data for <u>P. cuspidatus</u>. Krombein (1967) reported that fifty-eight provisioned cells from 3.2 mm bore diameter trap nests had a mean length of 16.3 mm and a range of 8 - 52 mm. Four cells from 4.8 mm bore diameter were 7, 8, 13, and 126 mm long and one 6.4 mm bore diameter trap nest had four cells 6, 7, 7, and 9 mm long respectively. Fye (1965b) reported a 6.4 mm bore diameter with four cells, with a mean cell length of 15 mm. Vincent (1978) reported data from 83 soda straw nests with 4.0 mm bore diameters. One hundred-eleven female cells had a mean length of 10.09  $\pm$  2.19 mm and one hundred-ten male cells had a mean length of  $8.82 \pm 2.16$  mm.

Data from Krombein (1965b) and Vincent (1978) suggest that <u>Passaloecus</u> spp. would optimize nesting material by decreasing cell length as bore diameter increases. To test whether <u>Passaloecus</u> spp. would optimize their use of bore volume, trap nests of several bore diameters were made available as nesting sites. Provisioned cell length data were collected from trap nests provisioned by four <u>Passaloecus</u> spp.: <u>annulatus</u>, <u>areolatus</u>, <u>cuspidatus</u>, and <u>monilicornis</u>. Adequate sample sizes were obtained by pooling data from 1984-1987 for <u>P. areolatus</u> and <u>P. cuspidatus</u>. Data for <u>P. monilicornis</u> were sketchy.

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Previous research on <u>Passaloecus</u> makes no reference to cell volume, and no anaylses have been done on relationships between number of prey per cell, cell length, cell volume and bore diameter. If <u>Passaloecus</u> spp. made maximum use of available bore space we could expect constant volumes for cells from different bore diameters. This hypothesis was evaluated by determining cell volumes from mean cell lengths and bore diameters for <u>P. areolatus</u>, <u>P. cuspidatus</u>, and <u>P. monilicornis</u>. The results of these calculations are given in Table 11, and show that mean cell volume increased along with increasing bore diameter for each species considered.

Table 11.

	<u>Passaloecus</u> spp. provisioned cell volumes (mm <sup>3</sup> )							
Bore (mm)	areolatus	cuspidatus	monilicornis					
1.6	30.42 ± 7.66							
2.0	42.44 ± 11.90		44.52 ± 8.54					
2.4	57.36 ± 14.77	60.76 ± 14.43	56.41 <u>+</u> 13.34					
2.8			60.41 ± 12.87					
3.2		100.53 ± 28.87	79.86 <u>+</u> 10.18					
3.6			75.53 <u>+</u> 5.54					
4.0		131.57 <u>+</u> 39.08						
4.8		182.22 ± 60.98						

Bore diameters and provisioned cell volumes for three Passaloecus spp.

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A related question is whether increased cell volume is associated with larger number of provisions. Aphid provisioning data were analyzed for 3.2 and 4.0 mm bore trap nests provisioned by <u>P</u>. <u>cuspidatus</u> with <u>Myzus monardae</u> (Davis). Data for cells with extraordinary length and/or cells in which significant larval feeding had occurred prior to examination of cell contents were excluded from this analysis. Data were available from 58 cells of 3.2 mm bore and 59 cells from 4.0 mm bores. Ranges and means for number of aphids per cell, cell lengths, and cell volumes were determined for these respective bore diameter classes and are presented in Table 12. The t(II) test shows no significant difference in the numbers of aphids provisioned in 3.2 and 4.0 mm bore trap nests. However, differences in cell lengths and volumes were significant. As bore diameter increases, cell lengths decrease and cell volume increases. No data were collected on actual volumes of aphid provisions but a relative index to utilization of available space is cell volume  $(mm^3)/aphid$ . The index for 3.2 mm bore trap nests is 2.895 and for 4.0 mm bores, 3.336. If an equal mean volume per provisioned aphid is assumed for these bore diameters, these indices show a more efficient use of the These results agree with the general subjective 3.2 mm bore. observation that the free space above the aphid provisions was larger in 4.0 mm bores.

Table 12.

An analysis of number of aphids [<u>Mvzus monardae</u> (Davis)] provisioned per cell, cell lengths and cell volumes in 3.2 mm bore and 4.0 mm bore trap nests provisioned by <u>P. cuspidatus</u>, 1987.

				t(II	) sta	tistic	
	Bore	Range	Mean	t value	df	prob	
# of aphids	3.2	22 to 66	35.81 ± 10.25	4 0000			
per cell	4.0	4.0 14 to 74	14 to 74	38.67 <u>+</u> 13.03	1.3098	115	p >.05
Cell	3.2	7 to 23	12.89 <u>+</u> 3.29	4.0706		- ( 0005	
(mma)	4.0	6 to 23	10.27 <u>+</u> 3.28	4.2796	115	p (.0005	
Cell	3.2	56.30 to 184.98	103.67 <u>+</u> 26.49				
volume (mm <sup>3</sup> )	4.0	75.40 to 289.03	129.02 <u>+</u> 41.19	3.9331	115	p <.UUU5	

Scatter plots of numbers of aphids provisioned per cell and cell volumes for 3.2 and 4.0 mm bore trap nest are given in Figures 6 and 7. Simple linear regression of cell volumes on number of aphids provisoned per cell gave the respective regression equations: (Y =54.88 + 1.36X, r = .53) for 3.2 mm bores and (Y = 86.75 + 1.09X, r = .35) for 4.0 mm bores. The correlation coefficients for these data indicate what cell volume is weakly related to numbers of aphids provisioned. In the case of 3.2 mm bores, 25% of the variance of cell volume is accounted for by the variance of numbers of aphid provisions; in 4.0 mm bores only 12.25% of the variance of cell volume is accounted for by the variance of aphid provisions. Cell volumes are not closely related to the numbers of aphids provisioned.



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In addition to bore diameters, several other factors could contribute to variations in lengths of provisioned cells. Vaso behavior related to the placement of cell partitions and closures. could be altered by age, prey availability, proximity of prey, prey switching, weather conditions, competition for nesting sites, and the activity of parasites. To determine whether extraordinary cell lengths were a result of wasp senescence, cell length data for trap nests with known closure dates were examined from P. cuspidatus trap nests of 1984 and 1987. If extraordinary cell lengths were a result of senescence, such lengths would be noted most frequently in late-season nests. Provisioned cells of extraordinary length (24 -116 mm) were found in trap nests provisioned throughout P. cuspidatus nesting season, and in all but three cases the extraordinary cell was the last cell provisioned (Table 13). Senescence can thus be excluded as a principal factor contributing to increased cell length.

Tabl	e 1	13.
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ordinary	length	l <b>.</b>								
Date of	Bore				Cell	length	(mm.)			
closure	(mm)	1	2	3	4	5	6	7	8	9
6-18-84	4.0	11	11	94 <b>*</b>						
6-18-84	4.0	15	101×							
6-20-84	4.8	116 <b>*</b>								
6-21-84	4.8	8	10 <b>8</b> *							
7-09-84	4.0	7	56¥							
7-16-84	4.8	17	24 <b>*</b>	17	56)	ł				
7-16-84	4.8	14	14	72¥						
8-07-84	4.8	14	12	78¥						
6-15-87	4.0	10	10	72¥						
6-19-87	4.0	13	97¥	r						
6-19-87	5.6	7	7	101 <b>*</b>						
7-03-87	3.2	19	19	12	67)	ł				
7-06-87	4.0	7	7	8.5	14	7	7	7.5	13	46¥
7-08-87	4.0	13	10.5	15.5	10	10	67 <b>*</b>			
7-08-87	3.2	47¥								
7-08-87	3.2	16	47 <b>*</b>							
7-08-87	4.8	10	13	77 <b>*</b>						
7-08-87	3.2	23	25¥	51¥						
7-10-87	4.0	12	15	14	59+	ł				
7-10-87	4.0	10	8	8	94*	ł				
7-20-87	4.8	9	105 <del>×</del>							
7-20-87	4.0	10	9	46 <del>*</del>						
7-20-87	4.8	35¥	88¥							
7-20-87	4.8	12	12	91¥						
7-20-87	4.8	13	13	44×						
7-24-87	4.0	23	75 <b>*</b>							
7-27-87	3.2	12	16	17.5	82)	E				

Seasonal distribution of Passaloecus cuspidatus cells of extra-

\*: extra-ordinary cell length

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Another possible cause for increased cell length is the activity of parasites. Data from <u>P. cuspidatus</u> nests of 1984 were examined for evidence that <u>Q. aeneus</u> activity contributed to increased cell lengths. Eighteen of 53 provisioned trap nests were parsitized. Parasitized trap nests contained a total of 59 cells and 27 of these were parasitized by <u>Q. aeneus</u>. Cell length data for these parasitized trap nests is given in Table 14.

Table 14.

Date of	Bore				Ce	ll leng	gth (m	)			
closure	( 💼 )	1	2	3	4	5	6	7	8	9	10
6-14-84	3.2	31#	10	24							
6-17-84	3.2	12#	11	14	12	12	10 <b>#</b>	10	11		
6-18-84	3.2	18#	20 <b>*</b>	27 <b>#</b>	24¥						
6-30-84	3.2	18	19	13	9¥						
7-16-84	3.2	22*	15								
7-24-84	3.2	27	8	12 <del>*</del>							
6-18-84	4.0	32 <b>#</b>	6	9 <b>#</b>							
6-19-84	4.0	25¥	9								
6-21-84	4.0	11	15#								
6-26-84	4.0	12	11	9	9	8¥	8				
7-03-84	4.0	8#	10								
6-12-84	4.8	7 <b>±</b>									
?	4.8	10#	10#								
6-21-84	4.8	8#	108								
6-30-84	4.8	10*	10								
7-16-84	4.8	14#	14	72							
7-16-84	4.8	17 <b>#</b>	24	17#	56						
6-18-84	6.4	6#	6	6 <del>1</del>	6	5¥	6	6	6	5	21

Cell length data from 1984 <u>Passaloecus cuspidatus</u> nests parasitized by  $\underline{0}$ . <u>aeneus</u>.

\*: parasitized cell

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Lengths of provisioned cells from all trap nests of respective bore diameters were as follows: 3.2 mm (6 to 31 mm, n = 79); 4.0 mm (6 to 101 mm, n = 29); 4.8 mm (5 to 116 mm, n = 52); and 6.4 mm (5 to 20 mm, n = 10). Cell length data for eight of 170 cells (approximately 5% of all values) were excluded in the analyses of these data. No cell lengths were excluded from 3.2 mm bore data, 3 cell lengths (56, 94, and 101 mm) were excluded from 4.0 mm bore data, and 5 cell lengths (56, 72, 78, 108, and 116 mm) were excluded from 4.8 mm bore data. No parasitized cells were noted among excluded cells. In each trap nest bore class, mean cell lengths were determined for: all cells, cells from trap nests free of parasites, cells from parasitized trap nests, and parasitized cells. These data are summarized in Table 15.

Table 1	15.
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Cell length data for cells from non-parasitized trap nests and parasitized trap nests provisioned by <u>P. cuspidatus</u>, 1984.

Hean Provisioned Cell Lengths (mm), Standard Deviations, and Number of Cells in Each Class

Bore	All Trap Nests		Trap Nests Free	Trap Nests With	Parasitized	
(mm)	in Bore Class		of Parasites	Parasites	Cells Only	
3.2	x	13.494	12.421	16.00	18.727	
	s	5.207	3.911	6.742	6.916	
	n	79	57	22	10	
4.0	X	12.192	12.8	11.8	16.167	
	s	6.102	4.833	6.747	9.263	
	n	26	10	16	6	
4.8	X	9.787	8. <b>8</b> 61	12.818	11.625	
	S	4.110	3.376	4.783	3.638	
	N	47	36	11	8	
6.4	X S N	7.3 4.584 10	- -	7.3 4.584 10	5.667 .471 3	

 $\overline{X}$  = mean; s = standard deviation; n = number in class.
Though sample sizes are relatively small these data show that parasitism of <u>P</u>. <u>cupidatus</u> cells by <u>O</u>. <u>aeneus</u> results in increased cell lengths in trap nests with bore diameters equal to or less than 4.8 mm. The t(II) test for differences in mean cell lengths between trap nests without parasites and trap nests with parasites was significant for 3.2 mm trap nests (t = 2.343, df = 77, p <.025) and for 4.8 mm trap nests (t = 2.5563, df= 45, p <.005). Parasitized cells from 3.2, 4.0, and 4.8 mm bores had cell lengths which were respectively 51%, 26%, and 31% longer than cells from non-parasitized trap nests. In a single 6.4 mm bore trap nest parasitism did not result in increased cell lengths.

### Bore Depth and Cell Architecture

It was noted from trap-nesting studies of 1985 that small bore trap nests (1.6 mm), with depths of 120 mm, had basal cells of considerable length (84 to 114 mm). Additionaly, large bore trap nests (3.2 - 4.8 mm) occasionally had long vestibular cells. If availability of nesting sites were a limiting factor in provisioning activity. a wasp should maximize its use of available space in a trap nest. However, several factors could mitigate against maximization of bore volume. The distance traveled from the trap nest bore opening to the interior of the trap nest could represent a considerable expenditure of time and energy during cell provisioning and closure. If an aphid colony were some distance from the nesting site or if aphids were in short supply, a strategy that descreased the real time of provisioning activity would be optimal. To study the response of Passaloecus spp. to decreased bore depth. trap nests for the 1986 season were provided with bore depths of 60 and 120 mm. Data were collected on lengths of basal cells, provisioned cells, and vestibular cells; and numbers of cells provisioned.

Sixty-five <u>Passaloecus</u> spp. trap nests with bore depths of 60 mm had basal cells with a mean length of 4.05 mm. Sixty-eight <u>Passaloecus</u> spp. trap nests with bore depths of 120 mm had basal cells with a mean length of 22.09 mm. The Z - approximation of the Mann-Whitney U ranks test for these data was very significant (Z = 3.492, p <.0003). Data for basal cell lengths from <u>Passaloecus</u> spp. trap nests are summarized in Table 16. A decrease in bore depth was accompanied by a decrease in mean basal cell length. <u>Passaloecus</u> spp. were clearly sensitive to changes in bore diameter and depth. As bore diameter decreased, a longer portion of the trap nest bore was unused. Trap nests with bore diameters less than 3.2 mm most clearly demonstrate this phenomenon.

