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TESTING THE "COLD POCKET" HYPOTHESIS: OVIPOSITION PREFERENCE IN THE CANADIAN TIGER SWALLOWTAIL, *PAPILIO CANADENSIS*

By

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ABSTRACT

TESTING THE "COLD POCKET" HYPOTHESIS: OVIPOSITION PREFERENCES OF THE CANADIAN TIGER SWALLOWTAIL, *PAPILIO CANADENSIS*

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Three areas in Northern Michigan; Vanderbilt, Pellston and Cross Village were compared for climate differences; host plant phenology differences and *Papilio canadensis* Rothschild and Jordan (Lepidoptera: Papilionidae) oviposition preference differences. The 'cold pocket' hypothesis predicted that these sites were climatically distinct, with Vanderbilt the coolest site and Cross Village the warmest; that phenology in the 'cold pocket', Vanderbilt area, would be delayed; and that oviposition preference by 'cold pocket' *P. canadensis* butterflies would be for white ash.

Every year with regard to total degree-day accumulations, Vanderbilt was the coldest site. Vanderbilt was cooler than the other sites only sixteen times in twenty-nine years during the time period when *P. canadensis* butterflies were actively selecting host plants (March 1st – July 5th). In the years of this study, 1996 and 1997, host plant phenology was not delayed in the 'cold pocket'. In 1996 and 1997, *P. canadensis* butterfly populations from across Northern Michigan did not show oviposition preference differences. In 1996 and 1997, butterflies from the 'cold pocket' did not show an oviposition preference for white ash. These results indicated a greater depth and complexity to climate/ plant/ herbivore interactions than previously assumed by the 'cold pocket' hypothesis.

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Introduction

Climate, Plant and Herbivore Interactions

"The action of climate seems at first sight to be quite independent of the struggle for existence; but in so far as climate chiefly acts in reducing food, it brings on the most severe struggle between the individuals whether of the same or of distinct species, which subsist on the same kind of food." (Darwin 1859). The interaction between climate, plants and herbivores has been at the center of a great deal of ecological, environmental and evolutionary research. Basic aspects of biology are rooted here; population dynamics; nutrient flow and stabilizing mechanisms in ecology (Hairston et al. 1960); and coevolution of host plants and their herbivores (Thompson 1994) are ecological phenomenon where understanding is advanced by studies of climate, plant, and herbivore interactions.

Examining effects of predation and climate, in addition to phytochemistry, might further clarify plant/ herbivore relationships, as some scholars have suggested that phytochemical coevolution theories do not fully express the depth or variation found in plant/ herbivore relationships (Smiley 1978, Janzen 1988, Bernays and Graham 1988). A recent variant on the topic of plant/ herbivore relationships and the role of climate is the geographic mosaic theory of coevolution, which posits a coevolutionary relationship continuum in which interactions vary in intensity and expression within a species range (Thompson 1994). This theory incorporates the effects of abiotic variance, such as climate differences, on plant-herbivore interactions. Although much ecological research has delved into climate/ plant/ herbivore interactions, understanding is far from complete.

Plausibly, a variety of climatic factors could influence plant/ herbivore interactions, of which regional warmth or coolness, humidity and precipitation are but two examples (Barbosa 1988). A convenient measure of the former characteristic is thermal-unit accumulation. Host plant phenology has also been implicated in affecting herbivore selection, especially in cases where there are changes in environmental conditions (Barbosa 1988). Constraints on thermal units have been shown for latitudinal clines that can effect host choice (Scriber and Lederhouse 1992). This ‘voltinism-suitability’ hypothesis has been extended to local ‘cold pockets’ not simply latitude (Scriber 1996a).

The voltinism-suitability hypothesis has its wide-reaching roots in basic tenets of plant/ herbivore interaction theory. The tenets include factors that drive plant/ herbivore interactions and herbivore range. There are questions as to whether secondary phytochemistry, predators, and the environment are more important to herbivore population control and dynamics. Often, the range of suitable host plants can limit the distribution of associated herbivores. Host plant distribution can be limited by environmental conditions, particularly temperature. This could effect the distribution, development time, and fitness (Cockrell et al. 1994) of the associated herbivores.

Temperature can also affect the number of generations an herbivorous insect can complete in a growing season. Butterflies may make behavioral and physiological adjustments to prevailing weather conditions (Cockrell et al. 1994). In areas where the herbivore may not be able to complete one or two generations, as the area is thermally constrained, there are selection pressures on the herbivore to feed on the plant that will most enhance growth. For monarch butterflies, it was shown that latitude and oviposition date can influence the maturation time and the number of generations. Earlier oviposition dates had greater influence on maturation time of larvae than later oviposition dates (Cockrell et al. 1994). In addition to latitude, oviposition date, and climate differences affecting herbivorous insect behavior, growth, distribution and survival, host plant quality is also important. Not all host plants are equal in suitability for larval growth. Growth of many insect larvae is nitrogen limited (Mattson 1980, Scriber 1984a and b, Mattson and Scriber 1987). Since foliar nitrogen content and leaf water are correlated (Scriber and Slansky 1981, Mattson and Scriber 1987), larvae on leaves with low leaf water tend to grow more slowly (Scriber 1977). In areas that are thermally constrained, a herbivore that feeds on a more suitable host plant has an increased chance of pupating before the end of the season. In areas where the number of generations is not thermally constrained, selection pressures are lifted and herbivores are able to feed on a wider number of host plants successfully.

The interaction of thermal units and host plant distribution may create a dynamic interaction in which herbivore/ plant interactions vary across space and time, causing local specialization patterns for a polyphagous species. Evidence has indicated that some species of *Papilio* have an extremely localized oviposition preference in relation to thermal accumulation or phenology. These butterflies oviposit on leaves that are in full sun, or that may have higher water content (Grossmueller and Lederhouse 1985). In summary, in areas with a short growing season, there is selection pressure for a herbivore to consume a high quality food source that allows it to reach maturity earlier, albeit of smaller size (Ayres and Scriber 1994). The voltinism-suitability hypothesis is the direct predecessor to the cold-pocket hypothesis.

Papilio canadensis (Rothschild and Jordan) butterflies, their oviposition host plants and their larval performance have been studied as an example of climate/ plant/ herbivore interactions. These butterflies are excellent research organisms because they are common, showy, strong fliers, and have a variety of interactions with different host plants from extreme specificity to a great deal of polyphagy (Scriber 1995). Oviposition preferences within the *Papilio* group form a particularly intriguing way by which to test interactions, as part of the oviposition preference is genetically based and some of the genes effecting oviposition preference have been localized to a single chromosome (Thompson 1995). Oviposition preferences may be influenced by a variety of factors.

Not all oviposition sites afford similar nutrition, cover, and protection for larvae and adult butterflies. In the landscape of available oviposition sites, some sites are more rewarding. Since larvae generally do not move between sites, ovipositing female butterflies that choose oviposition sites that ensure the greatest fitness for offspring and survival of their genes would be reproductively successful. Because of their catholicism, choice of oviposition sites might be cued by the environmental situation during the flight season. The cues used by the butterflies could include visual ones, such as leaf shape (Rausher 1980, Papaj 1986, Renwick and Chew 1994), tactile ones, such as leaf toughness, and sensory responses to leaf chemical components (Renwick and Chew 1994). Larval growth potential need not be the only important consideration. Larvae may also be susceptible to host-specific predators or parasitoids (Thompson and Pellmyr 1991). In order to reduce the probability of being attacked by predators and parasitoids, some larvae use a form of crypsis (Thompson and Pellmyr 1991), but tree characteristics, such as secondary phytochemistry that reduce effects from parasitoids and predators, might be important selection factors (Thompson and Pellmyr 1991).

The direct measure of larval fitness and hence reproductive success of a test species follows the rearing of larvae to adults in the natural environment and determination of survival to sexual maturity. Survival in the field would also provide an estimate of natural levels of mortality. Indirect measures, more amenable to controlled experimentation, include pupal weight, length of time until pupation, and survival of the larvae. If oviposition preferences were being driven by qualities intrinsic to the host plant there could be a correlation between larval performance and host plant quality. If the system is being driven by extrinsic factors, those that increase the survival for the butterfly, but not necessarily for the larvae (Thompson 1988, Thompson and Pellmyr 1991), there should be less correlation between larval performance and oviposition preference for a host plant.

'Cold Pocket' Hypothesis:

In the Northern Lower Peninsula of Michigan, and in the Western Upper Peninsula of Michigan, there are areas of lower average annual frost-free days compared to nearby areas, known as 'cold pockets' (sensu Scriber 1996a). In these areas with a constrained growing season, it is implied that plant phenology and bud-break are delayed (Johnson and Scriber 1994, Scriber 1996a). It was observed that in these 'cold pocket' areas, *P. canadensis* butterflies preferred *Fraxinus americana* L., white ash, as an oviposition host plant (Johnson and Scriber 1994). Studies outside 'cold-pockets' had shown white ash to be of poor quality for hosting larval growth (Johnson and Scriber 1994) because ash quickly declines in some forms of soluble nitrogen and increases in leaf toughness after bud-break (Hunter and Lechowicz 1992). The ‘cold pocket’ hypothesis posits that white ash would not be as poor a host inside as it was outside of the ‘cold pocket’ as white ash, a late bud-breaking plant, would be even further delayed in bud-break in the ‘cold pocket’ (Scriber 1996a). White ash would be younger, with higher water content at the time that *P. canadensis* is flying. *P. canadensis*, if selecting leaves that increase larval performance, would choose these delayed white ash leaves as they would be more nutritive, with higher water content, an increase in some forms of soluble nitrogen, and with a lower leaf toughness. The increase in larval performance relative to other host species would not be seen on white ash outside the ‘cold pocket’ (Scriber 1996a).

Other rationales to explain the localized *P. canadensis* white ash oviposition preference have been proposed. These include the possibility that *P. canadensis* competes for resources with major forest defoliators such as *Malacosoma disstria* (Hübner), forest tent caterpillar, and *Lymantria dispar* L., gypsy moth (Scriber 1996a; Scriber and Gage 1995). As gypsy moth is known to avoid white ash as a host plant *P. canadensis* might be driven to utilize white ash in the face of such competition (Scriber 1996a). However, gypsy moth is a recent arrival to Michigan (Scriber and Gage 1995) and it seems unlikely that in 6-8 years gypsy moth would have driven *P. canadensis* to a white ash preference. *P. canadensis* preference for white ash has been observed in competitor-free laboratory trials (Scriber 1996a, Johnson and Scriber 1994), also suggesting that the choice was not due solely to forest pest outbreaks. Additionally, these forest pests do not occur in all of the 'cold-pockets', such as in the Upper Peninsula of Michigan, in which the oviposition preference shift was observed. Lastly, these two pests do occur in conjunction with *P. canadensis* outside of 'cold pocket' areas and where white ash is not a preferred host.

Papilio canadensis:

Papilio canadensis is a species in the *Papilio glaucus* L. group, and as a species only recently has been separated from *P. glaucus* (Hagen et al. 1991). The range of *P. canadensis* corresponds to the Pleistocene glaciation area of Northern America and constitutes a significantly distinct ecotone (Scriber and Gage 1995), extending from the Appalachian mountain range into the Great Lakes area, and north across Canada and Alaska (Hagen et al. 1991). The adaptations of *P. canadensis* for life in cold climates (Kukal et al. 1991, Ayres and Scriber 1994) as well as their ability to detoxify a great variety of plant allelochemicals, such as tremulacin from quaking aspen and other Salicacious plants, and prunasin from black cherry, demonstrates the successful escape from its tropical ancestry of the Papilionidae (Scriber 1995).

P. canadensis is a univoltine butterfly (Hagen and Lederhouse 1985), spending four to eight months of the year as a pupa, often buried under snow. In order to avoid eclosing before the temperature is sufficient to maintain metabolic and dietary needs, *P. canadensis* must be tuned in to local climate factors, such as precipitation and day length. Once it has emerged, it spends its three to six week adult life span (Scriber 1996b) feeding, mating and ovipositing. *P. canadensis* emerges from its puparium in late May

(Scriber 1996b). *P. canadensis* is protandrous in most years, with males emerging slightly before females (Lederhouse et al. 1995). Early emergence allows males greater access to females (Ae 1995), as well as salts and minerals (Lederhouse et al. 1990) that are possibly used for spermataphore construction (Lederhouse et al. 1990). A mature male patrols from site to site seeking receptive females (Brower 1959), chases, courts and attempts to copulate with a receptive female. *Papilio* butterflies are polygamous, with females sometimes mating five to six times (Scriber 1996b). After a mating, the female stores the spermataphore of the male in her bursa copulatrix, and may utilize the sperm of the most recent mating to fertilize her eggs (Scriber 1996b). After transfer of the spermataphore, females search for oviposition sites.

Upon alighting on a host plant, a female swallowtail uses her forelegs in a drumming behavior to ascertain host plant quality (Nishida 1995). She approaches the leaves, and curling the tip of her abdomen forward (Nishida 1995), deposits a single egg on the plant surface (Scriber 1996b). Eggs when freshly laid are a deep green, blending into the leaf surface color. As the embryo within the egg matures, the egg becomes deeper in color, and is almost brown at the time of ecdysis. After ecdysis, the larva eats the chorion of the egg in order to obtain some early nutrition, or perhaps to remove evidence of its presence from potential natural enemies (Scriber 1996b). The larva feeds on the leaves of the plant on which it was oviposited. If the plant has toxic chemicals, is low in nutrition, subject to desiccation, signals predators to feed on the larva, or affords little protection, the larva is less likely to survive.

P. canadensis is a polyphagous butterfly, unusual in the butterfly world because of the high degree of polyphagy, with adults and larvae utilizing a variety of host plants for feeding and oviposition (Scriber 1984a). *P. canadensis* can utilize plants from the families Salicaceae, Oleaceae, Rosaceae, Tiliaceae, Lauraceae, and others (Scriber 1984a). As *P. canadensis* host plants are trees, they are usually apparent and enduring, ensuring that *P. canadensis* can actively seek and oviposit on a host plant rather than lay eggs haphazardly (Wiklund 1984).

The trees investigated for oviposition preference by *P. canadensis* are listed in Table 1. For each, the northern portion of Michigan is roughly in the middle of its range. There are differences among the trees in preference for soil type, tolerance for shade, tolerance for water stress and other characteristics, as might be expected (Voss 1985, 1996, Crow 1990, Marquis 1990, Safford et al. 1990, Schlesinger 1990, Perala 1990). Of particular importance for this project is that bud-break depends on thermal accumulation with quaking aspen (Michaux) (Perala 1990) and paper birch (Marshall) (Safford et al. 1990) breaking bud early; and basswood (L.) (Crow 1990) and white ash (L.) (Schlesinger 1990) breaking bud late. Black cherry (Ehrhart) breaks bud intermediately (Marquis 1990).

The present study investigated *P. canadensis* oviposition preference in relation to larval performance using host material from areas with decreased thermal accumulation and from areas of greater thermal accumulations. Climatic differences at three different locations in Northern Michigan were characterized. Water content of host leaves in 1996 and 1997 was measured. Oviposition preference and larval performance experiments were carried out with a variety of *P. canadensis* populations in Northern Michigan in

1996 and 1997. The 1996 growing season was climatically typical for the region, while 1997, an El Niño year, was dryer and colder across the state. A few updating observations were made in May and June of 1998; both months were hot and dry.

Sites:

The surveyed sites covered a range of growing seasons based on the average number of freeze-free days as described by the Michigan Climatic Atlas (Eichenlaub et al. 1990, Scriber 1996a). The first site was the Pellston area (Pellston Plains; on Catsman□s corner; to the intersection of Riggsville Rd. and Bryant Rd., Emmet and Cheboygan counties). Pellston averages 90-100 freeze-free days in the growing season. The Vanderbilt area, a 'cold pocket', (near Vanderbilt in Pigeon River State Forest, on the border of Cheboygan and Otsego counties) was the second site. Vanderbilt averages 70 freeze-free days in the growing season. Thumb Lake was 'added' to the Vanderbilt site only for occasional collection of 'cold pocket' butterflies. For some oviposition preference trials, yields of Vanderbilt test organisms were inadequate for the experimental protocol and Thumb Lake specimens were taken to supplement Vanderbilt ones (Thumb Lake averages around 90 freeze-free days in the growing season). A third area beside Lake Michigan, near Cross Village, Wycamp, Hardwood State Forest (Emmet county) was examined. Cross Village averages 140-150 freeze-free days in the growing season. No butterflies collected from Cross Village laid any eggs. Most of the butterflies collected from Cross Village were collected early in the flight season and may have been unmated. In order to compare oviposition preferences of an outlying population of butterflies, butterflies were collected from across the Upper Peninsula and employed. The Upper Peninsula (Chippewa County) averages 110-130 freeze-free days; (Iron County) averages 70-90 freeze-free days; (Dickinson County) averages 100-110 freeze-free days.