Table 16.

		Bore de				
Bore diameters (mm)	60	(N)	120	(N)	Diam Class r	eter Deans
1.6	12.93	(15)	38.00	(11)	23.54	(26)
2.0	0.00	(17)	23.72	(18)	12.20	(35)
2.4	4.60	(15)	30.94	(16)	18.19	(31)
2.8	0.00	(3)	17.38	(6)	11.89	(9)
3.2	0.00	(6)	7.50	(4)	3.00	(10)
3.6	0.00	(6)	0.00	(6)	0.00	(12)
4.0	0.00	(2)	5.00	(5)	3.57	(7)
4.4	0.00	(1)	0.00	(2)	0.00	(3)
				<del></del>		<del></del>
Grand Means	4.05	(65)	22.09	(68)	13.27	(133)

Mean basal cell lengths from eight bore diameter classes and two bore depth classes. Pooled data from <u>Passaloecus</u> trap nests, 1986.

Data for basal cell lengths from trap nests of four <u>Passaloecus</u> spp. are summarized in Table 17. Lengths of basal cells in 60 mm bores were shorter for each <u>Passaloecus</u> spp.

Mean basal cell leng	ths for <u>Pass</u>	aloecus	spp., 1986.	
	depth (mm)			
Passioecus spp.	60	(N)	120	(N)
annulatus	9.17	(3)	48.33	(3)
<u>areolatus</u>	4.38	(21)	23.79	(28)
<u>cuspidatus</u>	0.00	(14)	6.37	(16)
monilicornis	3.72	(9)	40.25	(8)

Table 17.

A summary of provisioned cell length data for <u>Passaloecus</u> spp. is presented in Table 18. These data show a possible, though inconsistent trend of decreasing cell length as bore depth increases. The t(II) test for differences in mean cell lengths for <u>P areolatus</u> was non-significant (t = 1.7885; df = 132; p >.05, <.10). For <u>P</u>. <u>cuspidatus</u> differences in mean cell length for cells from 60 and 120 mm bores was very significant (t = 3.2554, df = 95, p <.001).

Table 18.

Mean lengths of provisioned cells of Passaloecus spp., 1986.

	Mean provisioned cell lengths <sup>#</sup> (mm)						
			Bore depths (mm)				
	A11 t'	nests	60		120		
Passaloecus SDD.	Mean	(N)	Mean	(N)	M <del>e</del> an	(N)	
<u>annulatus</u>	10.8	(20)	11.10	(10)	10.50	(10)	
areolatus	14.01	(134)	13.45	(56)	14.50	(78)	
<u>cuspidatus</u>	10.13	(96)	9.06	(36)	10.70	(61)	
monilicornis	11.72	(45)	11.76	(21)	10.40	(24)	

\* The effects of occasional extraordinary cell lengths have been compensated for by a standard deletion of 10% of cell length values from the skewed end of the data for each species.

Pooled data of vestibular cell lengths from <u>Passaloecus</u> spp. trap nests for 1986 showed differences in vestibular cell lengths were most pronounced in bore diameter classes less than 3.2 mm. The 2 approximation of the Mann-Whitney U ranks test for differences in lengths of vestibular cells between 60 and 120 mm bores was significant (Z = 1.8826, p <.03). Vestibular cell lengths were influenced by bore depth, with vestibular cell lengths shorter in 60 man bores in six of eight bore diameter classes. In 60 mma bores with diameters of 1.6, 2.0, and 2.4 mm, vestibular cells were respectively 51.57, 42,33, and 46.42 % shorter than vestibular cells in respective 120 mm bores. The mean vestibular cell length for all 60 mm bores was 21.38 mm and for 120 mm bores, 34.23 mm. Vestibular cell lengths in 60 mm bores were 37.54 % shorter than vestibular cells in 120 mm Mean vestibular cell lengths for four <u>Passaloecus</u> spp. are bores. given in Table 19. With the exception of P. monilicornis, these data are consistent with results of the analyses of the pooled data, with vestibular cells shorter in 60 mm bores.

		Bore dep	ths (mm)	
Passaloecus spp.	60	(N)	120	(N)
annulatus	8.50	(3)	29.67	(3)
areolatus	23.48	(21)	38.45	(28)
<u>cuspidatus</u>	37.86	(14)	61.00	(16)
monilicornis	11.67	(9)	10.75	(8)

Table 19.

## Bore Depth and Numbers of Provisioned Cells

In 1986 <u>Passaloecus</u> produced 133 trap nests containing 363 cells (mean = 2.77). Sixty-five trap nests of 60 mm bore contained 157 cells (mean = 2.42). Sixty-eight trap nests of 120 mm bore contained 206 cells (mean 3.03). Data from bore diameters of 1.6, 2.0 and 2.4 mm totaled 43 trap nests of 120 mm bore with 124 cells (mean 2.88) and 47 trap nests of 60 mm bore contained 120 cells (mean 2.55).

Mean numbers of cells provisioned by <u>Passaloecus</u> spp. in trap nests of two bore depth classes are given in Table 20. For three <u>Passaloecus</u> spp. the mean number of provisioned cells decreased in 60 mm bore depth trap nests compared to 120 mm bore depth trap nests. Statistical tests for differences in numbers of provisioned cells per bore depth class were significant only for <u>P. cuspidatus</u>.

Hean number of cells po	er trap nes	t for <u>Passa</u>	loecus spp.	, 1986.				
		Bore depth (mm)						
Passaloecus spp.	60	(N)	120	(N)				
annulatus	3.33	(3)	3.00	(3)				
<u>areolatus</u>	2.36	(22)	2.76	(29)				
<u>cuspidatus</u>	2.62	(13)	3.70	(17)				
monilicornis	2.78	(9)	3.50	(8)				

Table 20.

A 100% increase in bore depth, and presumably potential volume for nesting, resulted in an average 25.2% increase in number of provisioned cells per trap nest. These increases were respectively by species: P. areolatus, 16.95%; P. cuspidatus, 48.1%; and P. monilicornis, 25.9%. These results generally suggest that small bore trap nests with proportionately shorter bore diameters are used more efficiently by these trap-nesting wasps. However, it is also noted that there was no significant difference in the frequency of trap nest selection based upon these bore depths.

Bore Opening Orientation and Frequency of Trap Nest Use

A possible concern in studies of trap-nesting bees and wasps is whether the orientation of trap nest bore openings influence the frequency of trap nest selection as a nesting site. The effect of bore orientation among trap nests distributed in a forest edge was tested by comparing orientation frequencies with trap nest selection frequencies. Trap-nesting materials from 1984 and 1986 provided data for this study. Trap-nesting stations were established within a mixed hardwoods edge between a red pine plantation and an old field. Bore openings had four orientations: south-west, facing the old field; north-east, facing the pine woods; and north-west and south-east with bores parallel to the long axis of the forest edge. Use of trap nests with north-west and south-east orientations were pooled into a edge class since field notes on those orientations were confused

Table 21 summarizes the results of this study. The chi-square (I) test for differences from expected frequencies of trap nest selection shows no significant difference between south-west and north-east orientation. Chi-square was also non-significant when south-west, north-east and edge orientations were tested. These data suggest that <u>Passaloecus</u> spp. have no preference for bore orientation among trap nests distributed in a forest edge. However, the influence of a north-west orientation vs. a south-east orientation needs further examination.

	Orientation *	Trap nest Frequency	U <del>se</del> Frequency
1984	old field (S-W)	189	18
•	edge (N-W, S-E)	54	3
•	pine forest (N-E)	189	18
986	old field (S-W)	360	28
•	edge (N-W, S-E)	432	35
•	pine forest (N-E)	360	22

Bore opening orientation and frequency of use by <u>Passaloecus</u> spp., 1984 and 1986.

Table 21.

\* All trap nests were placed in a mixed hardwoods edge between a red pine plantation and an old field.

#### Bore Diameters and Numbers of Provisioned Cells

As bore diameter increased the available volume for provisioned cells also increased but large bore trap nests did not generate more <u>Passaloecus</u> cells. Data from <u>P. cuspidatus</u> trap nests of 1984, 1985, and 1987 were pooled to examine the effects of bore diameter on the number of provisioned cells. One hundred forty-six nests contained 496 cells. The number of cells provisioned per trap nest ranged from 1 - 10 with a mode of 2, median of 2.85, and a mean of 3.42. Table 22 summarizes data from bore diameters 2.4 to 6.4 mm. Trap nests with bores of 3.2 - 4.8 mm accounted for 90.4 % of all <u>P. cuspidatus</u> trap nests and 88.91% of all <u>P. cupsidatus</u> cells. While there is no significant difference in the mean number of cells produced in 3.2 and 4.8 mm bores there is a significant difference in the numbers of nests  $(X^2 = 12.8444, df = 1, p < .0005)$  and number of cells  $(X^2 = 45.1201, df = 1, p , .0005)$ , produced in these bore classes.

Frequency of <u>P</u> . <u>cuspidatus</u> trap nests and cells from 120 mm bore trap nests from 1984, 1985, and 1987.									
Trap nest bore (mm)	Bore frequency	cusple nests	datus cells	Cells per nest	<b>%</b> of nests	% of cells			
2.4	339	9	31	3.44	6.21	6.25			
3.2	609	61	198	3.25	42.07	39.92			
4.0	609	42	1 <b>58</b>	3.76	28.97	31.85			
4.8	609	28	85	3.04	19.31	17.14			
5.6	339	2	4	2.00	1.38	0.80			
6.4	369	3	11	4.67	2.07	2.82			

Table 22.

Influence of Station Species on Frequency of Trap Nest Use

Station species have received little attention in previous research reported on trap-nesting <u>Passaloecus</u> spp. Several factors could contribute to the significance of station selection in These include the availability of appropriate trap-nesting studies. nesting cavities, presence of aphids, and closure materials. In 1984, all trap-nesting stations were Juglans, and P. cuspidatus was the only Passaloecus observed and reared. For 1986, nineteen of twenty-eight stations were Juglans and another nine stations included 5 Fraxinus, 1 Prunus, 2 Populus, and 1 Fagus. Thirty trap nests were provisioned by P. cuspidatus; eighteen by P. monilicornis; six by P. annulatus, and fifty-one by P. areolatus. Chi-square (I) was used to test for differences in <u>Passaloecus</u> selection of nesting stations between Jugians and other species. The expected frequencies were based upon station-species frequencies: Juglans (67.86%) and others (32.14%). Observed and expected frequencies of trap nest use are given in Table The chi-square (I) statistic is very significant ( $X^2 = 23.6592$ , 23. df = 2, p <.0005), and indicates that the differences in distribution of <u>Passaloecus</u> among these stations are not random and <u>P. areolatus</u> data made the strongest contribution to the chi-square statistic.

	Juai	ans	<u>Others</u>		
	Observed Expected		Observed	Expected	
<u>cuspidatus</u>	18	20.358	12	9.642	
monilicornis	16	12.2148	2	5.7852	
<u>areolatus</u>	49	34.6086	2	12.6354	

Station selection by three Passaloecus spp., 1986.

Data from a secondary site, consisting of stations 25 through 28. were particulary interesting relative to station selection. At these four stations (three Juglans and one Fagus) trap nest bundles were distributed at heights of 1 to 9 meters, with 1 meter intervals. One hundred eight trap nests were placed at each station, a bundle of 12 at each height. The frequencies of trap nest use at these four stations and 9 heights are summarized in Table 24. Of 432 trap nests, 259 were used by trap-nesting wasps and bees. The respective frequencies of use at these stations were 75, 71, 52, and 61. There was no significant difference in the frequency of trap nest use among these stations. However, the chi-square (I) test for differences in frequency of use by Passaloecus was very significant ( $X^2 = 30.03225$ , df = 3, p <<.001). Fifty-five trap nests were presumed to be provisioned by <u>Passaloecus</u> spp. based upon closure materials, aphid remains, and prepupae. P. areolatus was found in 40 trap nests

collectively from heights of 3, 6, and 9 m and used bore diameters of 1.6, 2.0 and 2.4 mm. P. <u>cuspidatus</u> was found in 5 trap nests collectively from heights of 4 and 7 m and bore diameters of 4.0 and 4.4 mm. While 61 trap nests were used at the <u>Facus</u> station by trap-nesting wasps and bees, no trap nests at this station were used by <u>Passaloecus</u>. Competition is not a likely explanation of the exclusion of <u>Passaloecus</u> from the <u>Facus</u> station since the arrays of trap nest users other than <u>Passaloecus</u> spp. among these stations were similiar. Other factors could account for the absence of <u>Passaloecus</u> spp. from <u>Facus</u>. These include lack of natural nesting cavities and closure material, such as resin, frass, and loose bark; and an absence of aphids. These data indicate a strong correlation between station species and <u>Passaloecus</u> use. <u>P. areolatus</u> prefers <u>Juclans</u> much more strongly than does <u>P. cuspidatus</u>. Frequency of trap nest use at secondary site by all trap-nesting wasps and bees, and by <u>Passaloecus</u> spp., 1986.

		All Wasps and Bees				Passaloecus spp.			
Height (m)		Jugla	ns	Pagus	Ju	ugi an:	9	Fagus	
9	9	9	4	4	7	7	1	0	
8	11	10	6	9	0	0	0	0	
7	5	9	1	8	0	4	0	0	
6	9	9	5	1	7	9	2	0	
5	10	8	5	10	0	0	0	0	
4	4	5	6	8	0	2	0	0	
3	9	7	8	3	3	6	6	0	
2	8	7	11	9	0	0	1	0	
1	10	7	6	9	0	0	0	0	
					-		-	_	
Totals	75	71	52	61	17	2 <b>8</b>	10	0	

Stations and Frequency of Use

Selection of trap-nesting stations for the 1987 season was based upon the relative abundance of tree species at the study site. This differed significantly from station selection for the Summer 1986, when <u>Pinus</u> was systematically excluded as a trap-nesting station. The species distribution of forty-nine trap-nesting stations for Summer 1987 was Pinus - 14, <u>Juglans</u> - 22, <u>Fraxinus</u> - 8, and others (<u>Ulmus</u>, <u>Acer</u>, and <u>Populus</u>) - 5. The respective frequencies of trap nest use by <u>P. cuspidatus</u> among these stations were: <u>Pinus</u> - 55, <u>Juglans</u> - 19, <u>Fraxinus</u> - 5, and others - 4 (Table 25). The chi-square (I) test statistic is very significant for these data ( $X^2 = 57.9884$ , df = 3, p <<.0005). <u>Pinus</u> stations are clearly preferred by <u>P. cuspidatus</u>.