Methods:

Climatology:

Daily degree-days were calculated using the averages method (Pedigo and Zeiss 1996) with a general insect threshold temperature of 10°C. Climate data from the three sites, from 1969-1997, were obtained from the Department of Geology, Climatology Lab, Michigan State University. These years had almost complete data sets across the sites. Three time periods were examined. The first time period was the seasonal accumulated degree-days (March 1st - October 31st). The 'cold pocket' hypothesis assumed climate differences across Northern Michigan based on seasonal freeze-free day differences, roughly correlated to seasonal accumulated degree-day differences. In order to make comparisons within the framework of the 'cold pocket' hypothesis, it was necessary to examine climate differences at this level. Degree-day accumulations that occur after leaf senescence and after larvae pupate, may contribute to overall degree-day accumulations, but are not very interesting biologically. Early season degree-day accumulations however, may be very important to the biological systems studied here. Early season degree-day accumulations can influence bud-break, leaf flush, and butterfly eclosion. For the next two analyses of degree-day accumulations, late season degree-day accumulations were excluded, and early season degree-days were included. Another time period examined was the flight and larval development season accumulated degree days (March 1st - July 31st). This time period included early season degree-day accumulations, the degree-days accumulated during the *P. canadensis* flight season (usually confined to June, sometimes occurring earlier in May), and during the time period when larvae were developing. The third time period examined was the flight season accumulated degree-days, (March 1st - July 5th). This time period included early season degree-day accumulations, and the degree-days accumulated during the *P. canadensis* flight season.

Degree-days (threshold temperature 10°C) accumulated in Vanderbilt for May, June, July, and August for each year, 1987-1997, were divided by the amount of precipitation in Vanderbilt in millimeters. Vanderbilt was the only site that had both reliable precipitation and thermal unit data. Such heat/ precipitation indices are good for indicating drought stress conditions (Gage, 1998).

Phenology:

Leaves were collected in 1996 from Pellston and Vanderbilt. Leaves were selected without conscious bias from several trees of each of five species: black cherry, paper birch, white ash, basswood and quaking aspen. Collections were made on nine dates between June 3 and July 23, although not all hosts were sampled from both sites on each date. There were at least four collection dates per species per site. Leaves were immediately placed into plastic, airtight bags and stored on ice. They were categorized by site, date and species. For water content determination, leaves were weighed the same day as they were collected, placed into a drying oven set at 50°C, for 3-4 days. Dry and wet weights were used to calculate percent water content.

In 1997, leaves were collected from all three sites. There were 38 collection dates between May 23 and August 13. Due to the labor-intensive nature of the sampling regime, Vanderbilt leaves were usually collected a day later than Pellston and Cross

Village leaves. Ten leaves of each species per date, per site, were processed.

Relationships among leaf water weight, tree species, site of origin, and date were examined using a stepwise regression analysis, with yearly data analyzed separately, then combined, to determine if there were year to year differences in phenology.

Oviposition Preference:

Four oviposition assays were carried out. In each, there was one butterfly, and one leaflet, leaf, or set of leaves per treatment per chamber. Lifetime assays were run (until the butterfly was weak or exhausted). Forewing length measurements and age estimates, as described by Lederhouse and Scriber (1987), were made on field-collected females before each was assigned a brood number and distributed to an oviposition preference trial. Leaves, of approximately equal surface area, refrigerated less than seven days were used. The leaf petiole was placed into a water-filled plastic aquapic. Random placement of all host plants in each array, around a clear plastic multi-choice oviposition chamber (25 cm diameter by 9 cm height) ensured that oviposition results were uninfluenced by sequence. Oviposition dishes were stacked on a rotating turntable (6 turns/h) lit by 60-watt incandescent bulbs (6h light-dark cycles) (Scriber 1993). Temperature inside the oviposition dishes was maintained near 30°C during peak oviposition times, when the oviposition dishes were illuminated to simulate daylight. Butterflies were removed from oviposition dishes and fed a 20% honey solution daily while eggs were collected and counted. Eggs on the paper liner, or plastic chamber were counted as on a leaf if they were within 1 cm of the leaf. If the egg was more than 1 cm from the leaf, they were counted as laid on a plastic or paper surface, which was considered a 'leaf type' in analysis. Leaves with eggs present were removed and stored (27 °C) for larval assays. Positions were refilled with fresh foliage of the same species. The replacement foliage was not necessarily from the same tree or collection date. In all cases, the foliage was from the same site.

Five choice array: Adult female *P. canadensis* were presented simultaneously with leaves of white ash, basswood, paper birch, black cherry and quaking aspen collected either in Pellston (1996 and 1997) or Vanderbilt (1997). Butterflies were collected from the Vanderbilt area (17 in 1996, 19 in 1997) and from outside the Vanderbilt area (54 in 1996, 16 in 1997).

Young and old white ash array: In 1998, an oviposition array consisting of two types of white ash foliage was tested. The two types were older, fully expanded leaves (collected from Okemos, Michigan) and young unexpanded leaves (collected from near the 'Mystery Spot' in Chippewa county). Butterflies were collected from Vanderbilt (n=2) and five other sites across Northern Michigan and the Upper Peninsula (n=13.)

Phenology array: In 1997, oviposition arrays consisting of white ash foliage collected from the three principal sites, plus one more, were tested. The fourth site, in Okemos, near Michigan State University, was outside the geographic region, and south of the range of *P. canadensis.* Butterflies were collected in Vanderbilt (n=6) and outside this area (n=6).

Chemical extract array: White ash leaflet material was collected from four sites: Pellston, Vanderbilt, Cross Village and Okemos. Leaves from Pellston were collected on 10 June 1997 and 24 June 1997; and extracted on 16 June 1997 and 27 June 1997. Vanderbilt leaves were collected on 4 June 1997 and 11 June 1997; and extracted on 5 June 1997 and 16 June 1997. Cross Village leaves were collected on 10 June 1997 and 24 June 1997; and extracted on 16 June 1997 and 30 June 1997. Okemos leaves were collected on 12 June 1997 and 24 June 1997; and extracted on 16 June 1997 and 26 June 1997. The leaflet material (petiole and rachis not included) from each site, on each extraction date was placed in a sterile liquid nitrogen cooled mortar and pestle and roughly ground. This material was then placed in a sterile Electric Coffee and Spice Grinder (Regal, Kewaskum, WI) and ground until the material was homogeneous, and fine. Thirty to forty g's of the dispersion was placed in a filtration column (149 mm x 450 mm) that had been packed with cotton swabbing, and methanol (175 mL) was added. (An oviposition assay in 1996, testing *Papilio glaucus* oviposition preference for white ash extracts found a higher response to methanol rather than hexane or ethyl acetate. Extracts in 1996 were also solubalized in acetone and sprayed onto quaking aspen leaves with a plant sprayer.) After 30 min., the column stopcock was opened and effluent was collected. The stopcock was closed, and the collected effluent was added back to the column. This process was repeated two times. After the effluent was collected a third time, the solubalized extract was concentrated in a rotovap (Brinkmann Instruments Inc., Westbury, NY) at 100 °C (there was not a successful vacuum created by the rotovap set-up used), until all volatile components had been removed. The residue was weighed and acetone was added to make a 1g/1L, or 10% suspension. Using a plant sprayer, this was sprayed to saturation onto quaking aspen leaves that were placed in oviposition arenas. Ovipositional responses to such extracts, from Pellston, Cross Village, Vanderbilt and Okemos, were measured and compared to the response to leaves sprayed with acetone alone and water alone. Butterflies were collected from Vanderbilt (n=4) and from outside Vanderbilt (n=5).

Larval growth:

Eggs were placed in dishes marked with a brood number and the host plant preference of the mother. Mother preference was defined as the oviposition host plant with the highest percentage of eggs. Dishes were stored in a Percival growth chamber at 27 °C (18 L: 6 D) and checked daily for eclosion. When neonates emerged, all larvae from the same brood were distributed randomly to a feeding assay on black cherry, paper birch, white ash, quaking aspen or basswood leaves. Few larvae were set up on paper birch or basswood in 1997, as these were found to be poor hosts in 1996. No more than five or six larvae per dish were assigned to initial feeding assays. Larvae were reared at 27 °C (18 L: 6D) in Percival growth chambers. Larvae were checked every two to three days (or more frequently if leaf material was rapidly consumed), the dishes were cleaned, leaf material replaced, and the date, number of surviving larvae, and the instar of each larvae were recorded. When the larvae reached the third instar they were separated and reared in individual dishes to reduce crowding effects. After pupation, they were weighed to the nearest 0.0001g and sexed. Weight, length of time to pupation, length of time in each stage of metamorphosis and overall survival were recorded. Overall survival was the percentage of neonate larvae that pupated relative to the number set up on the host plant.

Statistical analyses:

Data were analyzed in spreadsheet format using Microsoft Excel 5.0 (Microsoft, 1994). Normality was confirmed with the Shapiro-Wilkes tests in the proc univariate program (SAS Institute Inc., 1989). Climate data were analyzed with proc glm in SAS to observe statistical differences in mean degree-day accumulations between sites; and using proc reg in SAS to investigate relationships between year, site and accumulated degree-days. As Cross Village data were not complete for the 1985-1997 period, missing years were excluded from regression and analyses of variance. Phenology data were analyzed using proc reg in SAS for 1996, 1997 and the two years combined to probe relationships between site, date, accumulated degree-days, host-plant species, year, and foliar percent water content. Oviposition data ratios were arcsine transformed and analyzed using proc glm in SAS with an ANCOVA where approximate butterfly age and winglength were covariates. Statistical significance was assigned at $\alpha = 0.05$ using Fishers least significant difference test.

The most important contributing factor to significant interactions was determined by slicing the interactions in SAS. All reported means and standard errors are least square means as these means and standard errors are adjusted as if the design had been balanced. They provide a population marginal mean, and allow that the sum of oviposition preference ratios will add to one. Mean pupal weight differences were analyzed using proc glm in SAS with an ANOVA to uncover significant differences in pupal weight attributable to pupal sex or host-plant. Mean days to pupation differences were analyzed using proc glm in SAS with an ANOVA to discover significant differences in the days to pupation attributable to pupal sex or host-plant. Difference in survival of larvae per instar (where the larval host plant, the mother's oviposition preference, the instar the larva was in, and the length of time the larva spent in that instar were variables) was analyzed with a repeated measures analysis in proc mixed in SAS, with the covariance parameter estimate as a diagonal arcsine model.

As there is some concern as to how a butterfly's oviposition preference should be weighted, the oviposition assays were examined using an additional protocol. In this analysis, only butterflies that laid a minimum of ten or more eggs were included. The cut-off value of ten was used, because this was the historical cut-off value in prior examinations of the 'cold pocket' hypothesis. While this analysis may skew the results in favor of butterflies that lay more eggs, it minimizes the chance that the results may be skewed by butterflies that lay few eggs, and may not really exhibit host plant preferences. This statistical analysis was conducted in the same manner as the above, with the exception that butterflies laying fewer eggs were excluded.

Results:

Climatology:

Over the time for which comparable data were available (i.e. 1969-1986), generally, Cross Village had the largest average number of accumulated degree-days and Vanderbilt the smallest. This was true whether or not one was examining accumulated degree-days for the season (March 1st - October 31st); early season to the time of pupation (March 1st - July 31st); or the early season and the butterfly flight period (March 1st - July 5th) (Table 2).

Mean seasonal accumulated degree-days, March 1st – October 31st, were significantly different between Vanderbilt and the other two sites ($p<0.0001$); and Pellston and Cross Village ($p < 0.05$). Mean flight and larval development accumulated degree-days, March 1st – July 31st, were significantly different between Pellston and Cross Village ($p <0.002$) and Vanderbilt and Cross Village ($p <0.0001$). There was no statistically significant difference for this period between Pellston and Vanderbilt. Mean flight season accumulated degree-days, March 1st – July 5th, were not statistically significantly different between Vanderbilt and Cross Village; Vanderbilt and Pellston; and Pellston and Cross Village. In 5 years of 29 the difference in seasonal degree-days between Vanderbilt and Pellston exceeded 200 at July 31st. In 5 years of 29 the difference between Vanderbilt and Pellston at July 5th exceeded 100 (Figure 1).

Vanderbilt showed a significant warming trend in total seasonal accumulated degree-days (Figure 1). For the two shorter periods, trends in the Vanderbilt accumulated degree-days, while positive, were not statistically significant. Neither Cross Village nor Pellston showed any persistent trends over 29 years.

For all three time intervals, the year to year variance in accumulated degree-days was greater than site to site variation in accumulated degree-days. Stepwise analysis for the flight season degree-day accumulations, March 1st - July 5th, removed site differences from the model, as it didn't add to the power of the regression, showing that site differences were not significant (Table 3).

As precipitation differences and water stress could influence host plant quality for larval growth, heat/ precipitation indices are of particular relevance to this project. Heat/ precipitation indices (Figure 2) for the Vanderbilt area for years 1987-1997 indicated that May, 1997, was the driest of all Mays and that 1997 had the second most drought-like June. (June 1991, had a higher heat/ precipitation index and was both hot and dry.) July and August of 1997 had heat/ precipitation indices similar to those of other years.

Phenology:

In 1996, leaf water content varied among tree species, i.e. interspecifically, and collection date, i.e. seasonally (Table 4). However, within a given plant species, and on a particular date there were no site differences (Table 4). When data were adjusted for degree-day accumulations, stepwise regression analysis kept all factors in the regression model, but site differences were the least important (Table 4). Water content declined in tree leaves throughout the season, with quaking aspen and paper birch having high water content early in the season, with water contents declining earlier, and basswood and white ash maintaining a high water content longer (Figure 3).

A greater number of phenological assessments were made in 1997, using three sites, five host plant species, and nineteen dates. Leaves were indexed early, before bud-break of some species, so that bud-break and early leaf flush water contents could be recorded for some species, providing a clearer picture of water content and suitability for larval nutrition. Stepwise regression analysis on these data showed that leaf water content varied with tree species (interspecifically), collection date (seasonally), and with site (Table 5). The contrast with 1996 results was explored by stepwise regression on leaf water contents at the sites (Pellston and Vanderbilt) common to both years. Similar regression results were found, both with and without adjustment for degree-day contributions when Pellston and Vanderbilt were compared, and when Pellston, Vanderbilt and Cross Village were compared. Site contributions were the least meaningful contributor to the regressions (Table 6). As in the previous set of measurements, leaf water content declined throughout the 1997 season for all species. Across all three sites, quaking aspen and paper birch had high water content early in the season and water content declined rapidly early; basswood and white ash did not break bud as soon, but maintained a high water content later (Figure 4).

Data for Pellston and Vanderbilt for the years 1996 and 1997 were compared (Table 7). Stepwise regression indicated that leaf water content varied seasonally, interspecifically, geographically, and annually. When these data were degree-day adjusted, annual variation remained a significant factor, second in importance to seasonal influence (Table 7).

Oviposition Preference:

Five choice array: In 1996, oviposition preference was attributable to species of host, but not butterfly origin (Table 8). *P. canadensis* preferred to oviposit on quaking aspen, with 29.8% of eggs laid on these leaves when the data was pooled (Figure 5). Significantly more eggs were laid on quaking aspen by the *P. canadensis* test group than on any other leaves. For pooled data, quaking aspen and white ash did not have a significantly different number of eggs laid on them. Black cherry and basswood did not have a significantly different number of eggs laid on them. Paper birch and the chamber paper were also not significantly different from each other in the percentage of eggs laid on these substrates. All three groups were significantly different from the other two groups (Table 8). Using a cut-off value of ten eggs per female for inclusion in the analysis did not change the results, or effect the significance of any of the factors.

In 1997, neither the origin of the butterfly, nor the site of origin of the leaf material was correlated to host preference (Table 9). Again there was an oviposition preference attributable to tree species. Oviposition preference was greatest for black cherry, with 29% of the total eggs laid on these leaves when data were pooled for leaves from the Pellston (Figure 6) and Vanderbilt (Figure 7) sites and for butterfly location. Mean percent eggs laid on a treatment were similar for: white ash, basswood and quaking aspen; basswood, quaking aspen, paper birch and chamber paper; black cherry was significantly different from all other treatments (Table 9).

Using a cut-off value of ten eggs for inclusion in the analysis did slightly change the results. In this case, the origin of the host plant, and the origin of the butterfly did not significantly affect the oviposition preference. However, the species of tree, the interaction of the butterfly origin and the species of tree, and the interaction of the origin of the host plant and the species of tree were all found to be significant. When the butterfly origin by species of tree interaction was examined, it was found that tree species contributed most significantly to oviposition preference except for butterflies from Vanderbilt; the butterfly origin contributed significantly to the interaction on black cherry host plants. When the tree collection site and tree species interaction was compared, it was determined that the tree species contributed most significantly to the interaction. Mean percent eggs, with a cut-off value of ten, laid on a treatment were similar for: black cherry, white ash, and quaking aspen; basswood and quaking aspen; basswood and paper birch; and paper birch and chamber paper.