Table 25.

				Station s	peci	<b>es</b>		
	Pinus		Juglans		Fraxinus		Others	
Station Frequency	14	(28.57%)	22	(44.90%)	8	(16.33%)	5	(10.20%)
U <b>se</b> Frequency	55	(66.27%)	19	(22.89%)	5	(6.02%)	4	(4.82%)

Station species frequency and frequency of trap nest use by Passaloecus cuspidatus, 1987.

### Aphid Provisioning by <u>Passaloecus</u> <u>cuspidatus</u>

<u>P. cuspidatus</u> was selected for intensive investigation of trap-nesting biology during the summer of 1987. <u>P. cuspidatus</u> is the largest <u>Passaloecus</u> in the study area, its color markings (the ventral surface of scape, dorsal surface of mandible, and basal portion of hind tibia are white) and consistent pattern of ringing nest openings with resin prior to provisioning, make accurate field identification possible. Other <u>Passaloecus</u> including <u>annulatus</u>, <u>areolatus</u>, and <u>monilicornis</u> are smaller and lack distinctive color markings, making field identification uncertain.

P. cuspidatus was presumably active in the study area prior to site establishment on May 29, 1987. Five trap nests were ringed with resin as of June 1, 1987. Trap nest provisioning was observed on June 1 (4 trips, 2:39 pm - 3:20 pm); June 3 (7 trips, 12:31 pm - 1:35 pm); June 18 (16 trips, 10:17 am - 11:43 am); and July 5 (8 trips, 4:31 pm to 5:13 pm). Nesting activities continued through the first week of August with no trap nests ringed or closed with resin after August 6, 1987. Cessation of <u>P. cuspidatus</u> activity was verified by observations on August 8, 14, and 21, 1987, which provided no evidence of additional activity. The minimum provisioning period for this wasp population was seventy days. This corresponds well with the range of flight dates (June 14 - August 14) for <u>P. cuspidatus</u> material from the

Museum of Zoology of the University of Michigan and the Entomology Museum of Michigan State University, and is supported by my observations of <u>P</u>. <u>cuspidatus</u> activity in 1984 and 1985. In 1984, provisioning activity was first observed between June 4 and 12 and terminated between August 4 and 13. In 1985, emergence of <u>P</u>. <u>cuspidatus</u> from a natural nest occurred May 10 and nesting activity ceased August 20.

The provisioning period of <u>P</u>. <u>cuspidatus</u> for 1987 was divided into seven, 10-day intervals and tallies were made of ringed and closed trap nests for each interval and are given in Figures 8 and 9. Increasing numbers of closed trap nests in intervals three and four suggest that <u>P</u>. <u>cuspidatus</u> made a behavioral response to increased numbers of prey. The chi-square (I) test for differences in closure frequency for these intervals is significant ( $X^2 = 24.8387$ , df = 6, p <.001).



Figure 8. Frequency of ringed and closed trap nests during 10-day intervals beginning May 29 and ending August 6, 1987.



Figure 9. Cummulative frequencies of ringed and closed trap nests during 10-day intervals beginning May 29 and ending August 6, 1987.

P. cuspidatus used <u>Cinaria</u> sp., <u>Dactynotus</u> sp., <u>Euceraphis</u> sp., <u>Macrosiphum euphorbiae</u> (Thomas), <u>Myzus</u> sp., <u>Myzus</u> <u>cerasi</u> (Fabricius), <u>Myzus monardae</u> (Davis), and <u>Sitobium avenae</u> Fabricius as provisions. Table 26 summarizes data on six presumed types of aphid provisions. Multiple t(II) tests for differences in number of aphids provisioned are significant for <u>Myzus monardae</u>, <u>Cinaria</u> sp., and <u>Macrosiphum</u> euphorbiae, [Myzus monardae and Cinaria sp., t(II) = 7.05053, df = 193, p < .001; <u>Cinaria</u> sp. and <u>Macrosiphum euphorbiae</u>, t(II) = 3.62055, df = 72, p < .001; and Myzus monardae and Macrosiphum <u>euphorbiae</u>, t(II) = 10.7478, df = 197, p < .001]. Differences in number of aphids provisioned can be correlated to relative aphid size, with <u>Myzus monardae</u> the smallest and <u>Macrosiphum euphorblae</u> the largest. In some cases larval development in interior cells was guite advanced and much of the provisons were consumed. Thus the mean number of aphids provisioned per cell is a minimum, the true mean being slightly higher for each species of aphid provisioned.

Aphids provisioned by <u>P. cuspidatus</u> , 1987.								
Aphid Type*	Number of Trapnests	Number of Cells	Mean # of Aphids	Standard Deviation	Standard Error			
1	46	160	37.0375	11.8080	.9335			
2	9	35	26.8287	7.6625	1.2952			
3	12	39	21.7949	8.2902	1.4882			
4	3	8	28.5000	7.7298	4.1748			
5	3	8	43.0000	17.5770	2.7 <b>329</b>			
6	1	6	34.8333	9.0077	3.6774			

Table 26.

\* 1 = Myzus monardae; 2 = Cinaria sp.; 3 = Macrosiphum
euphorbiae; 4 = Euceraphis sp. and Myzus sp.; 5 = Myzus cerasi;
6 = Sitoblum avenae.

The range of numbers of aphids provisioned per cell for aphid species 1 through 6 were: 9 - 74, 13 - 51, 9 - 43, 18 - 39, 23 - 74, and 24 - 47 respectively. The mean number of aphids provisioned per trap nest were: species 1 - 128.83; species 2 - 104.33; and species 3- 70.75. The mean number of cells provisioned by P. <u>cuspidatus</u> for these three aphid species were: species 1 - 3.48; species 2 - 3.89; and species 3 - 3.25.

Two trap nests had an extraordinary number of provisions. One contained 430 aphids (eight cells, 53.75 aphids per cell) and another contained 334 aphids (five cells, 66.80 aphids per cell). Unfortunately, aphid samples for identification were not taken from these trap nests.

Figure 10 summarizes data on the seasonal changes in aphid by P. cuspidatus and relative numbers of aphids selection provisioned. P. cuspidatus was not restricted to a particular aphid species and was able to switch to available resources. Peaks In provisioning rates were assumed to be related to increased aphid numbers. Figures 11 and 12 summarize data on aphid provisioning activities. The provisioning period was divided into fourteen 5-day intervals. The number of aphids provisioned in each interval were tallied. Initial provisioning activity was moderate and five trap nests were ringed with resin within one or two days of trap nest station establishment. Between May 29 and June 7, <u>Cinara</u> sp., Euceraphis sp., Myzus sp., and Sitobion avenae Fabricus were

11-7 IIIV <u>Hacrosiphus</u> euchordiae (Thomas) Seasonal changes in prey selected by P. <u>cuspidatus</u>, Summer 1987. Sitobium avenue Fabricius Acception of the second D Uzus maardae (Davis) 111 S-E **A** Claaca sp. 111 **A - 65** 114 × **Z-ZI**M 0 • Passaloecus cuspidatus Prey Selection Summer 1987 Intervals in Provisioning Season **2-91** IIA LI-ELIM VII 8-12 712 J-C IIV V126-V112 **/Z・Z** W 2-91 IA LI-SI IN VI 8-12 Figure 10. 7-2 W 21A-62 A **₹-१२**∧ 000 100 ė 200 

Number of Aphids Provisioned / Interval





Number of aphids provisioned by P. cuspidatus during 5-day intervals beginning May 29 and ending August 6, 1987. Figure 11.





Cummulative number of aphids provisioned by P. <u>cuspidatus</u> during 5-day intervals beginning May 29 and ending August 6, 1987. Figure 12.

used as provisions. From June 8 through July 27, <u>Myzus monardae</u> (Davis) was the preferred prey while <u>Macrosiphum euphorbaie</u> (Thomas) and <u>Myzuz cerasi</u> (Fabricius) were provisioned in significant numbers between June 28 and July 17.

Provisioning rates were guite varied and were estimated on the basis of number of cells provisioned and dates of bore ringing and closure. A scatter-gram (Figure 13. A.) summarizes data from 79 trap nests. Trap nests with estimated provisioning periods of one to three days contained from one to ten provisioned cells. Trap nests with estimated provisioning periods of 6 to 8 days contained two to eight provisioned cells. Trap nests with provisioning periods of 10 to 21 days contained one to five provisioned cells. The estimated number of cells provisioned per day ranged from a low of 0.1 to a high of 5. Several variables could influence provisioning rates. Exceptionally high provisioning rates could be the result of close proximity of aphids and closure materials to the nesting station. Aphids and closure materials somewhat removed from the nesting station could produce low provisioning rates. An additional possible cause for low provisioning rates would be a temporary cessation of provisioning activity. This cessation might be necessary to allow the development of additional ova following a period of provisioning and oviposition Two hundred eighty cells were provisioned during a activity. cummulative provisioning period of 381 days. The average provisioning rate per trap nest was .7349 cells per day. Trap nests worked less than four days had a higher than average provisioning rate and trap nests worked longer than four days had lower than average provisioning rates.

Least squares simple linear regression of average numbers of cells provisioned and length of the provisioning period per trap nest produced the regression equation Y = -.20X + 3.99 (Figure 13. B.) and a correlation coefficient of -.59, suggesting a weak negative relationship between length of the provisioning period and number of cells provisioned. With the deletion of five extreme data points (Figure 13.: m, n, o , p, and q), least squares regression produced the equation Y = .30X + 2.12 (Figure 13. C.) and a correlation coefficient of .78, indicating a moderate positive correlation between the duration of a trap nest provisioning period and the number of cells provisioned.



Figure 13. Provisioned cell production rates for <u>P. cuspidatus</u>.

# Economics of Cell Partitions and Closures

Resin gathering activity was observed at resin flows on Pinus strobis on June 17, 1987. One and one-half inch fence staples had been used to secure trap nest bundle carriers to trunks of trees selected as trap-nesting stations. Resin flows were produced in response to fence staple wounds. P. cuspidatus selected resin flows with dimensions 9 mm by 4 mm. The wasp's mandibles were used in a scissors-like fashion to excise a drop of resin with a diameter the width of the wasp's head. When separation of a resin drop was nearly complete, the wasp backed directly away from the resin flow. A thin strand of resin, connecting the resin drop to the flow, was drawn into the excised drop by lateral and circular motions of the wasp's head. Any remaining remnant of the resin strand was cut off by a continued backward movement combined with an abrubt turning to the left or right. Twenty-two resin gathering trips were observed between 9:47 am and 11:42 am. Resin drops were carried on the ventral surface of the mandibles.

Three separate resin flows were used during these resin gathering activities. Resin flow (I) was visited repeatedly and the wasp returned directly to the resin flow, landing within a few centimeters of the flow and approaching it directly. After a number of resin gathering trips, the remaining portion of the resin flow was too small, or of improper consistency, and was abandoned as a resin source.

The <u>Pinus</u> trunk was searched for another appropriate resin flow and resin gathering resumed. Resin flow (II) was then used repeatedly as a resin source. After three or four trips to resin flow (II) the wasp made a trip to resin flow (I), explored the resin mass, and returned to resin gathering at flow (II). Resin gathering was again observed June 18 (eight trips, 4:31 pm - 5:13 pm) and July 24 (11 trips between 9:00 am and 10:00 am, with no elapsed time recorded). Ringing of trap nest bore openings was also observed and the following action pattern was noted. <u>P. cuspidatus</u> landed at or within a few centimeters of the trap nest opening, entered head first, exited and re-entered gaster first. The wasp then appeared at the nest opening and with her mandibles spread a thin layer of resin on the face of trap nest at the margin of the opening.

Krombein (1967) noted that resin partitions were usually .25 and occasionally 4.0 mm thick, while closures, ranging from .25 to 4.0 mm, were usually 1.0 mm thick. Vincent (1978) noted that 4 drops of resin Data from my studies of 1987 were were used for nest closures. examined to determine the variability of partition and closure dimensions, their volumes, and the energetics of resin gathering. It was noted during resin gathering described above that an excised drop of resin had a diameter approximately equal to the width of the wasp's head. Given a diameter of 1.5 mm. a resin drop carried by P. cuspidatus has a volume of  $1.77 \text{ mm}^3$ . The thickness of resin partitions of 295 provisioned cells ranged from 0.1 to 5.0 mm in trap nests with bore diameters 2.4 to 6.4 mm. Median and modal partition thicknesses were 0.5 mm; the mean partition thickness was 0.66 mm.

Seventy-one closures had thicknesses ranging from 0.25 to 4.0 mm with a mean of 1.69 mm.

Based upon the bore diameters and thicknesses indicated above, the volume of resin required for partitions and closures ranged from 1.13  $mm^3$  to 62.83 mm^3. The volumes of resin required for partitions and closures in bores most frequently used by P. cuspidatus are respectively: 3.2 mm - 5.31 and 13.59; 4.0 mm - 8.29 and 21.24; and 4.8 mm - 11.94 and 30.58 mm<sup>3</sup>. Given a volume of 1.77 mm<sup>3</sup> per resin drop, the numbers of resin gathering trips for partitions and closures for these respective bores are: 3.2 mm - 3 and 7.68 (8); 4.0 mm - 4.68 (5) and 12.0; 4.8 mm - 6.75 (7) and 17.28 (18). These data are rather conservative since they have not taken into consideration the foundations for closures or partitions. Foundations, consisting of a resin ring on the wall of the trap nest bore, have base widths greater than that of their respective partition or closure. Resin partitions, closures, and their respective foundations, represent a significant energy investment. Resin volumes and bore diameters across which resin must be drawn possibly contribute to the upper limits of the bore diameters used by <u>P. cuspidatus</u>. The distribution of partition and closure thicknesses from P. cuspidatus trap nests are given in Figure 14.



Thickness of resin partitions and closures in E. cuspidatus trap nests. Figure 14.

#### SUMMARY AND CONCLUSIONS

Several <u>Passaloecus</u> spp. were found in a small study area on the campus of Concordia College, Ann Arbor, Michigan. <u>Passaloecus</u> spp. that used artificial nesting materials in the area included: <u>P. annulatus</u>, <u>P. areolatus</u>, <u>P. cuspidatus</u>, <u>P. monilicornis</u>, and <u>P. singularis</u>. <u>P. lineatus</u> and <u>P. turionum</u> were also collected from the campus area but were not reared from trap nests at the study site.

Trap nests with bores greater than 4.8 mm were rarely used by Passaloecus spp. while diameters of 1.6 - 4.8 mm gave good results. Passaloecus nesting sites were partitioned on the basis of bore diameter, height, and station species. Passaloecus cuspidatus preferred <u>Pinus</u> stations. This preference is possibly associated with the availability of resin, which was enhanced by the method used to secure trap nest bundles to trap-nesting stations. P. cuspidatus also preferred trap nests heights below 3 meters and bore diameters from 2.0 to 4.8 mm. Passaloecus areolatus preferred Juglans stations, trap nest heights above 3 meters and bore diameters 1.6 - 2.4 mm. Bore selection seems to be based upon wasp size while height distribution could be influenced by the usual distribution of natural nest sites. It might be suggested that larger diameter natural nesting sites are distributed at lower heights and smaller natural nesting sites at greater heights.

Trap nest architecture, including the lengths of basal cells and vestibular cells was influenced by bore diameters and bore depths. An

inverse relationship was found between bore diameter and cell length. Increased bore diameters resulted in decreased lengths of provisioned cells, while activities of parasites were associated with increased cell lengths. Wasp senescence did not result in increased lengths of provisioned cells. Volumes of provisioned cells increased along with increased bore diameter, but numbers of aphids provisioned did not increase proportionately with increased volume. Bore volume was not maximally used for provisioned cells. Basal cell lengths, in trap nests with bore diameters less than 3.2 mm, were significantly reduced in trap nests of 60 mm bore depths. The number of provisioned cells per trap nest increased for all <u>Passaloecus</u> spp. as bore depth increased, but was not statistically significant. Small bore trap nests with 60 mm depths were used more efficiently that trap nests with 120 mm depths.

Passaloecus cuspidatus were active from late May through early August, and provisioned at eight species of aphids. The numbers of aphids provisioned differed significantly among three aphid species and was inversely related to the size of the aphid. Two hundred eighty cells were provisioned during 381 provisioning days for a rate of .7349 cells per day. The numbers of aphids used as provisions varied dramatically (9 - 74). While small variations could be explained on the basis of differences in sizes of aphids, such large differences are more problematical. Suggested causes of large variation include sudden weather changes and the disruptive behavior of parasites. Passaloecus spp. were parasitized by <u>Omalus aeneus</u>, <u>O</u>. iridescens, <u>Trichrysis doriae</u>, <u>Poemenia thoracica</u>, and <u>Poemenia</u> albipes.

These studies add significantly to the literature on the biology of <u>Passaloecus</u>. The efficiency of small bores (1.6 - 4.8 mm) and bore depths of 60 mm is demonstrated for small trap-nesting species. Techniques and methods described in this paper can be applied to the aphid provisioning activity of other <u>Passaloecus</u>. This study also shows that <u>Passaloecus</u> should be added to the classical list of aphid predators. Finally, artificial nesting materials were used very successfully and provided an inexpensive and biologically interesting technique for the study of aphid hunting wasps.
APPENDICES

#### APPENDIX 1

Record of Deposition of Voucher Specimens\*

The specimens listed on the following sheet(s) have been deposited in the named museum(s) as samples of those species or other taxa which were used in this research. Voucher recognition labels bearing the Voucher No. have been attached or included in fluid-preserved specimens.

Voucher No.: 1989-08

Title of thesis or dissertation (or other research projects):

TRAP-NESTING BIOLOGY OF PASSALOECUS CUSPIDATUS SMITH (HYMENEOPTERA: SPHECIDAE) AND SYMPATRIC SPECIES

Museum(s) where deposited and abbreviations for table on following sheets:

Entomology Museum, Michigan State University (MSU)

Other Museums:

Investigator's Name (s) (typed) John Morris Fricke

#### Date October 10, 1989

\*Reference: Yoshimoto, C. M. 1978. Voucher Specimens for Entomology in North America. Bull. Entomol. Soc. Amer. 24:141-42.

Deposit as follows:

Original:	Include as Appendix 1 in ribbon copy of thesis or dissertation.
Copies:	Included as Appendix 1 in copies of thesis or dissertation. Museum(s) files. Research project files.

This form is available from and the Voucher No. is assigned by the Curator, Michigan State University Entomology Museum.

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Species or other taxon	Label data for specimens collected or used and deposited	Larvae Eggs	Nymphs	Adults ¥	Adults d	Other	Museum where depos- ited
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Passaloecus annulatus (Say)	MICH: Ann Arbor Washtenaw Co. May 17, 1987 John M. Fricke Traonest 2-85-31			н			nsw
Passaloecus annulatus (Say)	MICH: Ann Arbor Washtenaw Co. John M. Fricke May 20, 1987 Trapnest 3A-86-63-1 Trapnest 3A-86-63-2			нн			nsw W
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Pomenia albipes (Cresson)	MICH: Ann Arbor Washtenaw Co. May 10, 1987 John M. Fricke Trapnest 1A-86-67-3 Trapnest 1A-86-67-3						MSU
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#### APPENDIX 2

Preliminary Surveys and Selection of Study Area

During the summers of 1982 and 1983 malaise trap (Towne's design) collections were made to survey in general the Hymenoptera of Concordia College, Ann Arbor, Michigan. The 235 acre campus is the former Earhart Estate. Pine plantations, mixed hardwoods, old fields and meadows provide generous areas for study removed from the central campus. Table 27 and Table 28 respectively give the families of Hymenoptera and sub-families and tribes of the Sphecidae that were collected. The <u>Passaloecus</u> collected included the following: <u>P. cuspidatus</u> Smith - 3; <u>P. lineatus</u> Vincent - 2; <u>P. singularis</u> Dahlbom - 42; and <u>P. turionum</u> Dahlbom - 4.

Table 27

Families of Hymenoptera collected at Concordia College, Ann Arbor, Michigan, during the Summers of 1982 and 1983 using a malaise trap of Towne's design.

Pamphiliidae Argidae Diprionidae Tenthridinidae Siricidae Xiphidriidae Braconidae Ichneumonidae Mymaridae Eulophidae	Euchartidae Perilamphidae Torymidae Pteromalidae Chaicididae Cynipidae Gasteruptiidae Heloridae Proctotrupidae Ceraphronidae	Diapriidae Scieionidae Chrysididae Bethylidae Dryinidae Tiphiidae Mutillidae Formicidae Vespidae	Eumenidae Pompilidae Sphecidae Colletidae Halictidae Andrenidae Megachilidae Anthophoridae Apidae
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Table 28

Sub-families and tribes of the Sphecidae collected at Concordia College, Ann Arbor, Michigan, during the summers of 1982 and 1983 using a malaise trap of Towne's design.

Sphecinae Sphecini Scelephronini	Larrinae Larrini Trypoxylonini Miscophini	Nyssoninae Alyssonini Nyssonini Gorytini				
Astatinae Astatini	Crabroninae Crabronini	Philanthinae Philanthini Cercerini				
Pemphredoninae Psenini Pemphredonini						

Concurrent with malaise trap collecting, trap-nesting studies were conducted between June 30, 1982, and August 26, 1983, to determine the effectiveness of trap-nesting techniques and the presence of trap-nesting wasps, especially <u>Passaloecus</u>. Trap nests were constructed using techniques described by Krombein (1967). Trap nest bundles were assembled for field distribution using Fye's methods (Fye, 1965). For the 1982 season trap nests consisted of clear white pine blocks (19 X 19 X 152 mm) drilled to a depth of 114 mm. Bore diameters were nominally 3.2, 4.8, 6.4, 8.0, and 9.6 mm. Trap nests were bound together into 3 X 3 bundles of nine trap nests. Bundles were attached to  $2' \times 2'$  wooden stakes, four bundles to a stake. Three sites were selected and three stakes (4 bundles of 9 trap nests each) were placed at each site (Figure 15). Site A was a forest edge adjacent to the campus ponds; Site B was a wooded fence row southwest of St. Paul Lutheran School; and Site C was an edge between a pine plantation and an old field that faces the Huron River.



Figure 15. Schematic map of Concordia College, Ann Arbor, Michigan. Indicating trap-nesting sites for 1982.

Three hundred twenty-four pine trap nests were placed in the field. In late September these materials were removed from the field sites. One stake from Site A and another from Site B were lost due to vandalism. Between October 4, 1983, and March 18, 1983, the remaining 252 trap nests were opened and 40 contained overwintering contents. Larvae and prepupae were removed from some trap nests and stored in alcohol vials. Others were placed in rearing tubes to rear out adults. Adults of the following families were obtained: Bombyllidae, Braconidae, Chrysididae, Eumenidae, Ichneumonidae, and Sphecidae (Sphecinae: Isodontia; Larrinae: Trypoxylonini). No <u>Passaloecus</u> were reared out.

Trap-nesting studies for the 1983 season were expanded in number of nests, sites, and variety of nesting materials. Nesting materials included <u>Rhus</u> twigs, 13 - 25 mm X 150 mm; one-to-two year old <u>Fraxinus</u> twigs, 150 mm long; plastic straws, 165 mm long with a 3.6 mm bore; and pine trap nests. Between May 3, 1983, and June 20, 1983, five sites were established (Figure 16).

Site I was near the central campus. One hundred forty-four pine trap nests were placed adjacent to a cedar border between the greenhouse and Manor I. Each of four stations at this site consisted of four 3 X 3 bundles on wooden stakes. A <u>P. cuspidatus</u> female was observed working a trap nest on June 17 and June 22. As of August 26, 106 trap nests showed nesting activity: Megachilids - 12; <u>Passaloecus</u> - 1; eumenids, <u>Isodontia</u>, Trypoxylonini, <u>Psenulus</u> and Pompilids - 93.

Site II was located in 100 meters of forest edge, between a red pine plantation and an old field, northeast of Pine Brae faculty housing. Sixteen bundles of pine trap nests, prepared after a

technique described by Fye (1965) were placed at this site. Bore diameters of trap nests were 3.2 mm and 4.8 mm. <u>P. cuspidatus</u> Smith females were observed working three days in June: one on June 20, three on June 23, and three on June 29. As of August 26, 142 of 144 trap nests were in use: megachilids - 18; <u>Passaloecus</u> - 27; eumenids, Trypoxylonini and others undetermined - 91.

Site III was a small clearing adjacent to the Concordia ponds. Nesting materials consisted of eight 3 X 3 bundles of pine trap nests with bores of 3.2 mm and 4.8 mm; and 72 <u>Rhus</u> cuttings 150 mm long. As of August 26, 1983, 69 pine trap nests were in use: megachilids - 3; <u>Passaloecus</u> - 12; eumenids, Psenini and Trypoxylonini - 54. No nesting activity was found in <u>Rhus</u> or <u>Rubus</u> cuttings.

Site IV was a south-facing slope overlooking the Huron River. The slope is bordered on the east by a small pine plantation and on the north by a mixed hardwoods. The slope is an old field covered with grasses and annual weeds. Rhus is established along the plantation edge and saplings of Fraxinus, Juglans and Robinia, along with mature <u>Cratageous</u> are scattered over the area. One hundred forty-four pine trap nests with bore diameters ranging from 3.2 mm to 8.0 mm were distributed at this site along with thirty-six 150 mm <u>Rubus</u> cuttings and thirty-six 150 mm <u>Fraxinus</u> twigs. One hundred eight of 144 pine trap nests were used: megachilids - 11; Passaloecus - 4; <u>Isodontia</u> - 3; and eumenids, Psenini, and Trypoxylonini - 90. One Rubus cutting was excavated and eleven Fraxinus twigs had mud plugs.

Site V was in a 100 meters of fence row bordering the western edge of the campus, south of Geddes Road. The plant cover at this site consisted of <u>Rhus</u>, <u>Robinia</u>, and grasses. Nesting material included 54 pine trap nests with bore diamters of 3.2 mm to 8.0 mm, 108 <u>Fraxinus</u> twigs, 27 <u>Rhus</u> twigs, and 27 plastic straws. As of August 26, 1983, forty-five pine trap nests were used: megachilids - 2; <u>Passaloecus</u> -1; <u>Isodontia</u> - 9; others - 32. Twenty-five <u>Fraxinus</u> were used and no activity was observed in <u>Rhus</u> cuttings or plastic straws.



Figure 16. Schematic map of Concordia College, Ann Arbor, Michigan, Indicating trap-nesting sites for 1983.

Table 29 summarizes the frequency of use of various nesting materials. These studies clearly demonstrate an abundance of trap-nesting wasps on Concordia's campus. Artificial nesting materials, i. e. trap nests and <u>Fraxinus</u> twigs, were highly efficient in attracting trap-nesting wasps. <u>Rhus</u>, <u>Rubus</u>, and plastic straws were very ineffective.

Table 29

Frequency of Nest Use by Nest Material Type.							
Nest Type	Number Available	Number Used	* Used				
Pine trap nests	558	369	<b>66.</b> 13				
<u>Fraxinus</u> twigs	144	36	25.00				
Rhus	171	0	0				
Rubus	144	0	0				
Plastic straws	27	0	0				
All Traps	1044	405	38.79				

<u>Passaloecus</u> was the presumed user of 45 pine trap nests based upon direct observations of wasps at trap nests, closures consisting of resin, or resin and impressed aphids. Examination of the contents of these trap nests and reared wasps confirmed <u>Passaloecus</u> use in 23 trap nests. Eight male and six female <u>Passaloecus cuspidatus</u> Smith, five <u>Omalus</u>, and four ichneumonids were reared. Trap nest use by <u>Passaloecus</u> was limited to bore diameters of 3.2 mm and 4.8 mm, and all <u>Passaloecus</u> trap nests, confirmed on the basis of reared materials, were from Site II.