Young and old white ash array: There was no difference in preference attributable to butterfly collection site. There was a significant difference in preference for young, unexpanded white ash leaves, versus fully expanded white ash leaves, versus a paper (no leaf) control. When data were pooled, the most eggs (Table 10, Figure 8) were laid on the unexpanded white ash, and the least eggs laid on chamber paper (Table 10, Figure 8). An intermediate number were laid on the expanded older white ash leaves (Table 10, Figure 8). The interaction of butterfly collection site and white ash phenology was also significant. When this interaction was examined, it was determined that the white ash age contributed most strongly to every interaction, except that white ash age did not affect oviposition preference for butterflies collected from Charlevoix or butterflies collected from Vanderbilt. Both of these populations consisted of two or fewer butterflies. It was also determined that the butterfly collection site did significantly affect oviposition preference for old white ash leaves. When the data was examined with a cut-off value of ten eggs, there was no difference in the results.

Phenology array: There was no significant difference in preference for different phenological stages of white ash as indexed by four collection sites by all butterflies tested (Table 11). Differences in preference by butterflies from the Vanderbilt area versus the Pellston area were not significant (Figure 9). The sole significant difference between treatments was that fewer eggs were laid on chamber paper than on any of the foliage treatments (Table 11). When analyses were performed with a cut-off value of ten eggs, there were no differences in the results.

Chemical array: There was no preference difference by all butterflies tested for methanol extracts of white ash collected from four different sites or the controls (Table 12, Figure 10). When analyses were performed with a cut-off value of ten eggs, there were no differences in the results.

Larval Performance:

Overall survival from neonate to pupa in 1997 was low. No larvae reared on paper birch and basswood survived to pupation. The survival of larvae on black cherry was 33%, followed by quaking aspen, 13.5%, then followed by white ash, 7.3% (Table 15, Figure 11).

Survival in each instar in 1997, with host plant, host plant preference by the ovipositing female, larval instar, and days per instar showed that the host plant and the days per instar were important and significantly different in percent larval survival in each instar (Table 13).

Pupal weight varied depending upon the host plant species in 1996. Pupal weights on black cherry, quaking aspen, and white ash were not significantly different, although the least square means were higher on quaking aspen, followed by black cherry, followed by white ash (Table 14). Pupal weight on basswood was similar to weight on white ash (Table 14, Figure 12).

In 1997, there was a (1: 1) ratio of pupal males to females (72 males: 78 females). Variation in pupal weight was examined by looking at differences explained by the rearing host plant, and the sex of the individual. The pupal weight was mainly explained by host plant (Table 15). Pupal sex, and the sex by host plant interaction were not significant contributors to pupal weight. Pupal weights were highest for larvae reared on black cherry, and were significantly different than the weights of larvae reared on white ash and quaking aspen (Table 15, Figure 13).

Days to pupation: Time to reach pupation was also examined as a fitness indicator. In 1997, the length of time it took to reach pupation was not statistically dependent on host plant, pupal sex, or the sex by host plant interaction. Although duration to pupation was not explained by host plant, individuals on quaking aspen seemed to reach pupation slightly faster than other individuals, and the males even faster than the females, but this trend was not significant (Table 16, Figure 14).

Discussion:

Papilio canadensis, the Canadian tiger swallowtail, is common throughout the Northern United States. Adults emerge in early summer, nectar, mate and females lay eggs on a variety of plants. The eggs ecdyse and the neonates feed, develop and pupate all within a few weeks (Scriber 1996b). The larvae usually stay on the same leaf, at least in the first two instars and thus selection of oviposition sites by the egg-laying female is important (Watanabe 1995). If she selects a site less suitable for the growth, development and survival of offspring, her fitness, in an evolutionary sense, is inferior. Oviposition preferences may be driven by intrinsic factors such as chemical cues of the host plant that reflect nutritional quality or that are feeding deterrent toxins, and by extrinsic factors such as protection from predation (Thompson 1988, Thompson and Pellmyr 1991). Many studies implicate allelochemicals in the process (Feeny 1995).

Some areas of the Northern Lower Peninsula of Michigan have fewer degree-days of thermal accumulation and fewer frost-free days over the growing season than other areas. It is proposed that *P. canadensis* has an oviposition preference for white ash as a host plant in colder areas, in contrast to warmer areas, as delayed white ash bud-break and leaf development would be better suited relative to other hosts to nurture rapid larval growth (Scriber 1996a). This 'cold pocket hypothesis' was a local modification of the voltinism-suitability hypothesis (Scriber and Lederhouse 1992). The purpose of the present project was to search for an effect of climate on oviposition preference of *P. canadensis*. It was supposed that host plants, which depend on accumulated degree-days in seasonal development, would be of different attractiveness in warmer and colder areas during the *P. canadensis* flight period, and that egg-laying females would differentially select among hosts in such areas.

White ash was predicted to be the preferred host plant for oviposition in the 'cold pocket', and larvae were predicted to perform better on white ash. Oviposition preference did vary with inter-specific differences in host plant, and with large differences in host plant phenology (newly flushed vs. older, tougher foliage). As host plants may vary in suitability for larval growth, inter-specific differences in host-plant quality are well documented and not surprising. Newly flushed leaves tend to have a higher percent water content and decreased concentration of certain 'quantitative' defensive compounds (Feeny 1976). As water can be a limiting factor for larval growth and defensive compounds can reduce or slow larval growth, that butterflies would prefer to oviposit on newly flushed leaves is also not surprising. There is some evidence in the literature that indicates that leaf age and bud burst phenology can play a role in oviposition preference (Hunter 1992, Hunter et al. 1997, Scriber and Slansky 1981). In a study with winter moths, Hunter et al. (1997) determined that local population variation was seemingly related to plant quality and budburst phenology. Other studies have indicated that oviposition preference is influenced more by the over-riding importance of inter-specific plant differences than intra-specific differences in plant quality (Schultz 1988).

Larval performance on the five host plants was examined. Significant differences in pupal weight on host plants were compared to differences in oviposition preference. In 1996, oviposition preference was the same for quaking aspen and white ash; black cherry and basswood; paper birch and chamber paper. In 1996, larval performance was similar on quaking aspen, white ash and black cherry; white ash and basswood. No larvae survived on paper birch. Similar differences existed in oviposition preferences and larval performance. In 1997, oviposition preference was not different on: quaking aspen, white ash and basswood; or quaking aspen, basswood, paper birch and chamber paper. Preference for black cherry was greater than in all other treatments. In 1997, larval performance was the same on quaking aspen and white ash. No larvae survived on paper birch or basswood. Performance on black cherry was higher than on all other treatments. Again oviposition preference and larval performance hierarchies were similar. Both oviposition preference and larval performance hierarchies on host plants changed between 1996 and 1997. This change occurred in all populations, and may have been attributable to the dry May and June of 1997.

Neither oviposition preference nor larval performance followed the 'cold pocket' hypothesis predictions in either 1996 or 1997. I tested the assumptions of the 'cold pocket' hypothesis, to determine if the initial conditions had been met, and to obtain a better picture of what was occurring in the 'cold pocket' in 1996 and 1997. These assumptions included determining if bud-break and host plant phenology were delayed in the 'cold pocket' and if the 'cold pocket' was a thermally unique area.

In 1996 and 1997, foliar percent water content for five test plants was measured as an index of plant nutritional quality. Foliar water content varied by host plant, time of season and year, but variance due to site was minimal. These data are in agreement with the climate data in that neither data set found site to site variation, but both detected yearly variation. These phenological data support the contention that partial (that is, early) season measurements of climate and foliar water content are important in this biological system as values are high and then taper off.

Twenty-nine years of weather data were available for three areas in the Northern Lower Peninsula. Vanderbilt was always cooler than Pellston and Cross Village when summing total seasonal degree-days (March 1st - October 31st) and flight and larval development seasonal degree-days (March 1st - July 31st). The differences in degree-day accumulations between sites were statistically significant for these two time periods. The whole-season difference justified calling the Vanderbilt area a 'coldpocket'. However, accumulated degree-days through the flight season up to July 5th alone, Vanderbilt was the coolest site only (16 times in 29 years), and site differences over this period were not significant. Early degree-day accumulation is most important to the biological processes I examined and differences over flight season among sites were obscured by the magnitude of year-to-year differences within a site. To the extent that climate indirectly influences oviposition preference, one might expect *P. canadensis* to show as much, or even more, lability in host plant choice across years at a given site, than across sites for a given year. It is also unclear how many catastrophic 'cold' years out of 29 years are enough to exert significant selection on host choice of *P. canadensis.* When climate data was examined across Northern Michigan, it was determined that the Vanderbilt area was not cooler when compared to nearby areas at a biologically significant time, (March 1st – July 5th). Also, when host plant bud-break and phenology were assessed, it was determined that they were not delayed in the Vanderbilt area in 1996 and 1997. The lack of thermal unit accumulation differences, and similar water content data supported the contention that Vanderbilt was not remarkable as a 'cold pocket' during recent flight seasons. As such, the 'cold pocket' hypothesis would predict no difference in the oviposition hierarchy amongst butterflies from these sites; or among butterflies for foliage from these sites. Subsequently, white ash should not be preferred as an oviposition host plant, and larvae should not have increased performance on white ash. My results with *P. canadensis*, were consistent with these observations.

Heat/ precipitation indices usefully depict one aspect of climatic variability. I prepared such indices for four months of Vanderbilt data from 1987 to 1997. The final year stood out as being unusually dry in both May and June. Dry conditions lead to water stress on a plant. As plant water content decreases, soluble forms of nitrogen increase (Mattson and Scriber 1987, Scriber 1977, Thomas and Hodkinson 1991). White (see Thomas and Hodkinson 1991) hypothesizes that water-stressed plants suffer increased herbivory; this theory is based on the observation that climatically disturbed areas often have insect outbreaks (see Thomas and Hodkinson 1991). Bultman and Faeth (1987) tested the hypothesis by examining leaf miner populations as an indication of predation pressure under water stress conditions (drought achieved by cutting off roots), where water had been added (irrigation) and in control conditions. Their findings contradicted the supposition: *Cameraria* sp. B, predicted to decrease, increased in the irrigated treatment; and *Cameraria* sp. A, predicted to increase, decreased in water stress conditions. Other studies also have shown that insect larvae perform less well on plants with low leaf water levels. Larvae on leaves with low leaf water grow more slowly and are less efficient at utilizing nitrogen, and water content of leaves may limit larval growth (Scriber 1977). Water stressed conditions can have consequential impacts on plants and their herbivore communities. The oviposition differences that we saw in 1996 and 1997 may, in some part, be due to the dramatic differences in May and June precipitation between the two years. The aspen seemed especially sensitive.

In summary, thermal unit differences from March 1st - July 5th in Northern Michigan differ between years rather than between sites. Plant quality and phenology differences vary by species, by seasonal fluctuations and by year-to-year fluctuations. In comparison, climatic and phenological spatial variations for the three test sites were not remarkable during the period of biological significance for the present project. Vanderbilt was not meaningfully a 'cold pocket' in the 1969-1997 interval at an appropriate time period, and the 'cold pocket' hypothesis could not apply here. Generalist oviposition preferences were labile and showed year to year flexibility. For *Papilio canadensis*, oviposition preference and larval performance hierarchies were similar. The 'cold pocket' hypothesis will have to be evaluated by comparing areas that differ more in climate during the early part of the year than did Vanderbilt, Pellston and Cross Village over the recent twenty-nine years. Although the whole season (March 1st – pupation) selects against oviposition mistakes on the wrong host plant, it is early season differences in host plant quality that the female must evaluate.

Vanderbilt had the lowest seasonal (March 1st - October 31st) accumulated degree-days over a 29 year period, as compared to Pellston and Cross Village. The flight season (March 1st - July 5th) accumulated degree-days did not differ between Vanderbilt, Pellston and Cross Village. Vanderbilt was generally the coldest site (March 1st - July 5th), (21 times in 29 years); (March 1st - July 31st), (23 times in 29 years); (March 1st - October 31st), (29 times in 29 years). Year to year fluctuations in accumulated degree-days were greater than site to site variation. Although there were year to year variations, the Vanderbilt site showed that there was a trend to the variance. This may be indicative of long term climate trends with short-term variation. Hypotheses based on supposed climate averages for a site may not usefully predict the outcome in any but the most average of years.

The assumptions of the 'cold pocket' hypothesis did not hold true in 1996 or 1997. The 'cold pocket', during the behaviorally critical time period (March 1st - July 5th), did not exist. There were no differences in intra specific host plant differences in phenology between the sites. Even considering the limited availability of butterflies, the white ash preference did not exist in 1996 or 1997 (only 19% and 18% in a five choice study respectively). There were no differences in oviposition preference of butterflies from different populations. Larval performance and oviposition preference hierarchies were similar in 1996 and 1997. Larvae did not perform well on white ash in either 1996 or 1997. This leads to interesting speculation regarding the interactions of plants, herbivores, the prevailing climate conditions, and the evolutionary significance of these interactions. The 'geographic mosaic' theory of coevolution describes the evolutionary landscape as dynamic, where coevolutionary relationships are not static across a host species range, but rather are labile in response to host plant distribution, competition and environmental differences, among other factors (Thompson 1994).

Given the nature of the relationships discovered and tested in this project, *P. canadensis* oviposition preference in the 'cold pocket' readily conforms to the defining principles of the geographic mosaic theory of coevolution. Under a given set of conditions, reduced number of accumulated degree-days and delayed bud-break, generalist herbivore oviposition preference was for a normally poor quality host plant, white ash. When these conditions varied, host plant preference varied. Snapshots of three different climatic conditions resulted in three different oviposition preferences. In cold years (1992-1995), white ash was preferred. In a thermally average year (1996), with average precipitation, quaking aspen was preferred. In a thermally average year (1997) with low precipitation, black cherry was preferred. Determining whether or not these relationships between localized climate and localized preference are true relationships, or artifacts due to either experimental procedure, low number of butterflies, or another source of variation, is an important priority in continuing this line of research. First, one would have to examine the preferences across years and sites and try to distinguish what, if any, trends exist.

This project indicates that both temperature and precipitation can be important factors influencing plant-herbivore interactions, and subsequently could be important evolutionary selective factors. In addition, responses to varying soil type, and other factors such as geographic variance and photoperiod could be controlled by common garden experiments or other studies. One example would include not only examining oviposition preference of field caught butterflies on field collected foliage, but also butterfly preference on foliage from trees reared in specific conditions. Through this combination of oviposition arrays, one might be able to determine if localized populations exhibit any variance in oviposition preference, or if the differences in oviposition preference are a species-wide response to differences in host plant quality.

My research showed that ash preference of butterflies from the Lower Peninsula 'cold pocket' of Michigan was less than 20% in five choice arenas in 1996 and 1997. This is a decline from the observation of these same populations in 1991 to 1995 that showed ash preferences of 92%, 71%, 60%, 39% and 34% respectively (Scriber 1996a and unpublished). This is especially interesting in view of the increase in seasonal degree-days observed during this period (e.g. 700, 800, 900, 1000 from 1992-1995; Figure 1) which could allow influx into the 'cold pocket' from surrounding areas, and the survival on most host plants during this period. Since 1991, there were no severely constrained years that could select out non-ash preferring females.

Table 1: Scientific and common names of host plants examined for *P. canadensis* oviposition preference

Scientific name	*Author*	*Common name*
Betula papyrifera	Marshall	Paper birch
Fraxinus americana	L.	White ash
Populus tremuloides	Michaux	Quaking aspen
Prunus serotina	Ehrhart	Black cherry
Tilia americana	L.	Basswood

Table 2: Accumulated degree-days °C (threshold temperature 10 °C) at three sites in Northern Michigan

Site	*Seasonal Mean Accumulated Degree-Days, March 1 - October 31 ± S.D.*	*Flight Season and Larval Development Period Mean Accumulated Degree-Days, March 1 - July 31 ± S.D.*	*Flight Season Mean Accumulated Degree-Days, March 1 - July 5 ± S.D.*
Cross Village	1047.1 ± 87.3	620.4 ± 238.5	424.3 ± 342.2
Pellston	982.7 ± 88.2	521.3 ± 56.2	269.3 ± 45.9
Vanderbilt	856.2 ± 119.1	462.3 ± 69.4	253.3 ± 45.4
ANOVA			
F value	20.39	12.40	1.67
p value	<0.0001	<0.0001	0.19

Table 3: Stepwise regression of accumulated degree-days at three sites, 1969-1997

Regressor	*p Value*	*Contribution to r^2*	*Remaining in model?*
March 1 - October 31			
year	<0.0001	0.28	yes
site	<0.004	0.15	yes
adjusted $r^2 = 0.34$			
May 1 - July 31			
year	< 0.0001	0.28	yes
site	<0.004	0.08	yes
adjusted $r^2 = 0.34$			
May 1 - July 5			
year	<0.08	0.06	yes
site	<0.18	0.04	no
adjusted $r^2 = 0.07$			

Table 4: Stepwise regression of water content of leaves of five species collected at Pellston and Vanderbilt, 1996

A.

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model?*
Date	<0.0001	0.42	yes
Site	<0.4	0.0007	no
Tree Species	<0.009	0.006	yes

$r^2 = 0.42$, adjusted $r^2 = 0.42$

Adjusted for Degree Day Differences, 1996

B.