#### APPENDIX 3

<u>Passaloecus</u> of Michigan (Hymenoptera: Sphecidae)

#### Introduction

The genus Passaloecus consists of small (4-9 mm) black wasps of the Pempredoninae that provision their nests with aphids. The genus is in the tribe Pemphredonini by virtue of the presence of two submarginal cells in the forewings and antennal sockets placed near the fronto-clypeal suture. The presence of three discoldal cells, two recurrent veins and a relatively small stigma place Passaloecus in the sub-tribe Pemphredonina. <u>Passaloecus</u> may be distinguished from other genera of this sub-tribe by the following characteristics: inner margins of compound eyes parallel or weakly converging below; scapal basin weakly depressed; mandible with two or three weak teeth; labrum nearly triangular with a pronounced rounded apex; pronotum with a strong transverse carlna: episternal sulcus well defined: hyposternaulus horizontal and the petiole shorter than broad (Bohart and Menke, 1976).

Recent taxonomic studies have increased the number of recognized Nearctic species from seven to sixteen. Bohart and Menke (1976) list seven Nearctic and four Holarctic species of <u>Passaloecus</u>. Muesebeck, C.F.W., et. al. (1979) list eleven <u>Passaloecus</u> in America north of Mexico. Vincent (1978) recognized thirty-five species, sixteen as North American, of which seven were known to occur in Michigan. He did not include <u>P. turionum</u> Dahlbom though a single male has been reported by Krombein (1961b) from Michigan. Eight species of <u>Passaloecus</u> are thus known to occur in Michigan. Specimens of <u>Passaloecus</u> were examined from the Museum of Zoology of the University of Michigan and the Entomology Museum of Michigan State University.

#### Biology of North American Passaloecus

<u>Passaloecus</u> are known to nest in decayed wood, abandoned beetle borings, stems of <u>Rhus</u>, <u>Rosa</u>, <u>Sambucus</u>, <u>Cornus</u>, bark of pine, cedar, and oak. Nests are linear and usually partitioned and closed with pine resin. All <u>Passaloecus</u> provision nests with aphids and a single <u>Passaloecus</u> species may prey on more than six different aphid species (Fye, 1965). Dixon (1973) states that aphid predators are more closely associated with particular habitats than they are to particular aphids. <u>Passaloecus</u> could then be described as general opportunists.

Passaloecus are markedly protandrous. Emergence occurs in late May and June. Mean emergence for males is nearly one week earlier than females. A few days after emergence females are observed searching for nesting sites. Preferred sites are found in moderate plant cover with nests in partial shade. Previously used nests are cleaned of debris and reused. New excavation is limited to decayed wood or pith. Generally, innermost cells produce females; outermost cells produce males. Data vary on the relationships between the sex of cell occupant, size of cell, and quantity of food stores. Eggs are placed on the thoracic and abdominal ventor of an aphid on the top of the food mass. Larval feeding is completed within 40 days (Fye, 1965) and <u>Passaloecus</u> over winter as prepupae. Pupation of Nearctic materials occurs in late April and May.

#### Aphid Prey of <u>Passaloecus</u>

Dixon (1973) notes that aphid parasitoids are fastidious, often preying on a single species, but predators feed on a number of Aphid prey of Passaloecus are given by Fye (1965) and species. Krombein (1955, 1956, 1958, 1960, 1961a, 1967). Passaloecus are apparently generalists in their prey selection. The number of prey provisioned by <u>Passaloecus</u> is extremely varied. Prey provisioned per cell ranged from seven to sixty-three; prey per nest ranged from fifty to two hundred. Corbet and Backhouse (1975) suggest that in favorable conditions a single female could kill fifteen hundred aphids based upon one cell provisioned per day (thirty aphids) and a hunting life of fifty days. No data have been given indicating mean numbers of aphids per cell, nor has any information been given on whether a relationship exists between aphid species provisioned and mean number of provisions.

### Key to Michigan <u>Passaloecus</u>

Readers are referred to Vincent (1978) for a discussion of the morphological features important in distinguishing <u>Passaloecus</u> species. A generalized diagram of the scutum and mesopleuron illustrating structural features and terminology used in descriptions and the following key may be found in Figs. 1 and 18. The following key is an adaptation of Vincent's Key to North American <u>Passaloecus</u> Shuckard to Michigan <u>Passaloecus</u>.

1.	Males: eleven flagellomeres; seven visible gastral
	terga; clypeus with dense covering of silvery setae;
	length of scape 2 times width 2
1'.	Females: ten flagellomeres; six visible gastral terga;
	clypeus with sparse covering of silvery setae; length
	of scape 3 - 4 times width
2.	Spinose tubercles present medially on gastral tergum VI 3
2′.	Spinose tubercles absent on gastral tergum VI 7
3.	Clypeal lobe tridentate (Fig. 8); apex of foretarsomere
	produced below
3′.	Clypeal lobe truncate or weakly concave 4
4.	Scrobal sulcus absent or weakly impressed (Figs. 19, 23) 5
4'.	Scrobal sulcus deeply impressed, areolate (Figs. 20 - 22) 6

5. Apical 1/3 to 1/2 of flagellomeres III - IX white or pale yellow; hind trochanter pale amber . . P. annulatus 5'. Flagellomeres, trochanters dark brown or black .... P. monilicornis 6. Mandibles, trochanters dark brown or black . . . . <u>P. lineatus</u> 6'. Mandible white or pale yellow; 7. Omaulus absent; scrobal sulcus absent; pronotal lobe and trochanters dark brown or black . . . <u>P. singularis</u> 7'. Omaulus present (Fig. 8); scrobal sulcus impressed, 8. Scutum anteriorally with interrupted transverse carinae; notauli longer then admedian lines, extending to mid-point of scutum (Fig. 2).... P. gracilis 8'. Scutum with course punctation, lateral margins with weak transverse carinae; notauli not longer than admedian lines, terminating before mid-point of 9. 

10.	Scutum anteriorly with interrupted transverse carinae (Fig. 2)
	no setal division pattern on face; notauli extending to
	mid-point of scutum; basal 1/4 of hind tibla creamy
	white P. <u>gracilis</u>
10′.	Scutum with course punctation and lateral margins with
	weak transverse carinae; notauli not extending to
	mid-point of scutum (Fig. 6); tibla black P. <u>turionum</u>
11.	Scrobal sulcus strongly impressed or areolate 12
11′.	Scrobal sulcus not present, or weakly impressed 14
12.	Scrobal sulcus strongly impressed; clypeal lobe
	tridentate (Fig. 8); pronotal lobe and basal $1/3$ to $1/4$ of
	hind tibla white
12′.	Scrobal sulcus areolate;
	clypeal lobe truncate (Figs. 10, 13)
13.	Clypeal lobe width 1/4 of clypeal base width;
	trochanters amber
13′.	Clypeal lobe width one-fifth clypeal base width;
	trochanters brown to black
14.	Clypeal lobe weakly tridentate and weakly upturned (Fig. 12);
	pronotal lobe, labrum and trochanters black <u>P. singularis</u>
14'.	Clypeal lobe concave or convex

15.	Clypeus concave	e (Fig.	. 7);	pro	onot	um	whi	te;	l al	orui	n br	rown	;
	trochanters	black	•	••	••	•	••	•	••	•	. <u>P</u> .	mo	nilicornis
15′.	Clypeus convex	(Fig.	14);	l al	orum	an	d						
	trochanters	amber	•	•••	• •	•	•••	•		•	••	P.	annulatus

k.

#### Michigan Passaloecus

#### PASSALOECUS ANNULATUS (SAY)

(Figs. 14, 15, 23, 24)

PEMPHREDON ANNULATUS SAY, 1837. Boston Jour. Nat. Hist. 1:379.

REMARKS: Females: clypeal lobe projecting strongly with margin weakly convex; pronotal lobe and palpi white; labrum, mandible and legs pale amber; males: apical 1/3 to 1/2 of flagellomeres I-X pale amber.

BIOLOGY: The biology of <u>Passaloecus annulatus</u> (Say) is reported by Krombein (1955, 1958, 1960, 1961a, 1963) and Vincent (1978). Nesting sites included anobid borings, beetle borings in wooden cowshed walls, twigs of <u>Rhus glabra</u> L. and <u>Juglans nigra</u> L. respectively, and a boring in a red cedar stump. Data are given on four nests. One pine trap nest contained three cells - 6.0, 10.0, and 12.0 mm long respectively. Two males were reared from this nest. One nest from <u>Rhus glabra</u> L. and another from <u>Juglans nigra</u> L. collectively contained six brood cells ranging from 10 mm to 30.7 mm long. Three adults, one male and two females were reared. Three others died in the prepupa stage. One nest had two vestibular cells, 19.0 mm and

16.0 mm long. Larval cocoons usually consisted of two transverse silken partitions, the first contiguous with the resin partition and the second 4.0 to 10.0 mm distant from the first. Krombein (1963) reported <u>P. annulatus</u> active from May 20 to October 13 and considered it multivoltine in the Washington, D.C. area. Vincent (1978) reported that collection records indicate <u>P. annulatus</u> is univoltine in Missouri.

MICHIGAN DISTRIBUTION: Fig. 23

MICHIGAN FLIGHT DATES: 5 June - 16 Aug.

PARASITES: Unknown.

PREY RECORDS: <u>Drepanaphis</u> (Krombein, 1955, 1958); <u>Macrosiphum</u> (Krombein, 1958, 1960); <u>Neothomasia</u> (Krombein, 1961a).

#### PASSALOECUS AREOLATUS VINCENT

(Figs. 3, 13, 21, 25)

PASSALOECUS AREOLATUS VINCENT, 1978. Wassman Jour. of Bio. 36:159. REMARKS: Females: clypeal lobe truncate; scrobal sulcus areolate and strongly impressed; notauli areolate and slightly longer than admedian lines; all trochanters, tibia, and tarsi of foreleg amber; males with slightly darker scape and mandibles. The light color of the trochanters contrasts dramatically against dark brown femur.

BIOLOGY: <u>Passaloecus areolatus</u> Vincent was reported by Krombein (1958, 1963) as <u>P</u>. <u>relativus</u> Fox. One female was observed carrying an aphid on May 30, 1957 and June 1, 1957. Wasps were observed at beetle borings from May 21 to June 2. Vincent (1978) reported on two nests in pine trap nests with 1.5 mm borings from Bolivar, Polk County, Missouri. Both had resin partitions and closures of resin and wood particles. One nest had four cells with lengths of 8.3, 8.5, 9.0 and 8.5 mm and two vestibular cells; one male <u>P</u>. <u>areolatus</u> and a chrysidid (<u>Omaulus</u> sp.) were reared. Others died during rearing. A second nest had five cells with lengths of 6.8, 7.0, 6.0, 15.5, and 16.0 mm. The four outermost cells had been destroyed and a single female <u>P</u>. <u>areolatus</u> was reared from cell number one.

MICHIGAN DISTRIBUTION: Fig. 25

MICHIGAN FLIGHT DATES: 25 July - 9 Aug.

PARASITES: A chrysidid, <u>Omaulus</u> sp. (Vincent, 1978). PREY RECORDS: Unknown.

#### PASSALAOECUS CUSPIDATUS SMITH

#### (FIGS. 8, 19, 26)

PASSALOECUS CUSPIDATUS SMITH, 1856. Cat. Hym. Brit. Mus. v.4:427 REMARKS: Females: clypeal lobe strongly tridentate; scrobal sulcus impressed, with weak longitudinal carinae; pronotal lobe, ventral surface of scape, basal 4/5 of mandible, labium, palpi, and basal 1/8 - 1/4 of hind femur white; males similar except tarsi and pre-tarsi of fore- and midleg amber. <u>P. cuspidatus</u> is the largest of the Michigan <u>Passaloecus</u>.

BIOLOGY: Records of Passaloecus cuspidatus Smith are provided by Fye (1965), Krombein (1956, 1958, 1963, 1967), and Vincent (1978). Nesting sites included beetle borings in wooden cowshed walls, artificial borings in elderberry and chinaberry, pine trap nests, and Krombein observed nesting activity near Arlington, soda straws. Virginia May 23 - May 29, 1956; May 30, 1958; May 17 - May 30, 1959; June 1 - June 7, 1960; May 22 - June 1, 1962; and May 19, 1963. Nesting activity was observed near Derby, New York June 7 - July 4, 1959 and June 1 - July 9, 1960. Twenty nests were in pine trap nests with a bore diameter of 3.2 mm. These nests contained 58 provisioned cells. Cell lengths were 8 - 52 mm (mean = 16.3). Eighteen female cells were 12 - 47 mm long (mean = 16.1) and 14 male cells were 10 -31 mm long (mean = 14.8). Two nests from 4.8 mm borings had 4 provisioned cells respectively 7, 8, 13, and 126 mm long. One 6.4 mm boring had 4 provisioned cells 7, 6, 7, and 9 mm long. No intercalary
cells were found and all but one nest had a vestibular cell. Vestibular cells were 5 - 145 mm long. Resin partitions were usually .25 mm thick with one occasionally 4 mm thick. Resin closures were usually 1 mm thick and ranged from .25 to 4 mm. Krombein (1967) reported that <u>P. cuspidatus</u> had a larval feeding period of 6 to 9 days. Fye (1965) found <u>P. cuspidatus</u> in two 6.4 mm borings in elderberry or chinaberry. One nest contained 4 cells; females were reared from 3 cells (11 - 21 mm, mean = 15; and one cell (11.2 mm) produced a male. The vestibular cell (102 mm) was closed with a 3.2 mm resin plug. A second nest of five cells (6.4 - 14.4 mm) produced females from one 6.4 mm and one 8.0 mm cell. The vestibular cell was 30 mm long, partitioned and closed with a 1.6 mm resin plug.

Vincent (1978) observed two females cleaning debris from old nests and provisioning nests August 12, 1972 at Willard's Peak, Utah (9500'). Prior to provisioning, wasps ringed nest openings with two drops of resin. Eight provisioning trips were observed. Trip duration was 3.8 - 10 minutes (mean =  $5.96 \pm 2.85$ ) Thirteen resin gathering trips were observed with durations of 0.5 - 8.0 minutes (mean =  $2.04 \pm 1.93$ ). Nest closure was achieved with four drops of resin spread diagonally across the nest opening. Nest architecture was reported from 83 soda straw nests from Montclair, Alameda Co., California. Straws measured 90 mm x 4 mm and contained two to nine cells (mean =  $6.14 \pm 1.75$ ). Five hundred-ten brood cells were examined. One hundred-eleven produced females. Cells were 5.0 - 18.0mm long (mean =  $10.09 \pm 2.19$ ). One hundred-ten male cells were 4.0 - 16.0 mm long (mean =  $8.82 \pm 2.16$  mm). Individual cells contained 7 - 32 aphids. Resin partitions were 0.5 - 4.0 mm. Vestibular cells werefound in all nests (3.0 - 21.0 mm long, mean = 9.89 ± 3.5, n = 108). Fifty- five nests had one vestibular cell, twenty-two nests had two, and three cells had three. Resin closures had coverings of coarse wood particles.