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model?*
Degree-Day	<0.0001	0.41	yes
Site	<0.02	0.02	yes
Tree Species	<0.01	0.004	yes

$r^2 = 0.42$, adjusted $r^2 = 0.42$

Table 5: Stepwise regression of water content of leaves of five species collected at Pellston, Vanderbilt and Cross Village, 1997

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model?*
Date	<0.0001	0.35	yes
Site	<0.0001	0.009	yes
Tree Species	<0.0001	0.02	yes

$r^2 = 0.38$, adjusted $r^2 = 0.38$

Table 6: Stepwise regression of water content of leaves of five species collected at Pellston and Vanderbilt, 1997

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model:*
Date	<0.0001	0.29	yes
Site	<0.0001	0.007	yes
Tree Species	<0.0001	0.01	yes

$r^2 = 0.32$, adjusted $r^2 = 0.32$

Table 7: Stepwise regression of water content of leaves of five species collected at Pellston and Vanderbilt for 1996 and 1997

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model:*
Date	<0.0001	0.33	yes
Site	<0.005	0.0003	yes
Tree Species	<0.0001	0.008	yes
Year	<0.0001	0.06	yes

$r^2 = 0.36$, adjusted $r^2 = 0.36$

Table 8: ANCOVA results for 1996 oviposition preference of *P. canadensis* on five host plant species

Source	*df*	*F Value*	*p Value*	*Host Plant/ lsmean of Percent Eggs per treatment/Differences By Fisher's LSD (α=0.05)*		
Butterfly origin	2	1.34	0.2619			
Approximate butterfly age❖	1	2.03	0.1554			
Butterfly winglength❖	1	1.76	0.1849			
Host plant species	5	16.46	<0.0001*	Black cherry	18.3± 2.0%	B
				Paper birch	8.3 ± 2.0%	C
				White ash	24.9 ± 2.0%	A
				Basswood	15.1 ± 2.0%	B
				Quaking aspen	29.3 ± 2.0%	A
				Chamber Paper	5.7 ± 2.0%	C
Butterfly origin x Host plant species	10	0.46	0.9151			

* significant at $\alpha = 0.05$ ❖covariate Values with the same letter are not statistically significant from each other.

Table 9: ANCOVA results for 1997 oviposition preference of *P. canadensis* on five host plant species

Source	*df*	*F value*	*p value*	*Host Plant/ lsmean of Percent Eggs per treatment/Differences By Fisher's LSD (α=0.05)*		
Host plant origin	1	0.01	0.9429			
Butterfly origin	2	0.12	0.8839			
Approximate butterfly age ❖	1	0.00	0.9886			
Butterfly winglength❖	1	0.41	0.5221			
Host plant species	4	4.92	<0.0001*	Black cherry	42.6 ± 5.7%	A
				Paper birch	6.9 ± 5.6%	C
				White ash	27.9 ± 5.7%	B
				Basswood	15.6 ± 5.9%	BC
				Quaking aspen	15.1 ± 5.7%	BC
				Paper	6.2 ± 5.7%	C
Butterfly origin x Host plant origin	2	0.15	0.7009			
Butterfly origin x Host plant species	8	0.86	0.5753			
Host plant origin x Host plant species	4	1.06	0.3839			
Butterfly origin x Host plant origin x Host plant species	5	0.30	0.9125			

* significant at $\alpha = 0.05$ ❖covariate Values with the same letter are not statistically significant from each other.

Table 10: ANCOVA results for 1998 oviposition preference of *P. canadensis* on young and old (fully expanded) white ash

Source	*df*	*F value*	*p value*	*Host Plant/ lsmean of Percent Eggs per treatment/Differences By Fisher's LSD* (*α=0.05*)		
Butterfly origin	5	0.04	0.9990	Old	40.7 ± 5.7%	A
				Young	59.9 ± 5.7%	B
				Paper	2.6 ± 5.7%	C
White ash age	2	30.41	<0.0001*			
Approximate butterfly age ❖	1	0.00	0.9708			
Butterfly winglength ❖	1	0.00	0.9765			
Butterfly origin x White ash age	6	2.50	0.0309*			

* significant at $\alpha = 0.05$ ❖covariate Values with the same letter are not statistically significant from each other.

Table 11: ANCOVA results for 1997 oviposition preference of *P. canadensis* on white ash collected from four sites, resulting in phenological differences in white ash

Source	*df*	*F value*	*p value*	*Host Plant/ lsmean of Percent Eggs per treatment/Differences By Fisher's LSD (α=0.05)*		
Host plant origin	4	2.80	0.0395*	Pellston	29.4 ± 5.8%	A
				Vanderbilt	19.8 ± 5.8%	A
				Cross Village	17.9 ± 5.8%	A
				Okemos	25.8 ± 5.8%	A
				Paper	4.5 ± 5.8%	B
Butterfly origin	2	1.20	0.3136			
Approximate butterfly age ✥	1	0.35	0.5578			
Butterfly winglength ✥	1	1.57	0.2180			
Butterfly origin x Host plant origin	8	0.82	0.5899			

* significant at $\alpha = 0.05$ ✥covariate Values with the same letter are not statistically significant from each other.

Table 12: ANCOVA results for 1997 oviposition preference of *P. canadensis* on white ash extracts from four sites

Source	*df*	*F value*	*p value*	*Host Plant/ lsmean of Percent Eggs per treatment*	
Extract	6	2.28	0.0673	Pellston	17.4 ± 4.2%
				Vanderbilt	16.2 ± 4.2%
				Cross Village	21.9 ± 4.2%
				Okemos	19.7 ± 4.2%
				Water	17.4 ± 4.2%
				Acetone	7.5 ± 4.2%
				Paper	5.3 ± 4.2%
Approximate butterfly age ❖	1	0.14	0.7080		
Butterfly winglength ❖	1	0.12	0.7353		

❖covariates

Table 13: 1997 *P. canadensis* larval survival in each instar for larvae reared on black cherry, paper birch, white ash, basswood and quaking aspen

Source	*Denominator df*	*F value*	*p value*
Host plant	1202	16.12	<0.0001
Mother Host plant Preference	519	0.11	<0.75
Instar	519	0.01	<0.92
Time	519	99.00	<0.0001

Table 14: Mean and percent differences in pupal weights of *P. canadensis* reared on black cherry, paper birch, white ash, basswood and quaking aspen, 1996

Host Plant	*Total Survival*	*Weight (g) ± SE*	*Pupal Weight Differences By Fisher's LSD (α=0.05)*
Black cherry	Not measured	0.84 ± 0.01	A
Paper birch	0		
White ash	Not measured	0.77 ± 0.02	AB
Basswood	Not measured	0.59 ± 0.13	B
Quaking aspen	Not measured	0.90 ± 0.02	A

Values with the same letter are not statistically significant from each other.

Table 15: Mean and percent differences in pupal weights of *P. canadensis* males and females reared on black cherry, paper birch, white ash, basswood and quaking aspen, 1997

	Initial Number	*Overall Survival*	*Weight (g) ± SE*	*Pupal Weight Differences by Fisher's LSD (α=0.05)*
Females	78		0.69 + 0.02	A
Males	72		0.66 ± 0.02	B
Black cherry	303	33%	0.73 ± 0.01	A
Paper birch	23	0%		
White ash	411	7.3%	0.66 ± 0.02	B
Basswood	32	0%		
Quaking aspen	141	13.5%	0.64 ± 0.03	B

Values with the same letter are not statistically significant from each other.

Table 16: Mean and percent differences in days until pupation of *P. canadensis* males and females reared on black cherry, paper birch, white ash, basswood and quaking aspen, 1997

Treatment	*Overall Survival*	*Days Until Pupation ± SE*	*Pupal Weight Differences By Fisher's LSD (α=0.05)*
Females		27.00 ± 0.66	A
Males		26.39 ± 0.65	A
Black cherry	33%	27.37 ± 0.45	A
Paper birch	0		
White ash	7.3%	27.32 ± 0.83	A
Basswood	0%		
Quaking aspen	13.5%	25.37 ± 1.02	A

Values with the same letter are not statistically significant from each other.

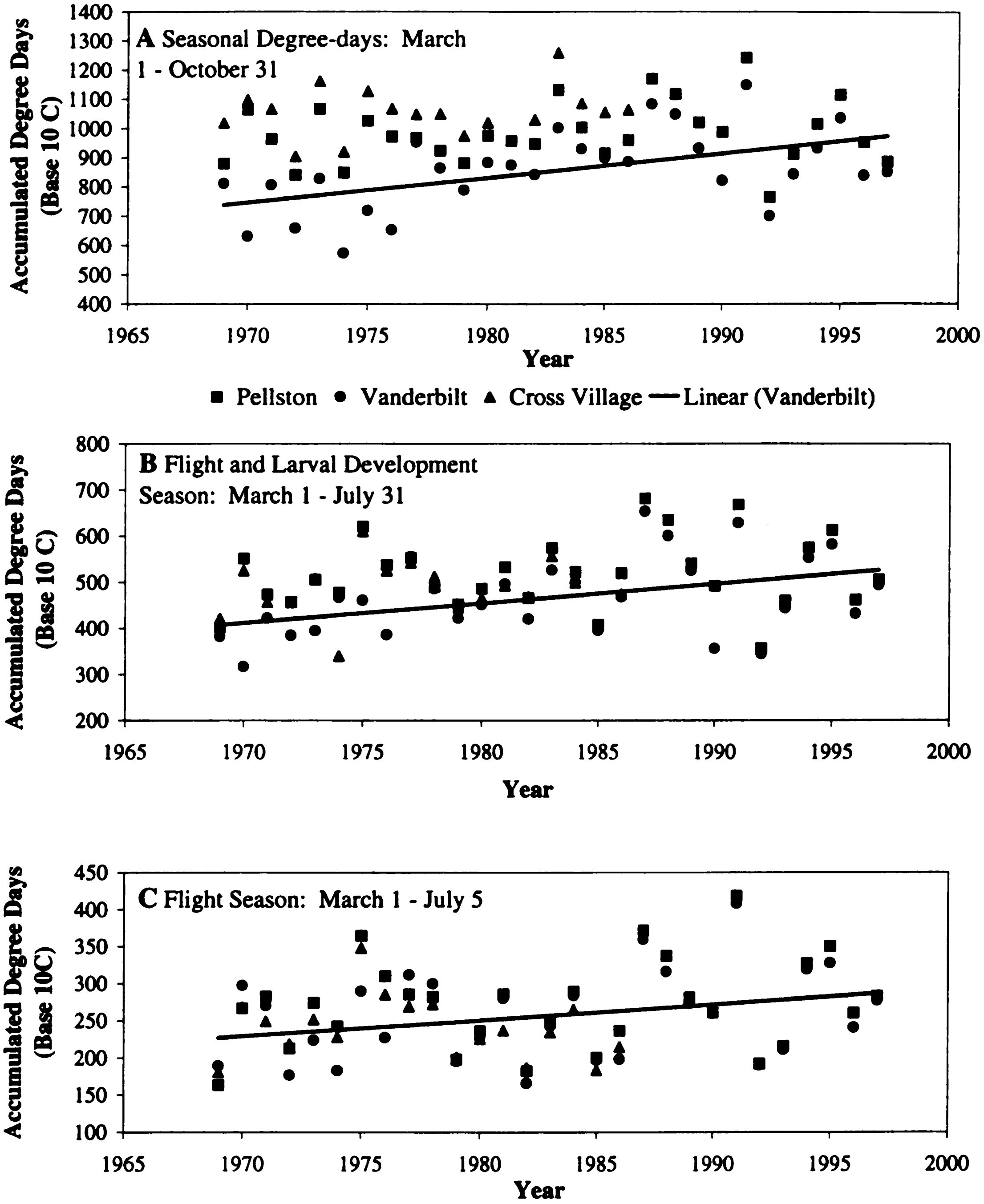

Figure 1: Accumulated degree-days at three sites; Cross Village, Pellston and Vanderbilt, 1969-1997. **A** is seasonal (March 1st - October 31st) degree-days; **B** is flight and larval season (March 1st - July 31st) degree-days; **C** is flight season (March 1st -July 5th) degree-days. Linear trends are illustrated for Vanderbilt data. The trend is statistically significant in **A** ($r^2 = 0.27$, n=29), but not in **B** ($r^2 = 0.18$),nor in **C** ($r^2 = 0.09$).

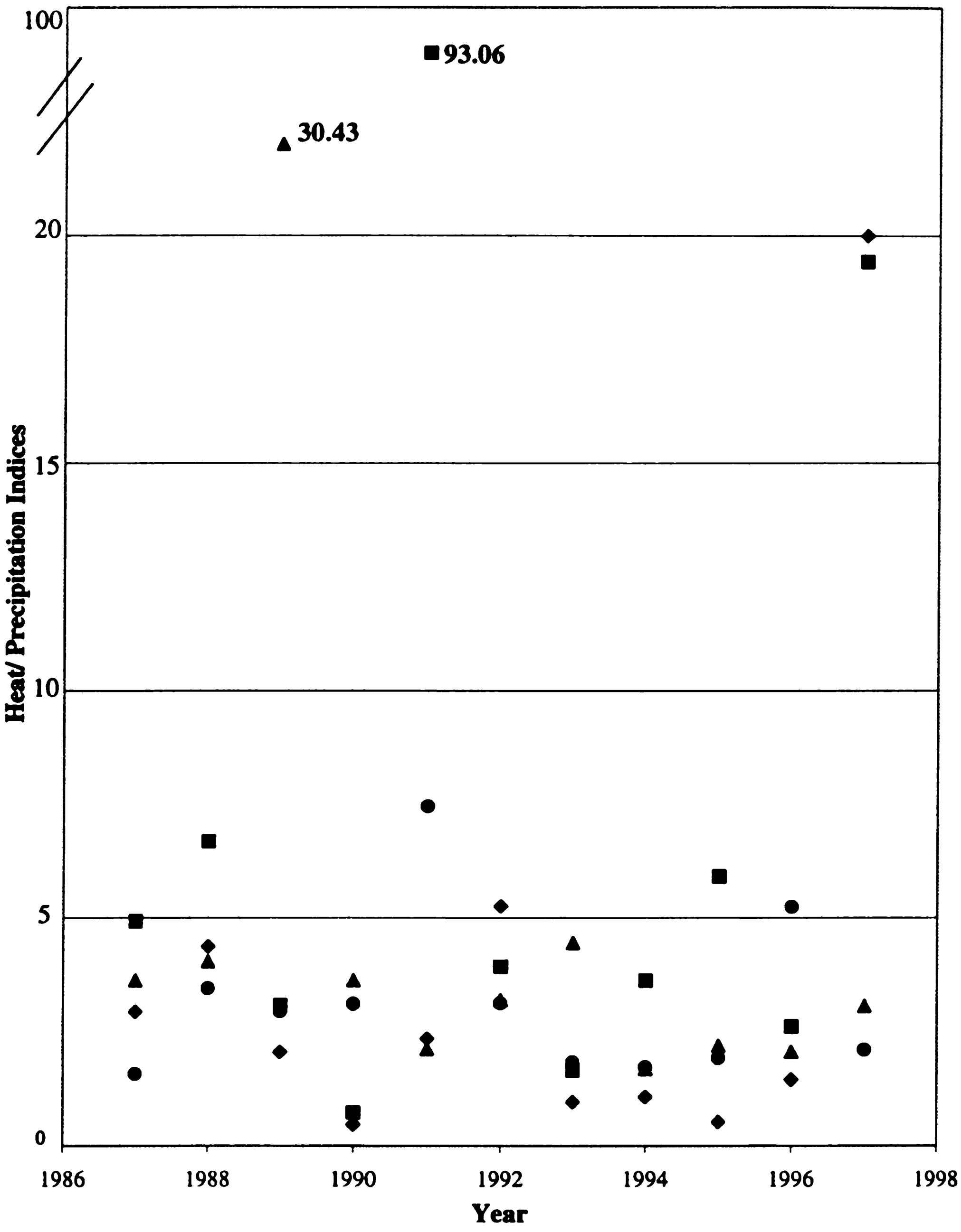

Figure 2: Heat/ precipitation indices for Vanderbilt, Michigan. May (diamonds), June (squares), July (triangles), and August (circles) 1987-1997. July, 1989 and June, 1991 are extreme outliers.

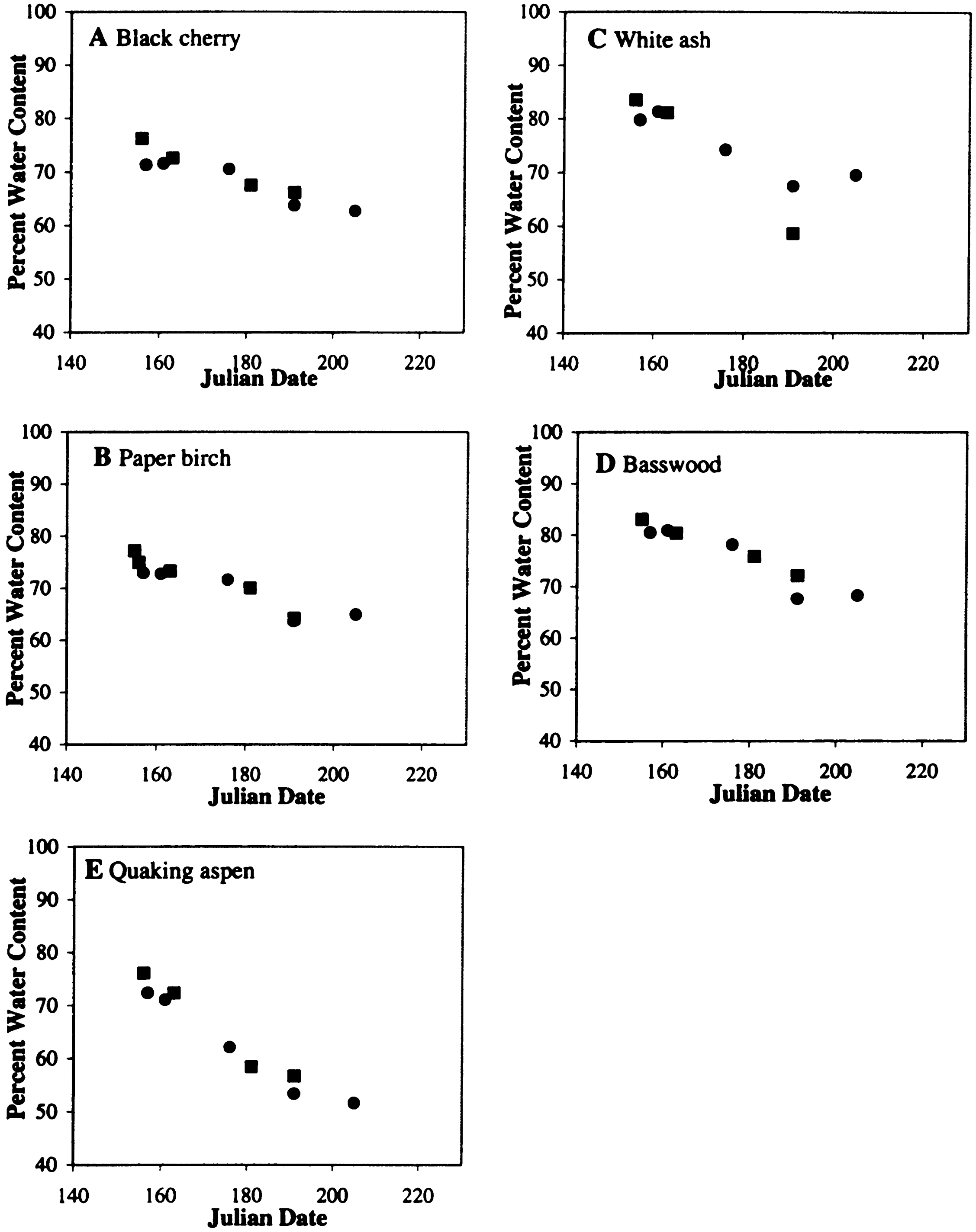

Figure 3: Percent water content of leaves from five species collected at Pellston (squares) and Vanderbilt (circles). A is black cherry; B is paper birch; C is white ash; D is basswood; and E is quaking aspen. Data from the 1996 season.

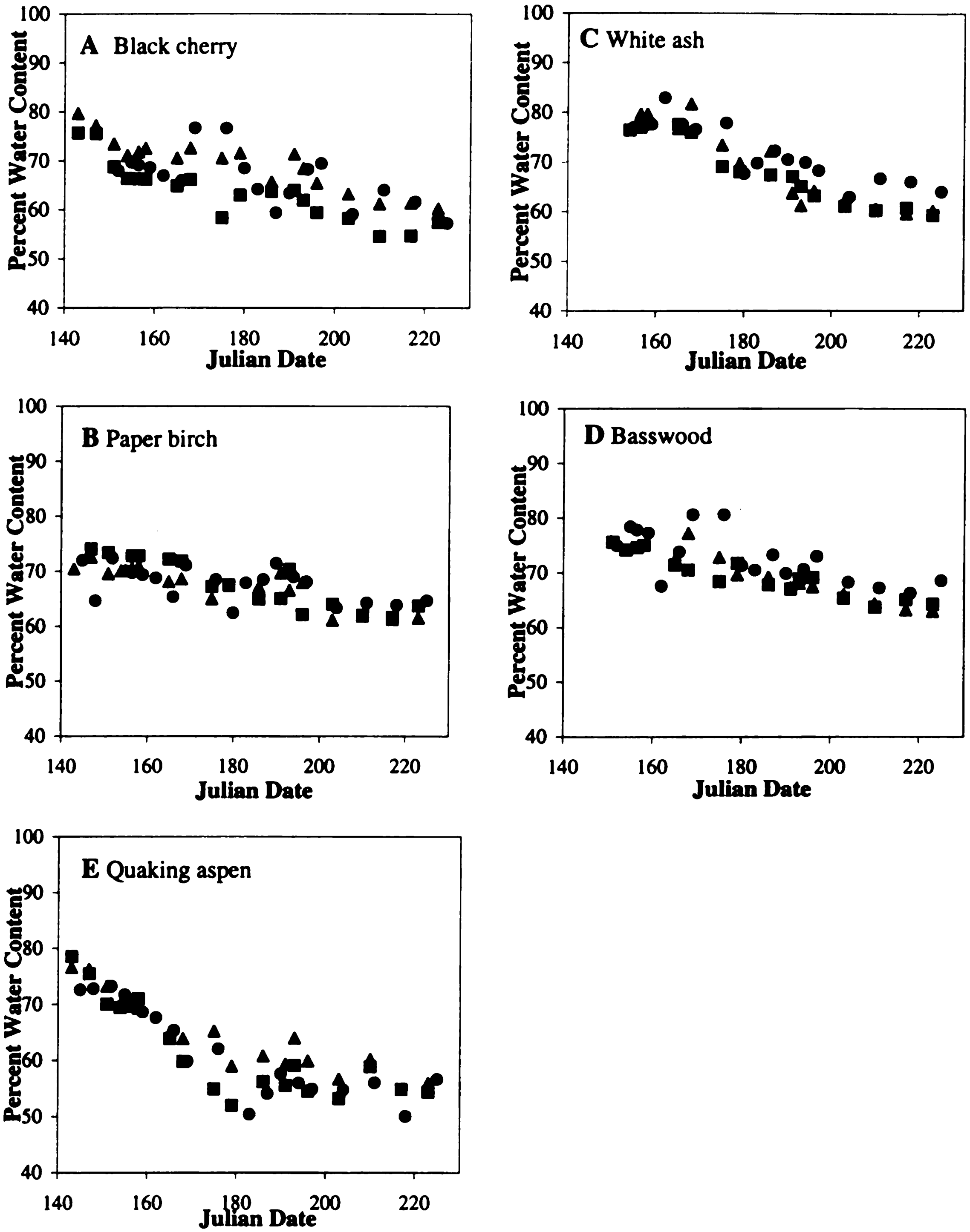

Figure 4: Percent water content of leaves from five species collected at Cross Village (triangles), Pellston (squares) and Vanderbilt (circles). A is black cherry; B is paper birch; C is white ash; D is basswood; and E is quaking aspen. Data from the 1997 season.

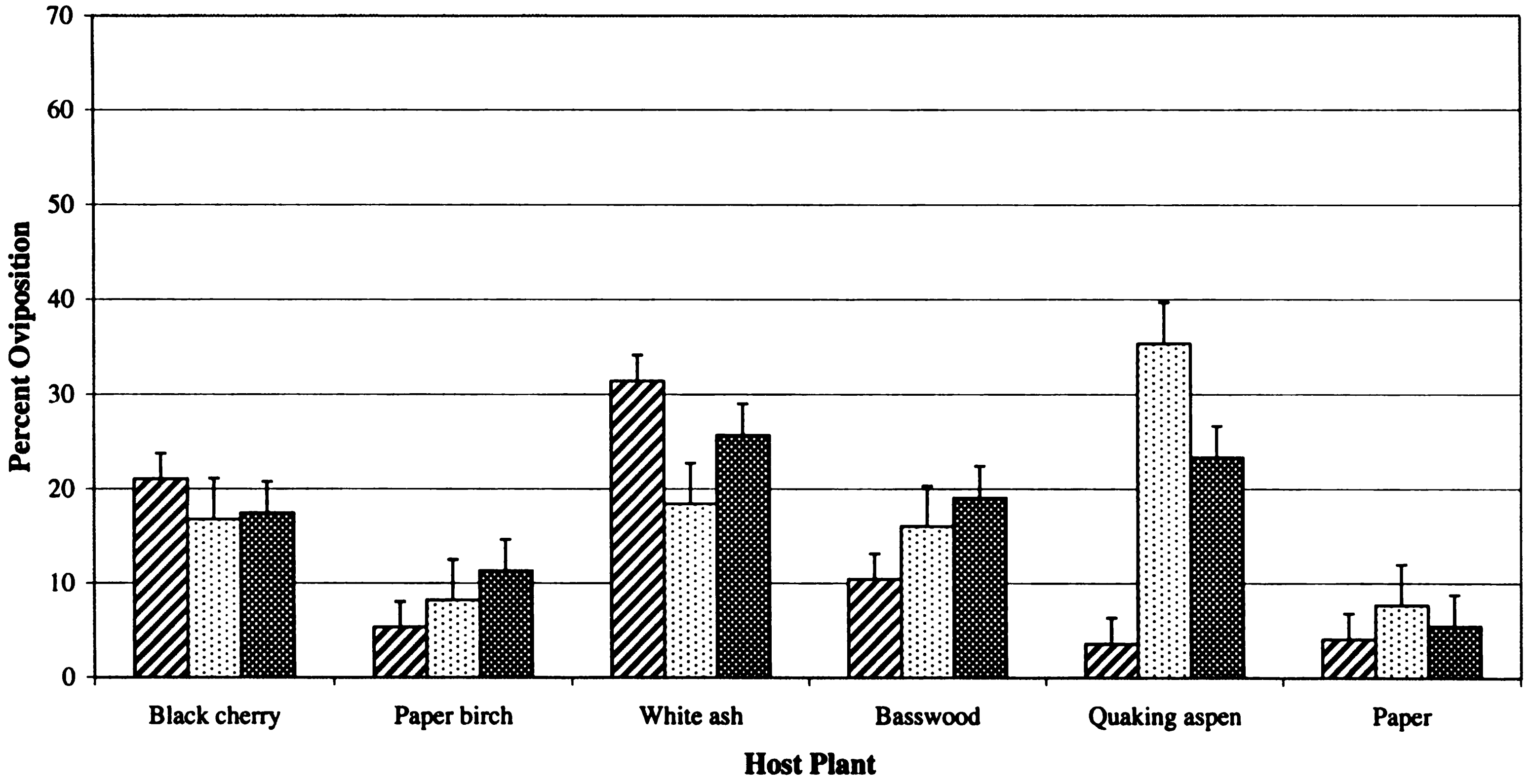

Figure 5: Preference of butterflies collected in Pellston (n= 31, diagonal striped bars), collected in Vanderbilt (n= 17, dotted bars), or collected in the Upper Peninsula (n= 23, cross-hatched bars) for oviposition on leaves of five species, or no leaf (paper). Represented means and standard errors of means for any one bar type are adjusted for a balanced design. Leaves were from the Pellston area. Data from the 1996 season.

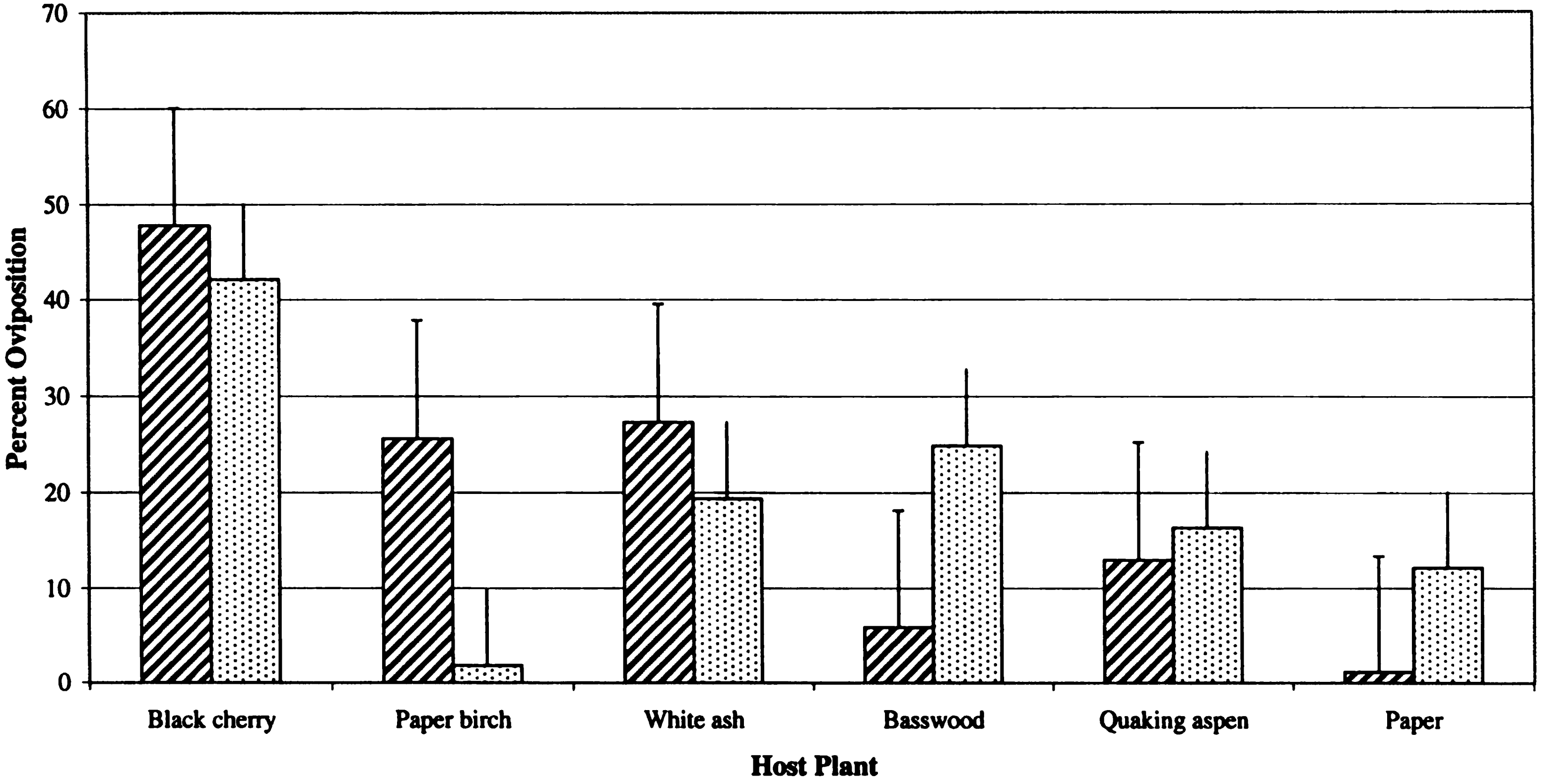

Figure 6: Preference of butterflies collected in Pellston (n= 7, diagonal striped bars), collected in Vanderbilt (n= 17, dotted bars) for oviposition on leaves of five species, or no leaf (paper). Represented means and standard errors of means for any one bar type are adjusted for a balanced design. Leaves were from the Pellston area. Data from the 1997 season.