MICHIGAN DISTRIBUTION: Fig. 26.

MICHIGAN FLIGHT DATES: 13 June - 14 Aug.

PARASITES: Two chrysidids: <u>Omaulus aeneus</u> (Fabricus), (Krombein, 1967; Vincent, 1978) and <u>Omaulus purpuratus</u> (Vincent, 1978); two ichneumonids: <u>Pomenia americana</u> (Cresson), (Krombein, 1967); and <u>Pomenia thoracica</u> (Cresson), (Vincent, 1978) PREY RECORDS: <u>Cinara</u>, (Fye, 1965); <u>Macrosiphum</u>, (Fye, 1965; Krombein, 1956, 1958, 1967); <u>Myzus</u> (Krombein, 1967); <u>Masonaphis</u>, (Krombein,

1967); <u>Rhopalosiphum</u>, (Fye, 1965).

## PASSALAOECUS GRACILIS (CURTIS)

(Figs. 2, 11, 22)

DIODONTUS GRACILIS CURTIS, 1834. British Entomology 11:496 REMARKS: Females: clypeal lobe concave, scrobal sulcus areolate; scutum with oval raised scutal patches; notauli areolate, extending to

midpoint of scutum; scutum anteriorly with transverse interrupted carinae; areolate omaulus narrowly separated from episternal sulcus; mandible, except apex, ventral surface of scape, pronotal lobe, foretibla and basal 1/4 of mid- and hind tibla creamy white. This species is very uncommon and the transverse carinae of the scutum are distinctive.

BIOLOGY: Unknown.

MICHIGAN DISTRIBUTION: One female; Wexford Co., 20 August 1973, collected by R. D. Averill; deposited in the Entomology Museum of Mighigan State University. Two males; Macomb Co., 19 March 1961, collected by S. J. Thomas, deposited in the USNM.

MICHIGAN FLIGHT DATES: 20 Aug.

PARASITES: Unknown.

PREY RECORDS: <u>Megorua</u>, (Danks, 1971); <u>Tuberculoides</u>, (Danks, 1971); <u>Holcaphais</u>, (Danks, 1971).

#### PASSALOECUS LINEATUS VINCENT

## (Figs. 5, 10, 27)

PASSALOECUS LINEATUS VINCENT, 1978. Wassman Jour. of Bio. 36:162 REMARKS: Females: clypeal lobe narrow and truncate; scrobal sulcus areolate and strongly impressed; notauli areolate extending to midpoint of scutum; pronotal lobe, ventral surface of scape, basal 2/3 of mandibles, and palpi white; trochanters dark brown; males similar.

BIOLOGY: Unknown

MICHIGAN DISTRIBUTION: Fig. 28.

MICHIGAN FLIGHT DATES: 13 June - 20 July

PARASITES: Unknown.

PREY RECORDS: Unknown.

## PASSALOELCUS MONILICORNIS DAHLBOM

#### (Figs. 7, 28)

PASSALOECUS MONILICORNIS DAHLBOM, 1842. Dispositio methodica:12 REMARKS: Females: clypeal lobe weakly concave or truncate; scrobal sulcus weakly impressed or absent; notaull areolate, as long as admedian lines; pronotal lobe, ventral surface of scape, basal 4/5 of mandile white; trochanters and femurs dark brown; tarsi and pre-tarsi light brown; males similar.

BIOLOGY: Fye (1965) and Krombein (1967) described nesting habits of P. monilicornis Dahlbom. Fye reported on thirty-seven nests in drilled elderberry twigs from the Black Sturgeon Lake area of northwestern Ontario. Nest diameters were 6.4 mm and 8.0 mm with 6.4 mm preferred. Female cells were 4.8 - 12.8 mm long (mean =  $8.66 \pm .5$ mma), male cells were 4.8 - 11.2 mm long (mean =  $7.8 \pm .3$  mm). Five nests of 6.4 mm boring had 5 - 10 cells each (mean = 7). Vestibular cells were 1 - 4 per nest, 26 - 77 mm long. Partitions and closures were of resin and closure plugs were 1.6 - 3.2 mm thick. In 8.0 mm borings mean length of female cells was 10.0 mma. A single male cell was 14.4 mm long. Univoltine and bivoltine populations were reported. The univoltine population provisioned nests in late June. The larval feeding period lasted up to 40 days. Pupation occurred the first and second week of the following June with emergence the last week in The blvoltine population provisioned nests in June; larval June. feeding was completed by mid-July and adults emerged July 29 - August

Nests provisioned by this summer generation were collected from 16
 August - 3 September and adults of the overwintering generation
 emerged the last week in June.

Krombein (1967) reported on six P. monilicornis nests in pine trap nests near Derby, New York. Four nests with 3.2 mm borings contained 20 provisioned cells 6 - 12 mm long (x = 8.6mm). Twelve female cells had a mean length of 9.6 mm and four male cells had a mean length of 6.7 mm. Three of these nests contained six cells each and a fourth nest contained two cells. A nest with a 4.8 mm bore contained 12 stored cells 6 - 12 mm long (x = 8.6) and a second 4.8 mm nest had three stored cells 19, 25, and 90 mm long respectively. No nests had intercalary cells and vestibular cells were 10 - 20 mm long. Resin partitions were .25 mm - .50 mm and closures were 0.5 - 1.0 mm thick. Krombein considered <u>P. monilicornis bivoltine in this area.</u> Adults, from four nests completed in late May and early June, emerged June 23 - July 18. A single adult emerged August 17 from a nest stored in mid-July. One nest, containing six completed cells, produced females from three inner-most cells, cells four and five produced males and cell six suffered egg death.

MICHIGAN DISTRIBUTION: Fig. 28.

MICHIGAN FLIGHT DATES: 24 May - 8 Aug.

PARASITES: Two chrysidids: <u>Omaulus aeneus</u> (Fabricus), (Fye, 1965) and <u>Omaulus iridescens</u> ? (Norton), (Fye, 1965); two ichneumonids: <u>Pomenia</u> <u>albipes</u> (Cresson), (Fye, 1965) and <u>Pomenia americana</u> ? (Cresson), (Fye, 1965).

PREY RECORDS: <u>Amophoraphora</u>, (Fye, 1965); Anuraphis, (Krombein, 1967); <u>Cinaria</u>, (Fye, 1965); <u>Euceraphis</u>, (Fye, 1965); <u>Macrosiphum</u>, (Fye, 1965); <u>Neosymdobius</u>, (Fye, 1965); <u>Pterocomma</u> ?, (Fye, 1965); <u>Rhopalosiphum</u> (Krombein, 1967)

#### PASSALOECUS SINGULARIS DAHLBOM

(Figs. 4, 12, 16, 29)

PASSALOECUS SINGULARIS DAHLBOM, 1844. Hym. Europaea, v.1: 243
REMARKS: Females: clypeal lobe weakly upturned and weakly tri-dentate; scutal patches present; no white markings; males similar. This species is the slenderest of the Michigan Passaloecus.
BIOLOGY: Unknown.
MICHIGAN DISTRIBUTION: Fig. 29.
MICHIGAN FLIGHT DATES: 17 May - 30 Aug.
PARASITES: Unknown.

PREY RECORDS: Unknown.

## PASSALOECUS TURIONUM DAHLBOM

(Figs. 6, 9, 17, 20)

DIODONTUS GRACILIS CURTIS, 1834. British Entomology 11:496 REMARKS: Females: clypeal lobe concave; scrobal sulcus strongly areolate: omaulus present: notauli areolate. as long as admedian lines; scutal patches present; ventral surface of scape and basal 2/3 of mandible dark broon to pale white. This species like P. gracillis possesses an omaulus, but lacks the transverse carinae of the scutum. BIOLOGY: While conducting preliminary research on the trap-nesting biology of Passaloecus five unusual females (one - 6 August 1982, one - 27 July 1983. two - 1 October 1983. and one - 30 August 1985) were collected. Using Vincent's revision of the <u>Passaloecus</u> of North America (Vincent, 1978) this material was identified as Passaloecus borealis Dahlbom. Subsequent to the use of Vincent's key this material was compared with a description of P. borealis and a specimen previously determined as <u>P. borealis</u> from the Michigan State University Entomology Museum Collection. The determination of this material was placed in doubt because of deviations from Vincent's description and distribution records for borealis that showed the eastern limit of its range to be Colorado. During a subsequent review of Yarrow's paper on nomenclatorial problems among European species of <u>Passaloecus</u> the present material was clearly described and identified as <u>Passaloecus turionum</u> Dahlbom (Yarrow, 1970).

Krombein (1961) reported on two male <u>Passaloecus</u> reared from a twig from Macomb Co. Michigan. Although positive identification was not possible he identified the material as standing close to

<u>P. brevicornis</u> Morawitz. A specimen was sent to Dr. J. deBeaumont, Lausane, Switzerland. He identified the material as <u>P. turionum</u> Dahlbom for which he considered <u>P. brevicornis</u> a synonym. Krombein considered <u>P. turionum</u> Dahlbom adventive in the United States since no records existed for this material prior to July 1941. Vincent (1978) assigned this material to <u>P. gracillis</u> (Curtis).

Yarrow (1970) untangled the nomenciatorial problems among names applied to <u>Passaloecus</u> spp. by British and Continental authors, and the confusion of <u>Passaloecus</u> types. He clearly distinguished three species of <u>Passaloecus</u> that possess an areolate omaulus anterior to the episternal sulcus: <u>P. gracilis</u> (Curtis), <u>P. turionum</u> Dahlbom, and <u>P. borealis</u> Dahlbom.

Vincent (1978) agreed with Yarrow's interpretation of this group and raised <u>P. turionum</u> Dahlbom from synonomy with <u>P. gracilis</u> (Curtis) to species status. However, he did not provide a description of this adventive species.

DESCRIPTION: Female, black; ventral surface of scape white, basal half of the anterior face of mandible light amber; pronotal lobe amber; fore-tibla above light brown; lablum, posterior face and distal half of mandible, pro-, meso-, and meta-tibla, pro-, meso-, and meta-femur dark brown; setal division pattern low on face at level of antennal sockets; clypeal setae on dorsal 1/2 inclined toward midline, on ventral 1/2 inclined ventrally; clypeal lobe weakly concave; interocellar distance equal to ocellocular distance; notauli impressed and areolate, as long as admedian lines; scrobal sulcus areolate; scutal margin opposite tegula strongly reflexed and areolate; scutum with dense, course punctation; posterior margin of scutum areolate with inner margins of fovaea open; lateral faces of pronotum with strong longitudinal carinae; dorsal surface of pronotum posterior of pro-notal carina areolate; omaulus present, nearly contiguous with episternal sulcus.

This material is differentiated from <u>P</u>. <u>borealls</u> Dahlbom by the following characters: head height/head width = 1; lack of white or amber markings on legs; dense, coarse punctation of the scutum; strong areolation of lateral margins of scutum (Fig. 6); distinct lateral carinae and areolate dorsal surface of the pronotum. Wing characters also differ from <u>P</u>. <u>borealls</u>. The distal portion of the marginal cell is narrowly pointed, the first radial-medial cross-vein is distinctly bent mid-way between the radius and medius; and the basal vein is strongly arched (Fig. 17). The gaster is differentiated by the angulate posterolateral margin of the gastral tergum II.

The material under consideration is placed in Vincent's "Gracilis Group - Group Assemblage II" on the basis of the following characters: females with scutal patches; concave clypeal lobe; and well-developed omaulus and scrobal sulcus (Fig. 20).

BIOLOGY: Unknown.

MICHIGAN DISTRIBUTION: Five females, Washtenaw Co., one each August 6, 1982, July 27, 1983, August 30, 1985, and two October 1, 1983; deposited in the Entomology Museum of Michigan State University. One female, Marquette Co., 23 June; deposited in the Museum of Zoology of the University of Michigan

MICHIGAN FLIGHT DATES: 27 July - 1 Oct.

PARASITES: Unknown.

PREY RECORDS: Unknown

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# APPENDIX 4

Data Tables from Trap-nesting Studies of Passaloecus, 1984-1987

Table 30.

Rearing data for <u>Passaloecus</u> cuspidatus, 1984.

Bore (mm)	Cells	Parasitized cells	Otherwise failed cells	Prepupae	Aduits Reared
3.2	78	10	5	63	30
4.0	29	7	4	18	9
4.8	52	8	4	40	31
6.4	10	3	1	6	5
Totals	169	28	14	127	75

		Bore [	)iameter (mm)	
	3.2	4.0	4.8	6.4
MEAN	13.5443	19.5862	17.1154	7.30
MEDIAN	12.07	11.125	9.6428	5.9286
S. D.	4.7702	23.4028	23.853	4.5837
S.E.M.	.53667	4.3458	3.3079	1.4495
	N = 79	N = 29	N = 52	N = 10
MEAN (A)	12.5811	11.5652	9.4783	7.30
MEDIAN (A)	11.90	10.00	9.375	5.9286
S. D. (A)	3.0359	2.3527	3.5737	4.5837
S.E.M. (A)	. 3529	. 4906	.5269	1.4495
	N = 74	N = 23	N = 46	N = 10

Bore diameters and lengths of <u>Passaloecus</u> cuspidatus cells, 1984.

Table 31.

<sup>(</sup>A): Data were adjusted by a deletion of 10% of cell length values from skewed end of distribution for pooled sample of all bore diameters.

Table	32.
Tanic	52.

Frequency of trap nest use and number of adults reared out for four <u>Passaloecus</u> spp., 1985.

			B	ore (mm)		
Pas	saloecus spp.	1.6	2.4	3.2	4.0	4.8
<u>P</u> .	<u>annulatus</u> (Say)	2(2)	3(6)			
<u>P</u> .	<u>cuspidatus</u> Smith			2(5)	2(5)	3(12)
<u>P</u> .	monilicornis Dahlbom	1(1)	5(13)			
P.	<u>singularis</u> Dahlbom	~•	1(3)			

Table 33.