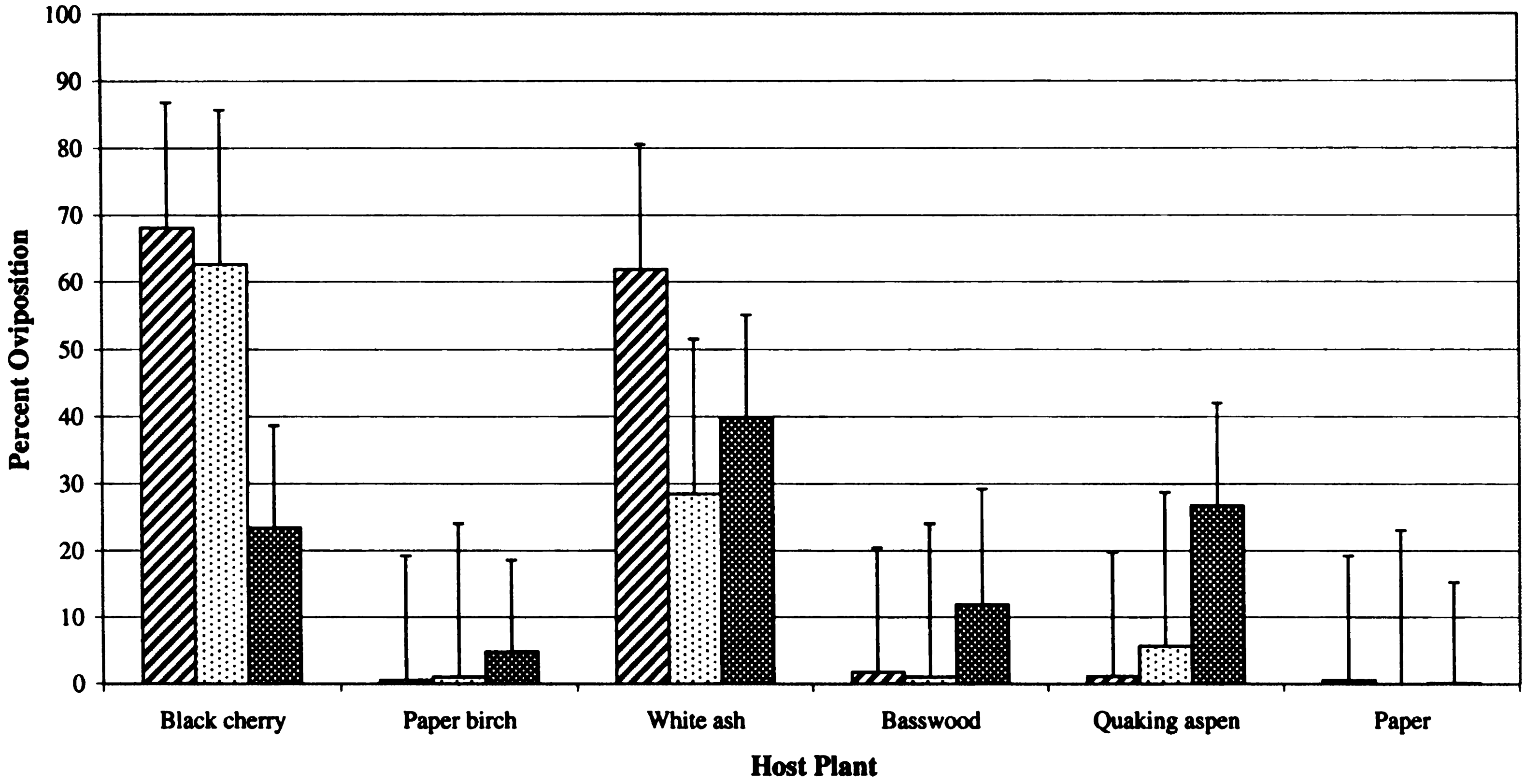

Figure 7: Preference of butterflies collected in Pellston (n= 3, diagonal striped bars), collected in Vanderbilt (n= 2, dotted bars) or collected in the Upper Peninsula (n= 4, cross-hatched bars) for oviposition on leaves of five species, or no leaf (paper). Represented means and standard error of means for any one bar type are adjusted for a balanced design. Leaves were from the Vanderbilt area. Data from the 1997 season.

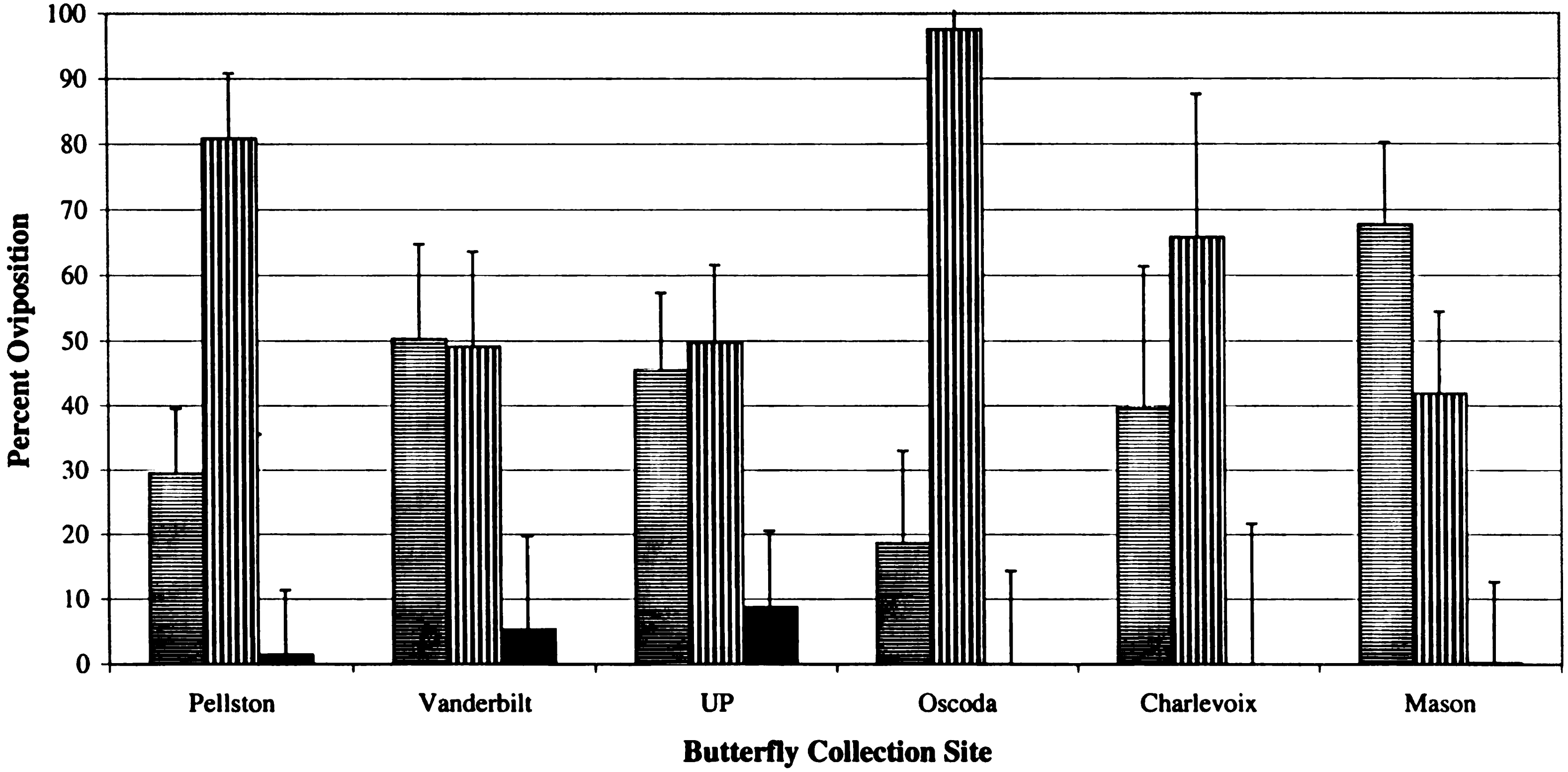

Figure 8: Preference of butterflies collected in Pellston (n= 4), Vanderbilt (n= 2), the Upper Peninsula (n= 3), Oscoda (n=2), Charlevoix (n=1) and Mason (n= 3) for oviposition on unexpanded white ash leaves (narrow horizontal line bars), fully expanded white ash leaves (dark vertical line bars), or no leaf (paper) (solid bars). Represented means and standard errors of means for any one bar type are adjusted for a balanced design. Data from the 1998 season.

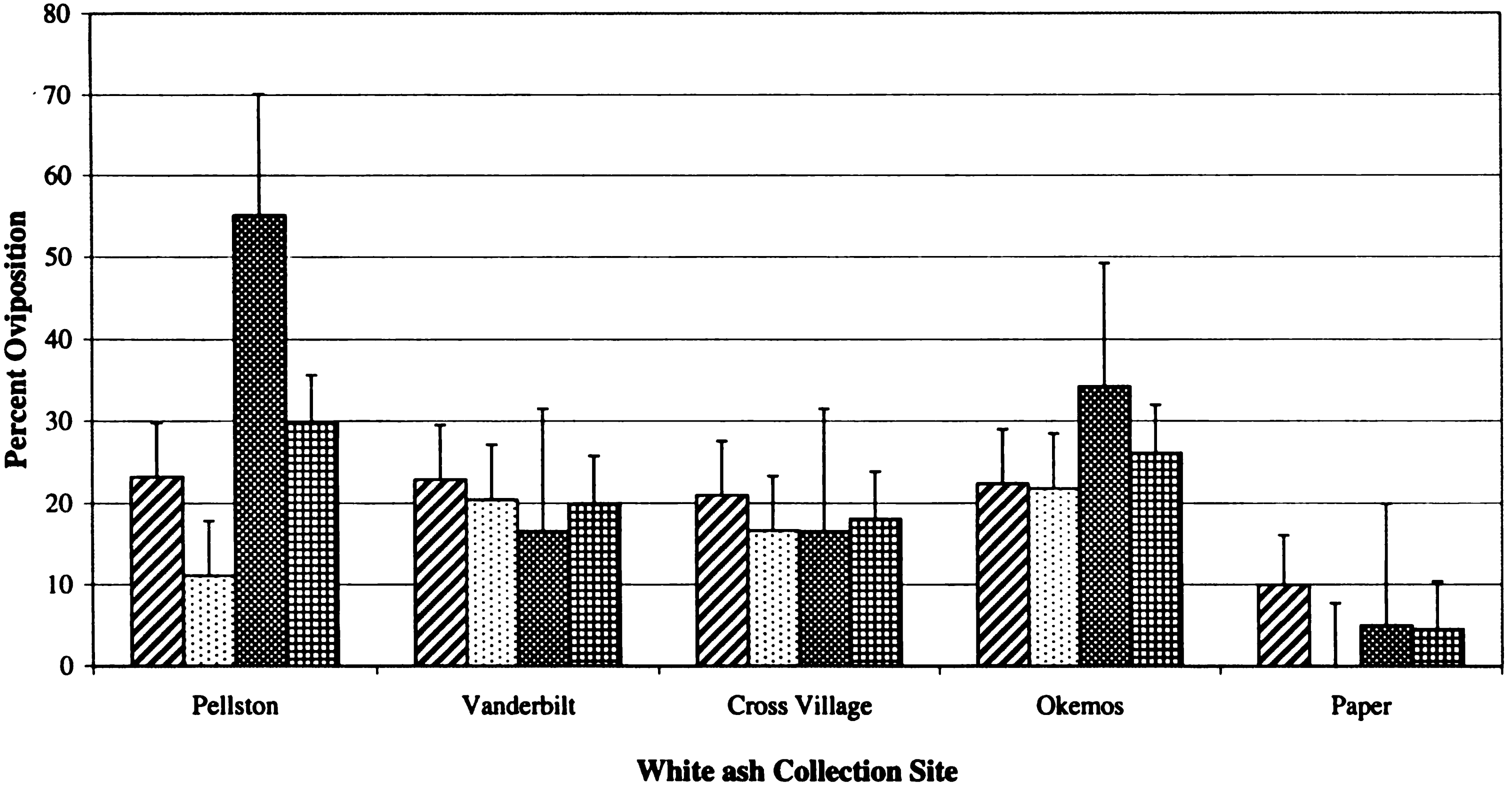

Figure 9: Preference of butterflies collected in Pellston (n= 6, diagonal striped bars), collected in Vanderbilt (n = 5, dotted bars), the Upper Peninsula (n=1, cross-hatched bars) and the combined populations (n = 12, gridded bars) for oviposition on leaves of five species, or no leaf (paper). Represented means and standard errors of means for any one bar type are adjusted for a balanced design. Data from the 1997 season.

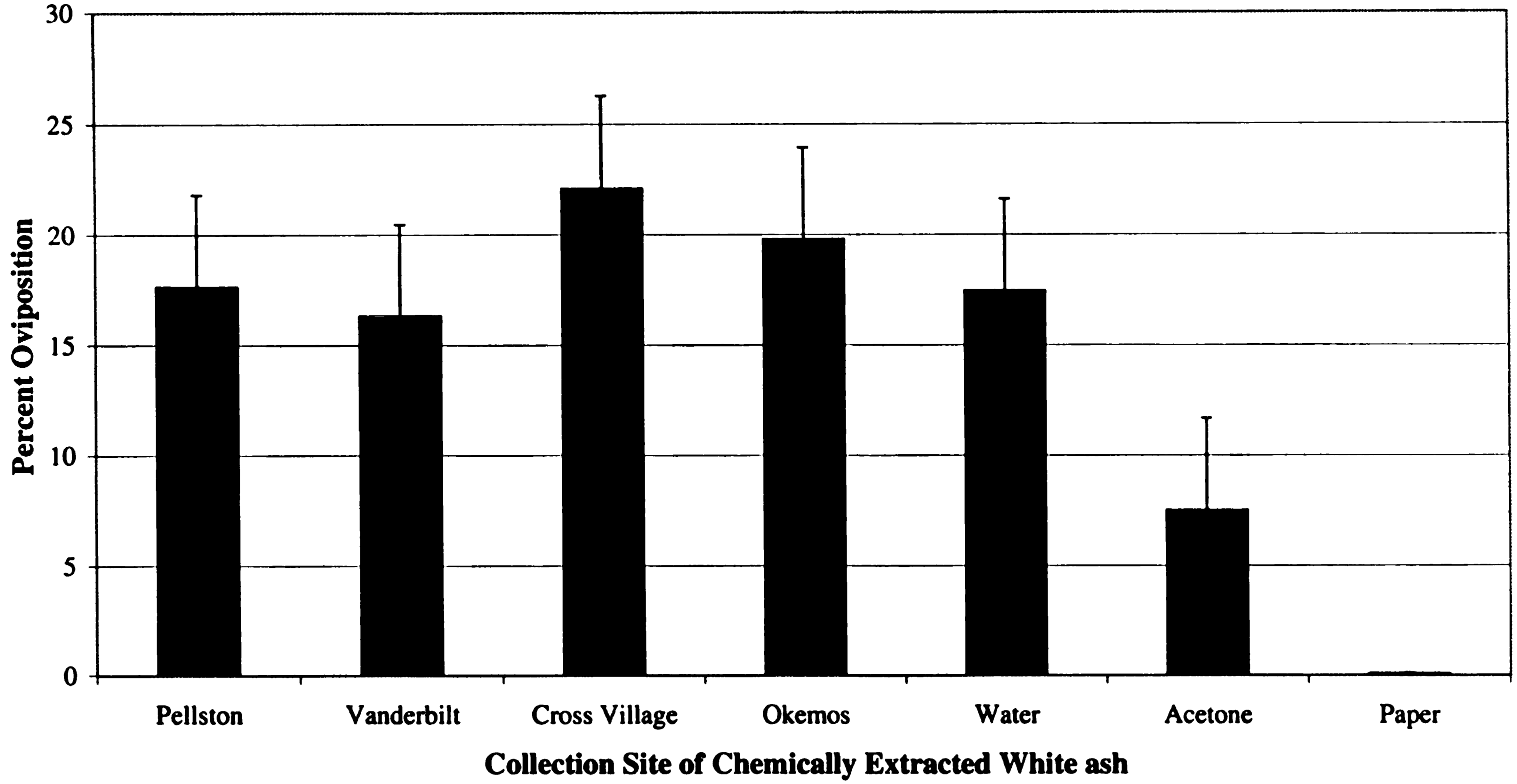

Figure 10: Ovipositon preference of *Papilio canadensis* on methanol extracts of white ash leaves collected from Cross Village, Pellston, Vanderbilt and Okemos (n=9). A leaf sprayed with water, a leaf sprayed with the acetone solvent, and eggs laid on paper all served as controls. Represented means and standard errors of means are adjusted for a balanced design. Data from the 1997 season.

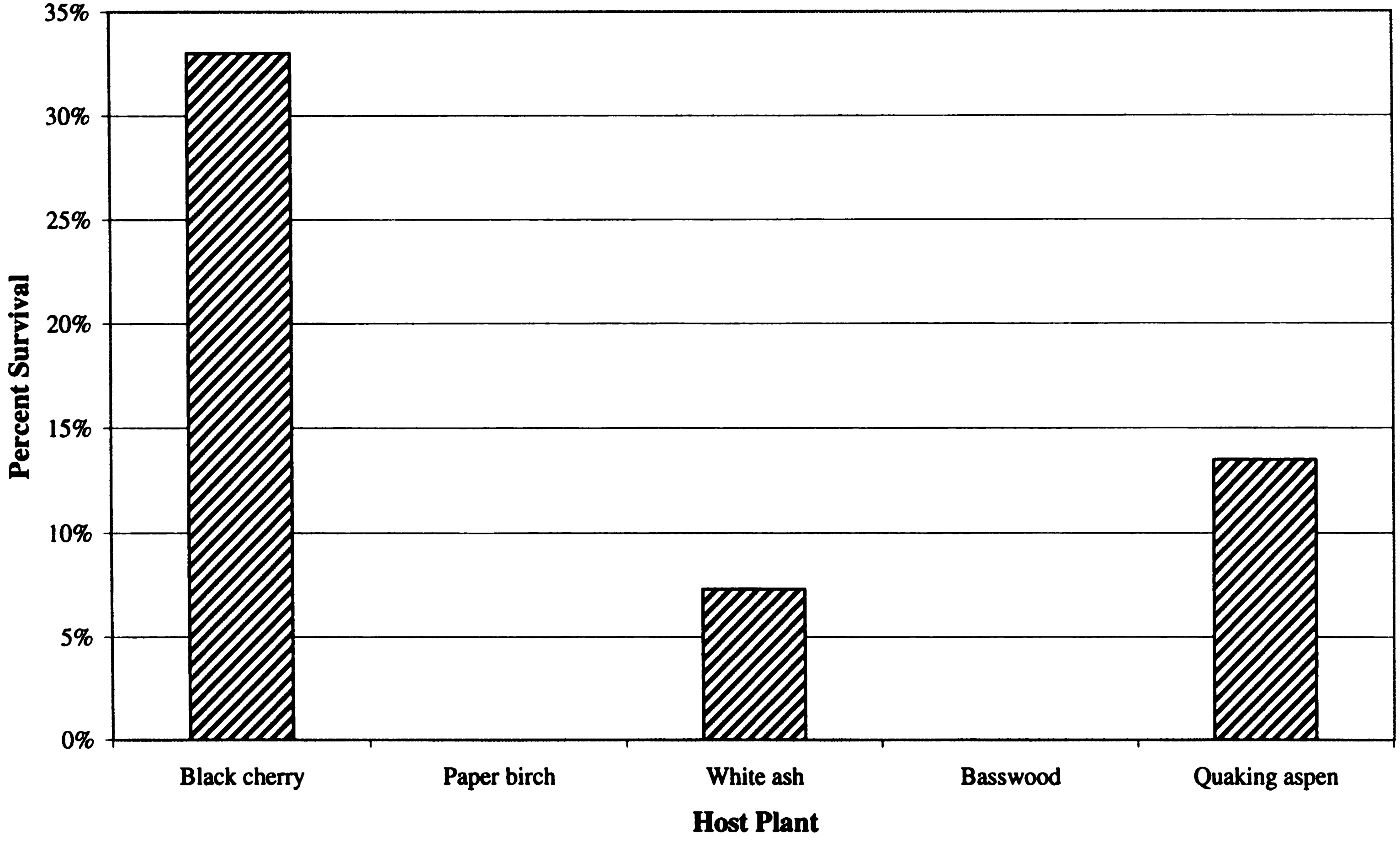

Figure 11: Total survival of *Papilio canadensis* on five host plants: black cherry, paper birch, white ash, basswood and quaking aspen. (No larvae survived on paper birch or basswood.) Data from the 1997 season.

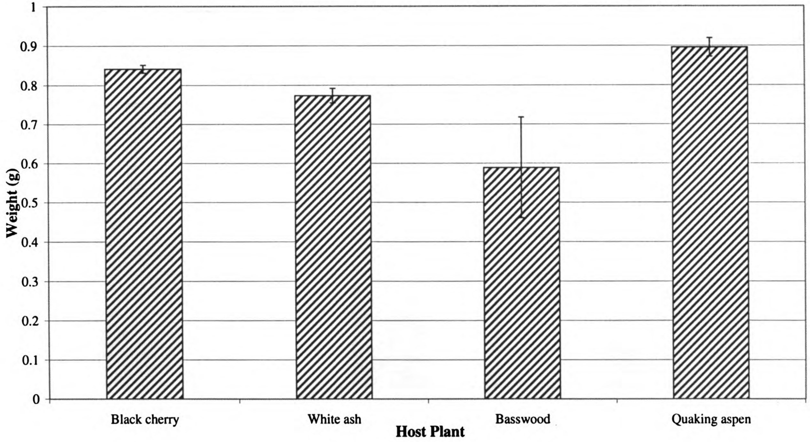

Figure 12: Mean pupal weights (g) of *Papilio canadensis* reared on five host plants: black cherry, paper birch, white ash, basswood, quaking aspen. (No larvae survived on paper birch.) Data from the 1996 season.

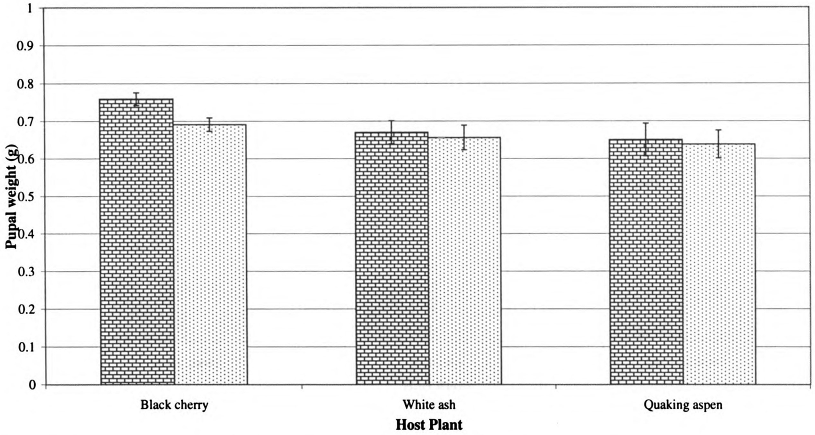

Figure 13: Mean pupal weights (g) of male (n = 72, dotted bars) and female (n = 78, bricked bars) *Papilio canadensis* reared on five host plants: black cherry, paper birch, white ash, basswood, quaking aspen. (No larvae survived on paper birch or basswood.) Data from the 1997 season.

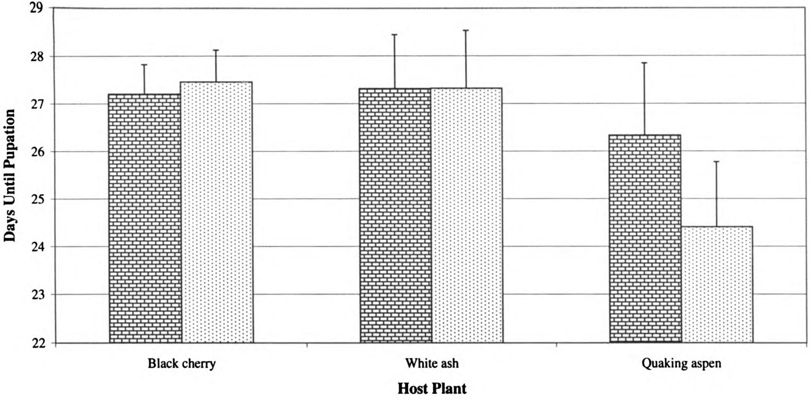

Figure 14: Mean days until pupation for male (n = 72, dotted bars) and female (n= 78, bricked bars) *Papilio canadensis* reared on five host plants: black cherry, paper birch, white ash, basswood, quaking aspen. (No larvae survived on paper birch or basswood). Data from the 1997 season.

APPENDICES

APPENDIX A

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.: 1998-6

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

Testing the 'Cold-Pocket' Hypothesis: Oviposition Preference of the Canadian Tiger Swallowtail

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

Entomology Museum, Michigan State University (MSU)

Other Museums:

Investigator's Name(s) (typed)

Piera Y. Giroux

Date 25 August 1998

*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: Include 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.

APPENDIX 1.1

Voucher Specimen Data

Page 2 of 2 Pages

		Number of:							
Species or other taxon	Label data for specimens collected or used and deposited	Eggs	Larvae	Nymphs	Pupae	Adults ♀	Adults ♂	Other	Museum where deposited
Papilio canadensis	lab reared stock from Dickinson County, MI V-27-98, Piera Y. Giroux lab reared stock from Dickinson County, MI V-25-1998, Piera Giroux lab reared stock from Dickinson County, MI V-27-1998, Piera Giroux Ludington, Mason County, MI V-21-1998, Piera Giroux lab reared stock from Dickinson County, MI VI-3-1998, Piera Giroux lab reared stock from Charlevoix County, MI VI-3-1998, Piera Giroux					3	3		Entomology Museum, Michigan State University (MSU)

(Use additional sheets if necessary)

Investigator's Name(s)

Piera Y. Giroux

Date 25 August 1998

Voucher No. 1998-6

Received the above listed specimens for deposit in the Michigan State University Entomology Museum.

Curator 26 Aug 1998 Date

APPENDIX B

APPENDIX B

Table 17: Stepwise regression of water content of leaves of five species collected at Pellston and Vanderbilt adjusted for degree-day differences, 1997

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model?*
Degree-Day	<0.0001	0.29	yes
Site	<0.0001	0.007	yes
Tree Species	<0.0001	0.01	yes

$r^2 = 0.32$, adjusted $r^2 = 0.31$

Table 18: Stepwise regression of water content of leaves of five species collected at Pellston and Vanderbilt adjusted for degree-day differences, 1996 and 1997

Regressor:	*p Value:*	*Contribution to r^2:*	*Remaining in model?*
Degree-Day	<0.0001	0.32	yes
Site	<0.2	0.0003	yes
Tree Species	<0.0001	0.008	yes
Year	<0.0001	0.06	yes

$r^2 = 0.35$, adjusted $r^2 = 0.35$

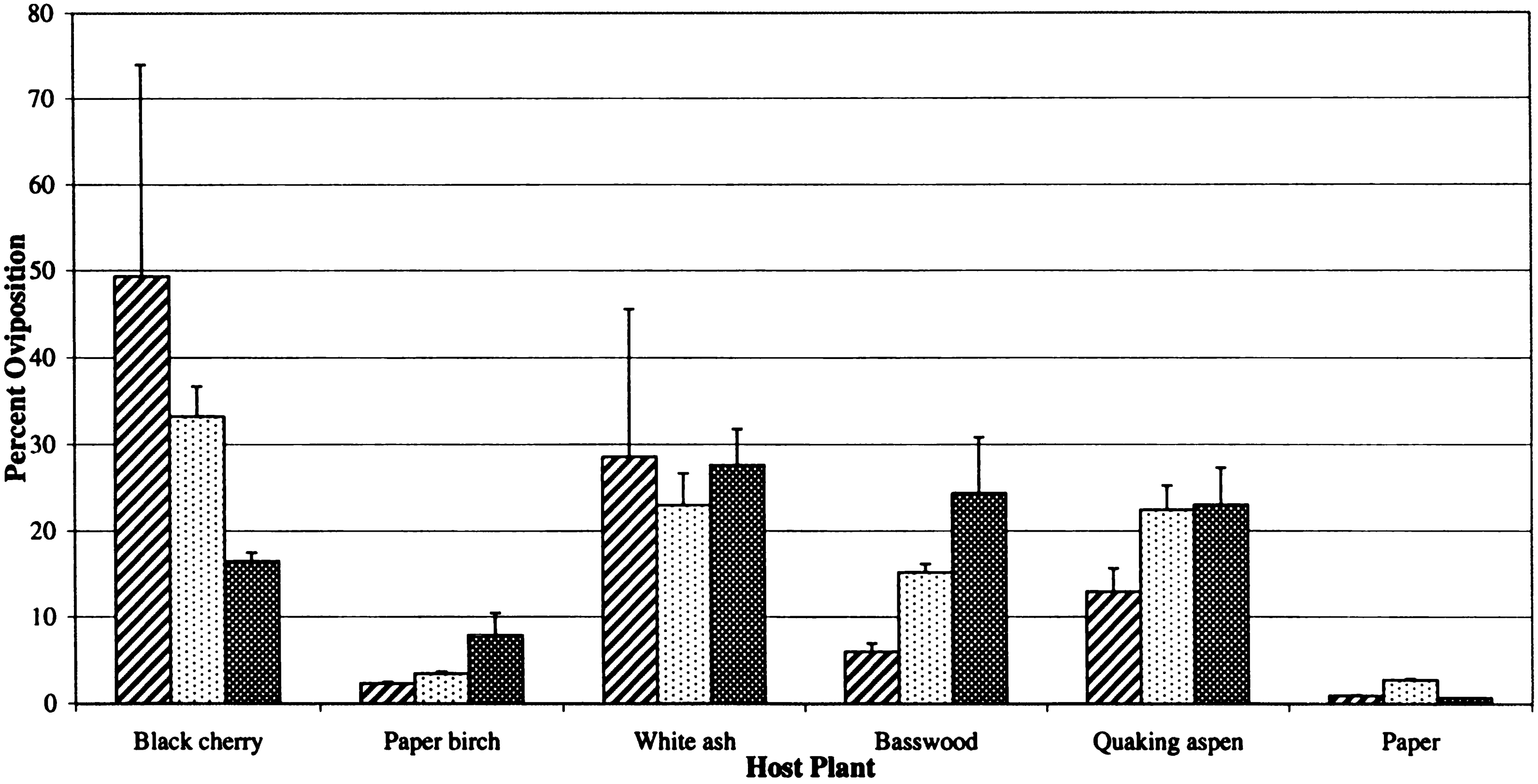

Figure 15: Preference of butterflies collected in Pellston (n= 10, diagonal striped bars), collected in Vanderbilt (n= 19, dotted bars) or collected in the Upper Peninsula (n= 4, cross-hatched bars) for oviposition on leaves of five species, or no leaf (paper). Represented means and standard errors of means for any one bar type are adjusted for a balanced design. Leaves were from the Pellston and Vanderbilt areas. Data from the 1997 season.

APPENDIX C

APPENDIX C

Table 19: 1996 Five choice oviposition preference by *P.canadensis*

Mother Number	Site Location	Assigned Site	Black cherry	Paper birch	White ash	Basswood	Quaking aspen	Paper	Total Eggs
P103	Emmet	1.0	14.5	2.6	72.4	1.3	7.9	1.3	76
P105	Emmet	1.0	5.8	11.5	31.7	14.4	34.6	1.9	104
P106	Emmet	1.0	9.0	0.0	62.7	0.0	28.4	0.0	67
P107	Emmet	1.0	19.0	3.4	36.2	1.7	39.7	0.0	58
P108	Emmet	1.0	13.8	15.4	42.3	10.6	17.1	0.8	123
P109	Emmet	1.0	44.4	0.0	3.7	25.9	25.9	0.0	27
P110	Emmet	1.0	19.0	4.8	54.8	1.2	19.0	1.2	84
P111	Emmet	1.0	73.3	0.0	3.3	16.7	6.7	0.0	30
P112	Emmet	1.0	28.4	4.9	13.6	2.5	46.9	3.7	81
P113	Emmet	1.0	9.9	12.7	32.4	7.0	26.8	11.3	71
P114	Emmet	1.0	17.8	9.6	33.0	6.6	27.4	5.6	197
P115	Emmet	1.0	26.2	0.0	26.2	7.1	35.7	4.8	42
P117	Emmet	1.0	13.0	14.9	5.8	7.8	51.3	7.1	154
P118	Emmet	1.0	25.9	0.0	55.6	3.7	14.8	0.0	27
P120	Emmet	1.0	11.0	17.6	44.9	2.2	22.8	1.5	136
P121	Cheboygan	1.0	19.3	2.3	33.0	11.4	30.7	3.4	88
P122	Cheboygan	1.0	14.8	7.4	23.3	23.3	27.0	4.2	189
P145	Emmet	1.0	29.7	8.1	25.6	19.2	10.5	7.0	172
P146	Emmet	1.0	0.0	25.0	0.0	75.0	0.0	0.0	4

P147	Emmet	1.0	17.2	9.9	37.7	11.3	21.2	2.6	151
P148	Emmet	1.0	2.6	0.0	60.5	28.9	7.9	0.0	38
P149	Cheboygan	1.0	21.8	1.1	20.7	11.5	39.1	5.7	87
P150	Cheboygan	1.0	0.0	0.0	0.0	0.0	100.0	0.0	1
P153	Cheboygan	1.0	20.0	0.0	4.0	4.0	66.0	6.0	50
P154	Cheboygan	1.0	9.3	10.5	23.3	18.6	17.4	20.9	86
P155	Cheboygan	1.0	58.8	0.0	0.0	5.9	17.6	17.6	17
P157	Cheboygan	1.0	25.3	1.2	0.0	2.4	68.7	2.4	83
P163	Cheboygan	1.0	7.1	7.1	51.4	17.1	15.7	1.4	70
P164	Cheboygan	1.0	4.5	0.0	27.3	9.1	59.1	0.0	22
P165	Cheboygan	1.0	12.0	4.0	20.0	20.0	44.0	0.0	25
P166	Cheboygan	1.0	0.0	0.0	0.0	0.0	100.0	0.0	1
P123	Charlevoix	2.0	100.0	0.0	0.0	0.0	0.0	0.0	1
P124	Charlevoix	2.0	8.3	16.7	0.0	16.7	41.7	16.7	12
P134	Charlevoix	2.0	33.3	0.0	0.0	0.0	66.7	0.0	6
P137	Charlevoix	2.0	25.0	0.0	20.8	8.3	29.2	16.7	24
P139	Charlevoix	2.0	26.4	0.0	9.4	43.4	17.0	3.8	53
P140	Charlevoix	2.0	32.2	12.6	15.4	12.6	16.8	10.5	143
P141	Charlevoix	2.0	5.5	14.4	9.6	15.1	50.0	5.5	146
P142	Charlevoix	2.0	11.8	5.5	36.4	16.4	14.5	15.5	110
P143	Charlevoix	2.0	50.0	0.0	0.0	50.0	0.0	0.0	4
P144	Charlevoix	2.0	9.5	5.2	6.9	17.2	56.0	5.2	116
P158	Charlevoix	2.0	15.1	2.7	37.0	21.9	13.7	9.6	73
P159	Charlevoix	2.0	0.0	50.0	0.0	25.0	25.0	0.0	4
P160	Charlevoix	2.0	25.0	0.0	25.0	0.0	50.0	0.0	4
P162	Charlevoix	2.0	5.9	14.7	8.8	11.8	58.8	0.0	34