Frequencies of trap nest use by four <u>Passaloecus</u> spp., 1986.

				Bore di	ameters	: (m)			
Species	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8
annulatus	1	1	4	0	0	0	0	0	0
<u>areolatus</u>	18	20	9	0	0	0	0	0	0
cuspidatus	0	1	4	6	7	7	5	3	0
monilicornis	1	3	8	2	2	2	0	0	0

			Dia	Diameter class						
		120			60		totals			
Bore diameter (mm)	Cum BCL#	# BC##	Mean BCL	Cum BCL	# BC	Nean BCL	Cum BCL	# BC	Mean BCL	
1.6	418	11	38	194	15	12.93	612	26	23.54	
2.0	427	18	23.72	0	17	0	427	35	12.20	
2.4	470	14	17 93	07	12	4.0	107	29	17.40	
2.0	30	4	7.5	n	6	0	30	10	3.00	
3.6	õ	6	0	ů.	6	Ő	õ	12	0.00	
4.0	25	5	5	Ō	2	Ō	25	7	3.57	
4.4	0	2	0	0	1	0	0	3	0.00	
Totals	1502	66	22.76	263	65	4.05	1765	131	13.47	

# Basal Cell Length
## Basal Cell

Table 34.

Basal cell lengths from eight bore diameter classes and two bore depth classes. Data compiled from four <u>Passaloecus</u> spp., 1986.

Passaloecus areolatu	<u>s</u> provisio	ned cell len	ngths, 1986.
	Bor	e dlameter	( mm )
length (mm)	1.6	2.0	2.4
7.0			1
7.5 8.0		1 4	1
8.5 9.0	2	2	2
9.5 10.0	1	3	2
10.5 11.0	2 1	11	12
11.5 12.0	1 1	35	3
12.5	7	34	4
13.5	3	11	1
14.5	2	45 5	2
15.5	23	1	
17.0	23		1
17.5	1	1	
19.0	L	1	
20.0 20.5	4	12	1
21.0	1	4	1
22.0	2	2	
23.0	1	2	
24.0 24.5		1	
25.0		1	
26.0 26.5	2		2
27.0 27.5	1	1	
28.0 29.0	1		
29.5 30.0	-		
30.5 31.0			2
36.0 38.0	1		Ī
41.0 42.0	1	1	
56.0 61.0	<u>1</u>		
7Ô.Ŏ	ī		

Table 35.

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Table 36.

<u>cassaluecus cuspilatus pluvisiuneu cell lenguns. 1704-17</u>	Passa	loecus	cuspidatus	provisioned	cell	lengths.	1984-198
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Cell				Bore	diame	ter (mr	ה)			
length (mm)	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.6	6.4
5.0						2		3		2
5.5						-		-		-
6.0				1	1	2		5		7
6.5					1	4				
7.0				5	3	б	1	9	2	
7.5				2	1	8	1			
8.0		2	3	8	1	21		13		
8.5				5	2	8	1	1		
9.0			4	22	2	24		6		
9.5			1	3	1	4		1		
10.0		3	4	21	1	20		10		1
10.5		•	1	4	1	4		•		1
11.0	1	3	3	14	2	13		8		
11.5		1	•	4		1	1	1		
12.0	1		3	23	1	11				
12.5		1	2	5		2		1		
13.0	1	2	2	11		(		5		
13.5		2	2			E	•	2		
14.0			3	14		2	1	3		
15.0		Ţ		3		2				
15.5				1		2		1		
16.0	1	1	1	10		2		•		
16.5	-	1	•	1		1				
17.0		1		6		2	1	2		
17.5				3		3	-	-		
18.0		2	1	5						
18.5				1						
19.0				4		1				
19.5				1						
20.0				3						

.

Cell				Bore	diame	ter (m	n)			
length (mm)	2.0	2.4	2.8	3.2	3.6	4.0	4.4	4.8	5.6	6.4
20.5		1								
21.0		1		3						1
21.5 22.0		1		1		1				
<b>22.5</b>				2		1		1		
24.0		1		2		•		•		
25.0 26.0				2 1		2 1				
27.0				3						
29.0				_				-		
30.0 31.0				2 1				2		
32.0						1		4		
35.0 39.0		1						1		
42.0 44.0								1 1		
46.0				2		2				
53.0				L	1			_		
56.0 59.0						1		1		
67.0 72.0				1		1		1		
75.0						1				
77.0 <b>78.</b> 0						1		1		
<b>82.</b> 0				1	1			1		
91.0								ī		
9 <b>4</b> .0 95.0						1	1			
<b>97.</b> 0 1 <b>00.</b> 0						1				
101.0						1				
105.0 106.0								1 1		
108.0								1		
								•		

Table 36., (cont'd)

f

Cell			Bore diam	eter (mm)		
ength (mm)	1.6	2.0	2.4	2.8	3.2	3.6
5.0						
6.0 6.5 7.0				1		4
7.5			3	2		1
9.0			2	1	1 3	]
10.0			1 5	1		
10.5			?		2	
11.5		1	12	2	1	
12.5		1	2	1		
13.5			4			
15.0			1			
16.0			3			
17.0			3			
18.0		1	1			
19.0			1			
20.0			1			
22.0	1					
24.0 25.0	1					
26.0 27.0			1			
28.0 29.0	1					
30.0 42.0	-					
92.0 108.0		1				1

Table 37.

ladie 30.
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Lengths of <u>Passaloecus</u> provisioned cells from eight bore diameter classes and two bore depth classes. Data were combined from four <u>Passaloecus</u> spp., 1986.\*

			Bore de	Diameter class						
		120			60			totals		
Bore diameter (mm)	Cum PCL##	‡ of Cells	Mean CL	Cum CL	t of Cells	Mean CL	Cum CL	‡ of Cells	Mean CL	
1.6 2.0 2.4 2.8 3.2 3.6 4.0 4.4	397 768 629.3 338.5 142 100 172 59	26 48 48 30 13 11 16 5	15.27 16.00 13.11 11.28 10.92 9.09 10.75 11.8	<b>456</b> 570 517 75.5 102.5 113.5 23 14.5	29 46 41 8 11 14 2	15.72 12.39 12.61 9.44 9.32 8.11 11.5 7.25	853 1338 1146 414 244 213.5 195 73.5	55 94 88 38 24 25 18 7	15.51 14.23 13.02 10.89 10.17 8.54 10.83 10.50	
Totals	2605.8	197	13.23	1872	152	12.32	4477.8	349	12.83	

\* Eight instances cells of extraordinary length were not included. Data from these deletions are summarized below. \*\* Provisioned Cell Lengths

		120		60			
Bore diameter (mm)	Cum CL	t of Cells	Mean CL	Cun CL	t of Cells	Mean CL	
1.6	126	2	63	80	2	40	
2.0 2.4	100	1	100	75	2	37.5	
2.8 3.2	<del>94</del>		 94				
3.6	446	5	89.2	60	_1	60	
4.4	<b>95</b>	1	95				

Bore depths (mm)

Table 39.

Provisioned cell lengths for four <u>Passaloecus</u> spp., 1986. Cell lengths are compared on the basis of bore diameters and bore depths.

		Mean cell lengths (am)								
	Bore				Bore	jepths (mm)	)			
	diameter (mm)	All T'nests		120		60				
Passaloecus spp.		Mean	(N)	Mean	(N)	Mean	(N)			
<u>annulatus</u>										
	<b>Y</b> 11	11.7272	(22)	11.54	(11)	11.909	(11)			
	1.6	12.33	(3)			12.33	(3)			
	2.0	12.20	(5)			12.20	(5)			
	2.4	11.43	(14)	11.54	(11)	11.00	(3)			
areolatus										
	<b>7</b> 11	11.658	(120)	17.657	(73)	15.106	(47)			
	1.6	21.039	(38)	22.435	(23)	18.9	(15)			
	2.0	14.607	(61)	16.086	(35)	12.615	(26)			
	2.4	14.69	(21)	14	(15)	16.417	(6)			
<b>cuspid</b> atus										
	<b>A</b> 11	14.287	(106)	16.463	(68)	10.1969	(38)			
	2.0	13	(4)	12	(1)	13.333	(3)			
	2.4	13.1	(10)	11.5	(2)	13.5	(8)			
	2.8	11.2857	(28)	11.8181	(22)	9.3333	(6)			
	3.2	9.1538	(13)	9.1	(5)	9.188	(8)			
	3.6	19.14	(21)	31.3	(10)	8.68	(11)			
	4.0	14.1818	(22)	14.1818	(22)					
	4.4	21.0625	(8)	25.67	(6)	7 <b>.25</b>	(2)			
monilicornis	3									
	- <u> </u> <u> </u> <u> </u> <u> </u> <u> </u>	15.78	(50)	18.0776	(26)	13.2925	(24)			
	1.6	23	(2)			23.00	(2)			
	2.0	37.625	(4)	46.00	(3)	12.5	(1)			
	2.4	14.00	(22)	15.42	(6)	13.47	(16)			
	2.8	9.8125	(8)	9.8125	(8)					
	3.2	9.9285	(7)	10.25	(4)	9.5	(3)			
	3.6	19.5	(7)	24	(5)	8.25	(2)			
	-			-						

Table 40.

Provisioned cell lengths for four <u>Passaloecus</u> spp., 1986 with the application of the 10% exclusion rule.

			Mear	an cell lengths (mma)					
B	ore			Bo	ore dept	hs (mm)			
dia (	meter mm)	All t'ne	ests	12	)	60			
Passaloecus spp.		Mean	(N)	Mean	(N)	Mean	(N)		
annulatus									
	A11	10.8	(20)	10.50	(10)	9.2	(10)		
	1.6	8.5	(2)			8.5	(2)		
	2.0	12.2	(5)			12.20	(5)		
	2.4	10.62	(13)	10.50	(10)	11.00	(3)		
areolatus									
	<b>XII</b>	13.94	(108)	14.134	(64)	13.4986	(44)		
	1.6	15.37	(31)	15.28	(18)	15.65	(13)		
	2.0	13.93	(59)	14.44	(33)	12.615	(26)		
	2.4	11.97	(18)	11.77	(13)	12.5	(5)		
<u>cuspidatus</u>									
	A11	10.13	(%)	10.7038	(59)	9.4189	(37)		
	2.0	13.00	(4)	12.00	(1)	13.333	(3)		
	2.4	10.22	(9)	11.50	(2)	9.86	(7)		
	2.8	11.23	(26)	11.3	(20)	9.333	(6)		
	3.2	9.1538	(3)	9.1	(5)	9.188	(8)		
	3.6	8.94	(18)	10.29	(7)	8.68	(11)		
	4.0	10.55	(20)	10.55	(20)				
	4.4	9.42	(6)	10.5	(4)	7.25	(2)		
monilicornis									
	<b>X</b> 11	11.72	(45)	10.3966	(24)	11.759	(21)		
	1.6								
	2.0	14.17	(3)	15	(2)	12.5	(1)		
	2.4	13.43	(21)	15.42	(6)	12.63	(15)		
	2.8	9.8125	(8)	9.8125	(8)				
	3.2	9. <b>9285</b>	(7)	10.25	(4)	9.5	(3)		
	3.6	7.4166	(6)	7.000	(4)	8.25	(2)		

Tab	le -	41.
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Number of <u>Passaloecus</u> provisioned cells from eight bore diameter classes and two bore depth classes. Combined data from four <u>Passaloecus</u> spp., 1986.

		Bo	ore depti	Diameter class							
Bore dlameter (mm)		120			60			totals			
	# C/#	T'NSTS1	Mean	# C/:	T'NSTS	Nean	¥ C/	* T'NSTS	Nean		
1.6 2.0 2.4 2.8 3.2 3.6 4.0 4.4	28 49 47 30 14 16 16 6	11 18 14 6 4 5 2	2.55 3.50 3.50 3.50 3.00 3.00	31 46 43 8 11 14 2	15 17 15 3 6 6 2	2.07 2.71 2.87 2.67 1.83 2.33 1.00 2.00	59 95 90 38 25 30 18 8	26 35 29 10 12 7 3	2.27 2.71 3.10 4.22 2.50 2.57 2.67		
Totals	206	66	3.12	157	65	2.42	363	131	2.77		

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B

<sup>1</sup>Number of Cells/Number of Trap Nests

Table 42.

Frequencies of trap nest height selection by four Passaloecus spp., 1986.

	Height (m)							
	.5	1	1.5	2				
<u>annulatus</u>	1	2	2	1				
arelatus	-	2	1	4				
<u>cuspidatus</u>	6	3	7	11				
monilicornis	3	8	5	2				

1	56
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Table 43.

			Bore dep	Diameter class					
		120			60		totals		
Bore diameter (mm)	Cum VCL	# VC	Mean VCL	Cum VCL	# VC	Mean VCL	Cun VCL	# VC	Mean VCL
1.6	319.5		29.05	211	<u> </u>	14.07	 530.5		20.40
2.0	705	18	39.17	384	17	22.59	1089	35	31.11
2.4	371 251	4	25.50	213 72	15 3	14.2 24	564 323	24	20.14
3.2	185	4	46.25	258	6	43	443	10	44.30
3.6	125	6	20.83	164	6	27.33	289	12	24.08
4.0	297	5	59.40	97	2	48.5	394	7	56.29
4.4	72	2	37.00	45	1	<b>4</b> 5	117	3	39.00
Totals	2327.5	66	35.27	1444	65	22.22	3771.5	131	28.79

Vestibular cell lengths (VCL) from eight bore diameter classes and two bore depth classes. Data compiled from four <u>Passaloecus</u> spp., 1986.

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Cell Data on Aphids Provisioned by <u>Passaloecus cuspidatus</u> , 1987.											
		Ag	oh i ds	per	Cell	(cell	1 in	ner-me	ost)		
Aphid spp.*	Trapnest number	1	2	3	4	5	6	7	8	9	10
1	1-85-116	32	38	25							
1	2-86-18	53									
1	1A-86-50	44									
1	2 <b>7-8</b> 6-24	36	37								
1	3-86-85	41	41	26							
1	2-85-096	30	27	26							
1	2-85-083	31	43								
1	4-85-049	36	52	40							
1	3-6A-86-15	30	30	23	23						
1	1 <b>B-86-</b> 14	23	20	21							
1	5-85-115	49	46								
1	2 <b>B-</b> 86-66	37	22	22	30						
1	2-5A-86-62	31	44	29	30	30	28				
1	3-6A-86-46	48	44	43	51	52					
1	2-5B-86-44	29	26	31	32	29					
1	6-7 <b>A-86-</b> 15	46	41								
1	3-6B-86-67	49	24	31	27	36					
1	2-5 <b>A-86-</b> 81	44	28	29	36	30	25				
1	2 <b>A-</b> 86-12	66	63	39	33						
1	3-6B-86-14	10	12	16	22	17	24	27	23	26	25
1	3 <b>A</b> -86-58	29									
1	2-5 <b>A-86-68</b>	29	26	31	33	36	30	37			
1	<b>2-85-</b> 055	5 <b>8</b>	49	30	37	25					
1	3 <b>B-86</b> -79	61	43	64	38	2 <b>9</b>	39				

¥	1	Ħ	Myzus	monar	dae;	2 = 9	Cinaria	a sp.	.; :	3 =	Mac	rosi:	phy		
			euphor	biae;	4 =	Euce	caphis	sp.	and	My2	<u>us</u>	sp.;	5	=	Myzus
			cerasi	L; 6 =	Site	obium	avena	2; 7	= <u>D</u>	acts	vnot	us.			

Table 44.

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Tab	le	44.,	(con	it'	'd.)
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		Ap	hids	per	Cell	(cell	1 in	ner-me	ost)		
Aphid	Trapnest										
spp.*	number	1	2	3	4	5	6	7	8	9	10
					_	_	-				
1	2- <b>5A-86</b> -67	51	5 <b>5</b>	29	37	33					
1	2 <b>A-86-44</b>	23	28								
1	<b>4A-86-31</b>	44	38	26							
1	2 <b>B-86-</b> 32	51	27								
1	3 <b>B-86</b> -21	36	50	30							
1	3 <b>A-86-</b> 47	57	67	73	39						
1	<b>2A-86-</b> 27	42									
1	<b>3a-86-85</b>	38	31	24	30	29	35				
1	3- <b>6A-86-</b> 66	74									
1	2-5 <b>A</b> -86-07	26	26	35							
1	2- <b>5A</b> -86-72	40	49								
1	3 <b>-6B</b> -86-20	9	29	14	17	25	35	36			
1	2 <b>B-</b> 86-82	34	41								
1	<b>3A-86</b> -32	35	49	52	61	43	40	46			
1	<b>3A-</b> 86-60	47	41	53							
1	3 <b>-6B</b> -86-07	47	53								
1	<b>4A-86-68</b>	47	53								
1	3 <b>-6B-86-</b> 10	51	62	40							
1	<b>4A-86-46</b>	37	45								
1	<b>4B-86-</b> 78	60	63	35							
1	2- <b>5A</b> -86-45	51	29								
1	3-85-114	54	35								
2	1 <b>B-86-</b> 29	18	28	18	33						
2	<b>2-85</b> -05 <b>8</b>	20	24	34	13	13					
2	1-85-050	34	32	30	32	28					
2	<b>2A-86-</b> 57	42	34								
2	1 <b>B-86</b> -26	27									
2	3 <b>A-</b> 86-43	31	22	19	21			-			
2	3-85-045	14	28	29	27	25	22	21	27	30	
¥ 1 =	Myzus monaro	dae: 2 =	: Cin	aria	SD.:	3 =	Macro	siphur			

euphorbiae; 4 = Euceraphis sp. and Myzus sp.; 5 = Myzus cerasi; 6 = Sitobium avenae; 7 = Dactynotus.

		y	oh i d <del>s</del>	per (	Cell (	cell	1 inn	er-mo	st)		
Aphid	Trapnest										
spp.*	number	1	2	3	4	5	6	7	8	9	10
					_					—	
2	2 <b>A-86-5</b> 1	51	29								
2	2B-86-02	26	29	28							
3	2- <b>85-078</b>	33	43	38	25						
З	3 <b>A-86-2</b> 7	29	30	20	32						
3	3 <b>B-86-78</b>	29	38	27	25						
3	2- <b>58-86-50</b>	21	18								
3	2-5 <b>B-86-18</b>	28	9	16	28	17	16				
3	3 <b>A-86-80</b>	22	23	28	17	20	19				
3	4 <b>B-86-</b> 57	26	15	17							
3	2-5 <b>A-86-</b> 19	13	13	13	18						
3	3-85-006	13	13	11							
3	2 <b>-5A-85-65</b>	9									
3	3- <b>6A-86-35</b>	24									
3	3 <b>-8</b> 5-075	14									
4	1 <b>A-86-47</b>	28	18	20	20						
4	2 <b>B-86-26</b>	39	33								
4	2 <b>A-86-</b> 15	37	33								
5	1-85-032	3	37	23	32	27					
5	2 <b>B-86-2</b> 1	69									
5	3 <b>-6A-86-17</b>	74	39	43							
б	1-85-059	27	24	46	29	47	36				
7	2 <b>-8</b> 5-052	27	30								
?	3-85-085	20	25	26							
?	3 <b>A-86-07</b>	41	43								
?	3-85-029	36	76	63	44	48	62	<b>58</b>	43		
?	4-85-003	75	71	86	55	47					
?	2 <b>B-86-</b> 15	32	37	36	38						
	Totals	2 <b>928</b>	2521	1608	10 <b>6</b> 5	686	411	225	93	5 <b>6</b>	25

Table 44., (cont'd.)

\* 1 = Myzus monardae; 2 = Cinaria sp.; 3 = Macrosiphum euphorbiae; 4 = Euceraphis sp. and Myzus sp.; 5 = Myzus cerasi; 6 = Sitobium avenae; 7 = Dactynotus.

Table 45.

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Aphid Spp.*	Trap Nest number	Total in n <del>es</del> t	Avg. per cell	# of cells	<pre># of days worked</pre>	date closed
1	1-85-116	95.00	31.67	3	7	6-12-87
1	2-86-18	53.00	53.00	i	2	6-13-87
1	1A-86-50	44.00	44.00	1	2	6-13-87
ī	2A-86-24	73.00	36.50	2	3	6-15-87
1	3-86-85	108.00	36.00	3	4	6-15-87
1	2-85-096	83.00	27.67	3	3	6-15-87
1	2-85-083	74.00	37.00	2	4	6-18-87
1	4-85-049	128.00	42.67	3	4	6-18-87
1	3-6A-86-15	106.00	26.50	4	4	6-18-87
1	1B-86-14	64.00	21.33	3	· 2	6-19-87
1	5-85-115	95.00	47.50	2	7	6-19-87
1	2B-86-66	111.00	27.75	4	3	6-20-87
1	2-5 <b>A</b> -86-62	192.00	32.00	6	10	6-24-87
1	3-6A-86-46	238.00	47.60	5	5	6-24-87
1	2-5B-86-44	147.00	29.40	5	6	6-25-87
1	6-7A-86-15	87.00	43.50	2	3	6-26-87
1	3-6B-86-67	167.00	33.40	5	6	7-01-87
1	2-5A-86-81	192.00	32.00	б	7	7-01-87
1	<b>2A-86-</b> 12	201.00	50.25	4	2	7-03-87
1	3-6B-86-14	202.00	20.20	10	3	7-06-87
1	3 <b>a</b> -86-58	29.00	29.00	1	2	7-05-87
1	2-5A-86-68	222.00	31.71	7	8	7-05-87
1	2-85-055	199.00	39.80	5	2	7-05-87
1	3 <b>B-86</b> -79	274.00	45.67	6	2	7-08-87
Table 45., (cont'd)

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					worked	c103ed
1	2-5A-86-67	205.00	41.00	5	7	7-01-87
1	2 <b>A-</b> 86-44	51.00	25.50	2	2	7-08-87
1	<b>4A-86-31</b>	108.00	36.00	3	2	7-08-87
1	2 <b>B-86</b> -32	78.00	39.00	2	11	7-0 <b>8</b> -87
1	<b>3B-86-</b> 21	116.00	38.67	3	2	7-10-87
1	<b>3A-86-4</b> 7	236.00	59.00	4	2	7-10-87
1	2 <b>A-86-</b> 27	42.00	42.00	1	4	7-14-87
1	3 <b>A-</b> 86- <b>8</b> 5	187.00	31.17	б	5	7-1 <b>4-8</b> 7
1	3-6A-86-66	74.00	74.00	1	5	7-14-87
1	2-5A-86-07	87.00	29.00	3	5	7-14-87
1	2-5A-86-72	89.00	44.50	2	4	7-14-87
1	3-6B-86-20	165.00	23.57	7	8	7-14-87
1	2 <b>B-</b> 86-82	75.00	37.50	2	6	7-20-87
1	3A-86-32	326.00	46.57	7	б	7-20-87
1	3 <b>7</b> -86-60	141.00	47.00	3	6	7-20-87
1	3-6B-86-07	100.00	50.00	2	б	7-20-87
1	4 <b>A-</b> 86-68	100.00	50.00	2	6	7-20-87
1	3-6B-86-10	153.00	51.00	3	б	7-20-87
1	4 <b>7-86-46</b>	82.00	41.00	2	6	7-20-87
1	4 <b>B-86-</b> 78	158.00	52.67	3	6	7-20-87
1	2-58-86-45	80.00	40.00	2	8	7-22-87
1	3-85-114	89.00	44.50	2	2	7-24-87
2	1B-86-29	97.00	24.25	4	4	6-02-87
2	2-85-058	104.00	20.80	5	1	6-03-87
2	1-85-050	156.00	31.20	5	4	6-06-87
2	2 <b>A-8</b> 6-57	76.00	38.00	2	7	6-07-87
2	1 <b>B-86-26</b>	27.00	27.00	1	1	6-08-87
2	3 <b>A-86-4</b> 3	93.00	23.25	4	3	6-08-87
2	3-85-045	223.00	24.78	9	3	6-08-87

 $\frac{euphorphae}{2}$ ;  $4 = \frac{Euceraphis}{Euceraphis}$  sp. and  $\frac{Hyzus}{Hyzus}$  sp.; 5 cerasi; 6 = Sitobium avenae; 7 = Dactynotus.

Table 45., (cont'd)

Aphid spp.*	Trap Nest number	Total in nest	Avg. per cell	# of cells	<pre># of days worked</pre>	date closed
2	2 <b>A-86-</b> 51	80.00	40.00	2	1	6-13-87
2	2B-86-02	83.00	27.67	3	4	6-12-87
3	2-85-078	139.00	34.75	4	2	7-05-87
3	31-86-27	111.00	27.75	4	7	7-08-87
3	3B-86-78	119.00	29.75	4	4	7-0 <b>8-87</b>
3	2-5B-86-50	39.00	19.50	2	2	7-10-87
3	2-5B-86-18	114.00	19.00	б	6	7-10-87
3	3 <b>A-86-8</b> 0	129.00	21.50	6	4	7-14-87
3	<b>4B-86-57</b>	58.00	19.33	3	б	7-20-87
3	2-5A-86-19	57.00	14.25	4	8	7 <b>-22-87</b>
3	3-85-006	37.00	12.33	3	7	7-27-87
3	2-5 <b>A</b> -85-65	9.00	9.00	1	5	7-29-87
3	3-6A-86-35	24.00	24.00	1	-	-
3	3-85-075	14.00	14.00	1	10	8-06-87
4	1 <b>A-86-4</b> 7	86.00	21.50	4	5	6-03-87
4	2 <b>B-</b> 86-26	72.00	36.00	2	5	6-03-87
4	<b>2A-86-15</b>	70.00	35.00	2	4	6-06-87
5	1-85-032	122.00	24.40	5	21	7-05-87
5	<b>2B-86</b> -21	69.00	69.00	1	3	7 <b>-08-87</b>
5	<b>3-6A-86-</b> 17	156.00	52.00	3	2	7-10-87
б	1 <b>-85</b> -059	209.00	34.83	б	10	6-08-87
7	2- <b>85</b> -052	57.00	28.50	2	5	7-29-87
?	3-85-085	71.00	23.67	3	1	6-08-87
?	<b>31-86-</b> 07	84.00	42.00	2	5	6-19-87
?	3-85-029	430.00	53.75	8	8	7-1 <b>4-87</b>
?	4-85-003	334.00	66.80	5	4	7-14-87
?	<b>2B-86-15</b>	143.00	35.75	4	3	7-27-87
	Totals	9618.00	34.23	281	381	

\* 1 = Myzus monardae; 2 = Cinaria sp.; 3 = Macrosiphum euphorbiae; 4 = Euceraphis sp. and Myzus sp.; 5 = Myzus cerasi; 6 = Sitoblum avenae; 7 = Dactynotus.

## APPENDEX 5

## Proposed Future Investigations

Prior to this investigation <u>Passaloecus areolatus</u> was reported from only two 1.5 mm bore trap nests (Vincent, 1978). My studies have identified an area with a significant population of <u>P. areolatus</u> and suggest factors significant in its distribution. To verify and expand upon these studies, it is proposed that a study of the following aspects of the trap-nesting biology of <u>Passaloecus areolatus</u> during the summer of 1990 be undertaken: preferences for station species, bore diameters, and nest height; duration of the provisioning season, and species of aphids provisioned.

Pre-split paraffin-coated trap nests with bore diameters 1.2 -2.8 mm with increments of .4 mm will be drilled to a depth of 60 mm. Fifteen stations will be selected, including five each of <u>Juglans</u>, <u>Pinus</u> and <u>Fraxinus</u>. Trap nest bundles will be distributed at heights of one to six meters with one meter intervals. Bundles will consist of fifteen trap nests - three from each of five bore diameters.

Trap nests will be distributed in the study area in mid-May. Inventories will be made each week, closed nests will be removed and replaced with trap nests the same bore diameter. Closed nests will be opened, data taken on nest architecture and provisions, and two aphids

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will be removed from each provisioned cell for identification. Observations will be continued through mid-August. Wasp larvae and provisions will be transferred to rearing vials and stored over winter in an unheated garage. Adults reared the following spring will be used to confirm identifications.

Chi-square (I) will be used to test for differences in preferences for station species, bore diameters and trap nest heights. One way ANOVA and t(II) tests will be used to test for differences in cell lengths and volumes among trap nests of different bore diameters. Aphid provisions will be analysed for differences in numbers of aphids provisioned and compared with aphids provisioned by <u>P. cuspidatus</u> to determine whether these wasps partition aphids by species.

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