P189	Otsego	2.0	3.4	29.3	15.5	10.3	32.8	8.6	58
P190	Otsego	2.0	31.3	0.0	6.3	0.0	62.5	0.0	16
P192	Otsego	2.0	15.4	3.8	30.8	15.4	19.2	15.4	52
P126	Chippewa	4.0	30.6	20.4	32.7	8.2	2.0	6.1	49
P127	Chippewa	4.0	13.8	6.9	20.7	37.9	13.8	6.9	29
P128	Chippewa	4.0	0.0	0.0	0.0	0.0	100.0	0.0	3
P129	Chippewa	4.0	19.5	9.8	9.8	11.0	40.2	9.8	82
P130	Mackinac	4.0	0.0	0.0	0.0	0.0	100.0	0.0	12
P131	Mackinac	4.0	6.3	4.2	72.9	0.0	2.1	14.6	48
P132	Mackinac	4.0	10.2	13.1	19.0	28.5	21.9	7.3	137
P133	Mackinac	4.0	2.0	2.0	18.0	4.0	72.0	2.0	50
P167	Chippewa	4.0	15.4	7.7	19.2	3.8	38.5	15.4	26
P168	Chippewa	4.0	12.5	29.2	29.2	16.7	12.5	0.0	24
P169	Chippewa	4.0	45.0	6.3	13.8	21.3	12.5	1.3	80
P170	Chippewa	4.0	26.8	10.3	21.6	19.6	13.4	8.2	97
P171	Chippewa	4.0	11.1	15.9	22.2	19.0	28.6	3.2	63
P174	Chippewa	4.0	22.4	11.9	9.0	7.5	44.8	4.5	67
P176	Chippewa	4.0	24.8	6.6	14.9	30.6	18.2	5.0	121
P178	Chippewa	4.0	20.0	5.0	15.0	30.0	25.0	5.0	20
P179	Chippewa	4.0	12.1	3.0	21.2	27.3	30.3	6.1	33
P182	Chippewa	4.0	16.2	21.6	13.5	45.9	2.7	0.0	37
P183	Chippewa	4.0	7.3	9.1	60.0	20.0	3.6	0.0	55
P184	Chippewa	4.0	0.0	0.0	100.0	0.0	0.0	0.0	3
P185	Chippewa	4.0	14.3	19.0	33.3	7.1	23.8	2.4	42
P186	Chippewa	4.0	0.0	0.0	0.0	100.0	0.0	0.0	1
P188	Chippewa	4.0	37.5	62.5	0.0	0.0	0.0	0.0	8

Table 20: 1997 Five choice oviposition preference by *P. canadensis*

Mother number	Site Location	Assigned Site	Leaves	Black cherry	Paper birch	White ash	Basswood	Quaking aspen	Paper	Total Eggs
P201	Cheboygan	1.0	Pellston	30.4	4.3	47.8	0.0	17.4	0.0	23
P203	Cheboygan	1.0	Pellston	0.0	0.0	0.0	0.0	100.0	0.0	1
P204	Emmet	1.0	Pellston	0.0	100.0	0.0	0.0	0.0	0.0	1
P205	Emmet	1.0	Pellston	32.9	0.0	41.4	15.7	8.6	1.4	70
P206	Emmet	1.0	Pellston	100.0	0.0	0.0	0.0	0.0	0.0	1
P212	Emmet	1.0	Otsego	75.0	0.0	25.0	0.0	0.0	0.0	4
P213	Cheboygan	1.0	Otsego	92.7	0.0	1.8	3.6	1.8	0.0	55
P214	Cheboygan	1.0	Otsego	0.0	0.0	100.0	0.0	0.0	0.0	1
P215	Cheboygan	1.0	Pellston	25.6	2.2	55.6	0.0	13.3	3.3	90
P219	Cheboygan	1.0	Pellston	40.0	0.0	33.8	1.3	25.0	0.0	80
P222	Cheboygan	1.0	Pellston	41.7	12.5	2.1	20.8	22.9	0.0	48
P225	Charlevoix	2.0	Pellston	77.8	0.0	0.0	11.1	11.1	0.0	9
P227	Charlevoix	2.0	Pellston	60.0	0.0	0.0	0.0	40.0	0.0	20
P228	Charlevoix	2.0	Pellston	22.6	0.0	0.0	28.3	49.1	0.0	53
P230	Charlevoix	2.0	Pellston	16.0	12.0	48.0	9.3	14.7	0.0	75
P231	Charlevoix	2.0	Pellston	11.8	0.0	20.6	35.3	11.8	20.6	34
P232	Charlevoix	2.0	Pellston	0.0	0.0	0.0	100.0	0.0	0.0	8
P234	Charlevoix	2.0	Pellston	3.8	3.8	30.8	42.3	15.4	3.8	26
P235	Charlevoix	2.0	Pellston	18.8	0.0	25.0	37.5	0.0	18.8	16
P237	Charlevoix	2.0	Pellston	0.0	0.0	0.0	0.0	0.0	100.0	2
P239	Charlevoix	2.0	Pellston	23.1	0.0	76.9	0.0	0.0	0.0	13

P241	Charlevoix	2.0	Pellston	0.0	0.0	50.0	50.0	0.0	0.0	2
P242	Charlevoix	2.0	Pellston	41.3	4.3	26.1	8.7	19.6	0.0	46
P244	Charlevoix	2.0	Pellston	100.0	0.0	0.0	0.0	0.0	0.0	1
P250	Charlevoix	2.0	Pellston	54.5	0.0	0.0	1.8	41.8	1.8	55
P251	Charlevoix	2.0	Pellston	36.5	0.0	32.7	9.6	21.2	0.0	52
P280	Otsego	2.0	Pellston	100.0	0.0	0.0	0.0	0.0	0.0	5
P283	Otsego	2.0	Pellston	13.3	10.0	3.3	26.7	46.7	0.0	30
P287	Otsego	2.0	Otsego	46.5	4.7	30.2	4.7	14.0	0.0	43
P288	Otsego	2.0	Otsego	71.4	0.0	28.6	0.0	0.0	0.0	7
P342	Iron	4.0	Otsego	10.9	0.0	21.7	39.1	28.3	0.0	46
P345	Iron	4.0	Otsego	0.0	0.0	94.7	0.0	5.3	0.0	19
P346	Iron	4.0	Otsego	20.9	27.9	9.3	34.9	7.0	0.0	43
P347	Iron	4.0	Otsego	66.7	0.0	0.0	0.0	33.3	0.0	6
P349	Iron	4.0	Otsego	18.4	0.0	26.3	10.5	42.1	2.6	38

Table 21: 1998 Young and old oviposition preference by *P. canadensis*

Mother number	Collection Site	Assigned Site	Old White ash	Young White ash	Paper	Total Eggs
14010	Oscoda	5.0	28.7	71.2	0.0	66
14011	Cheboygan/Emmet	1.0	17.6	82.3	0.0	17
14012	Cheboygan/Emmet	1.0	53.3	46.6	0.0	15
14014	Cheboygan/Emmet	1.0	9.0	90.9	0.0	22
14025	Oscoda	5.0	8.3	91.6	0.0	12
14031	UP	4.0	45.4	33.3	21.2	33
14039	Charlevoix	6.0	38.7	61.2	0.0	31
14043	UP	4.0	40.0	60.0	0.0	10
14046	UP	4.0	46.3	48.7	4.8	41
14059	Cheboygan/Emmet	1.0	34.4	59.7	5.7	87
14062	Mason	7.0	33.3	66.6	0.0	15
14068	Mason	7.0	66.6	33.3	0.0	15
14071	Mason	7.0	81.8	18.1	0.0	11
14078	Otsego	2.0	56.0	33.3	10.6	66
14081	Otsego	2.0	40.0	60.0	0.0	30

Table 22: 1997 *P. canadensis* oviposition preference for white ash collected from four sites

Mother #	Collection Site	Assigned Site	Pellston	Vanderbilt	Cross Village	Okemos	Paper	Total Eggs
P205	Emmet	1.0	32.1	39.2	17.8	10.7	0.0	28
P213	Cheboygan	1.0	0.0	0.0	0.0	100.0	0.0	1
P262	Cheboygan	1.0	36.5	7.6	9.6	44.2	1.9	52
P263	Cheboygan	1.0	26.6	31.6	25.0	15.0	1.6	60
P264	Cheboygan	1.0	12.9	33.3	20.3	32.4	0.9	108
P266	Cheboygan	1.0	23.0	15.3	46.1	15.3	0.0	13
P230	Charlevoix	2.0	11.1	40.2	27.7	20.8	0.0	72
P242	Charlevoix	2.0	11.2	35.4	20.9	32.2	0.0	62
P273	Otsego	2.0	13.1	26.3	11.8	47.3	1.3	76
P276	Otsego	2.0	20.1	35.0	16.2	25.3	3.2	154
P277	Otsego	2.0	0.0	0.0	00.0	0.0	0.0	1
P349	UP	4.0	48	11.5	11.5	28.8	0.0	52
P279	Otsego	2.0	17.3	30.4	4.3	47.8	0.0	23

Table 23: 1997 *P. canadensis* oviposition preference for extracts of white ash collected from four sites

Mother #	Collection Site	Assigned Site	Pellston	Vanderbilt	Cross Village	Okemos	Water	Acetone	Paper	Total Eggs
P262	Cheboygan	1.0	0.0	33.3	0.0	0.0	66.7	0.0	0.0	3
P264	Cheboygan	1.0	13.3	22.2	31.1	17.8	11.1	4.4	0.0	45
P230	Charlevoix	2.0	28.0	4.0	4.0	12.0	16.0	12.0	24.0	25
P273	Otsego	2.0	50.0	0.0	50.0	0.0	0.0	0.0	0.0	2
P360	Cheboygan	2.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0	3
P332	Iron	4.0	50.0	0.0	0.0	50.0	0.0	0.0	0.0	4
P340	Iron	4.0	7.3	26.8	17.1	22.0	24.4	2.4	0.0	41
P349	Iron	4.0	13.9	18.1	20.8	27.8	15.3	4.2	0.0	72
P310	Otsego	2.0	14.9	8.5	34.0	14.9	14.9	10.6	2.1	47

Table 24: 1996 *P. canadensis* pupal weight data

Mother #	Date	Host Plant	Pupal weight (g)
P106	7 July 1996	Black cherry	0.9079
P106	7 July 1996	Black cherry	0.7248
P106	7 July 1996	Black cherry	0.7652
P107	15 July 1996	Black cherry	0.7949
P107	20 July 1996	Black cherry	0.8989
P107	21 July 1996	Black cherry	0.8237
P107	21 July 1996	Black cherry	0.8755
P107	22 July 1996	Black cherry	0.759
P107	19 July 1996	White ash	0.9173
P107	19 July 1996	White ash	0.7792
P107	21 July 1996	White ash	0.7781
P107	22 July 1996	White ash	0.7889
P107	23 July 1996	White ash	0.6886
P107	23 July 1996	White ash	0.9493
P107	30 July 1996	White ash	0.7693
P107	30 July 1996	White ash	0.7217
P107	04-Aug-96	Quaking aspen	0.7707
P107	26 July 1996	Quaking aspen	0.8377
P107	29 July 1996	Quaking aspen	1.0304
P107	30 July 1996	Quaking aspen	0.9998
P108	19 July 1996	Black cherry	1.0166
P108	23 July 1996	Black cherry	0.572
P108	25 July 1996	Black cherry	0.6172
P108	27 July 1996	Black cherry	0.7725
P108	19 July 1996	White ash	0.7228
P108	20 July 1996	White ash	0.6648
P108	21 July 1996	White ash	0.6722
P109	10 July 1996	?	0.7358
P109	17 July 1996	?	1.0073
P109	19 July 1996	?	0.7351
P110	23 July 1996	Black cherry	0.7647
P110	26 July 1996	Black cherry	0.8324
P110	27 July 1996	Black cherry	0.5436
P110	31 July 1996	Black cherry	0.6517
P112	30 July 1996	Black cherry	0.6829

P113	19 July 1996	Black cherry	0.7946
P113	20 July 1996	Black cherry	0.893
P113	20 July 1996	Black cherry	0.9597
P113	21 July 1996	Black cherry	0.9267
P113	16 July 1996	White ash	0.7512
P113	26 July 1996	White ash	0.6496
P113	03-Aug-96	Basswood	0.5891
P113	19 July 1996	Quaking aspen	0.9136
P113	21 July 1996	Quaking aspen	0.9286
P113	21 July 1996	Quaking aspen	0.9496
P113	22 July 1996	Quaking aspen	1.0192
P113	22 July 1996	Quaking aspen	0.6217
P113	24 July 1996	Quaking aspen	0.81
P114	19 July 1996	Black cherry	0.911
P114	19 July 1996	Black cherry	0.9983
P114	19 July 1996	Black cherry	0.8709
P114	20 July 1996	Black cherry	0.89
P114	21 July 1996	Black cherry	0.9158
P114	21 July 1996	Black cherry	1.0838
P114	21 July 1996	Black cherry	0.9931
P114	21 July 1996	Black cherry	0.9469
P114	21 July 1996	Black cherry	0.8521
P114	22 July 1996	Black cherry	0.9252
P114	22 July 1996	Black cherry	0.7297
P114	23 July 1996	Black cherry	0.9103
P114	25 July 1996	Black cherry	0.8611
P114	27 July 1996	Black cherry	0.8608
P114	21 July 1996	White ash	0.67
P114	21 July 1996	White ash	0.7875
P114	21 July 1996	White ash	0.7683
P114	22 July 1996	White ash	0.7667
P114	24 July 1996	White ash	0.6671
P114	25 July 1996	White ash	0.6482
P114	19 July 1996	Quaking aspen	0.8926
P114	24 July 1996	Quaking aspen	0.966
P114	24 July 1996	Quaking aspen	0.8009
P114	25 July 1996	Quaking aspen	0.7388
P114	25 July 1996	Quaking aspen	
P114	26 July 1996	Quaking aspen	0.848

P115	15 July 1996	Black cherry	0.8454
P115	16 July 1996	Black cherry	0.9112
P115	16 July 1996	Black cherry	0.8899
P115	23 July 1996	Black cherry	0.765
P117	18 July 1996	Black cherry	0.7743
P117	18 July 1996	Black cherry	0.8255
P117	18 July 1996	Black cherry	0.8805
P117	19 July 1996	Black cherry	0.606
P117	19 July 1996	Black cherry	0.6817
P117	19 July 1997	Black cherry	0.8686
P117	20 July 1996	Black cherry	0.7997
P117	20 July 1996	Black cherry	0.9096
P117	20 July 1996	Black cherry	0.7997
P117	20 July 1996	Black cherry	0.9096
P117	21 July 1996	Black cherry	0.7435
P117	21 July 1996	Black cherry	0.8518
P117	21 July 1996	Black cherry	0.7877
P117	21 July 1996	Black cherry	1.0275
P117	21 July 1996	Black cherry	0.4811
P117	21 July 1996	Black cherry	0.7435
P117	23 July 1996	Black cherry	0.8044
P117	23 July 1996	Black cherry	0.8442
P117	23 July 1996	Black cherry	0.714
P117	23 July 1996	Black cherry	0.88
P117	25 July 1996	Black cherry	0.8257
P117	26 July 1996	Black cherry	0.6615
P117	27 July 1996	Black cherry	0.5926
P117	30 July 1996	Black cherry	0.7321
P117	30 July 1996	Black cherry	0.6692
P117	9 July 1996	Black cherry	0.8662
P118	26 July 1996	Black cherry	0.8617
P118	27 July 1996	Black cherry	0.6363
P120	15 July 1996	Black cherry	0.8327
P120	18 July 1996	Black cherry	1.1763
P120	18 July 1996	Black cherry	0.9493
P120	18 July 1996	Black cherry	0.8839
P120	20 July 1996	Black cherry	0.8426
P120	22 July 1996	Black cherry	0.7967
P120	24 July 1996	Black cherry	1.0106

P120	21 July 1996	White ash	0.817
P120	22 July 1996	White ash	0.9234
P120	24 July 1996	White ash	0.7703
P120	27 July 1996	White ash	1.0745
P120	27 July 1996	White ash	0.40
P120	21 July 1996	Quaking aspen	0.9434
P120	24 July 1996	Quaking aspen	0.83
P120	26 July 1996	Quaking aspen	1.0376
P121	20 July 1996	Black cherry	0.6873
P121	22 July 1996	Black cherry	0.7523
P121	25 July 1996	Black cherry	0.5143
P121	25 July 1996	Black cherry	0.5708
P121	27 July 1996	Black cherry	0.852
P122	20 July 1996	Black cherry	0.9653
P122	20 July 1996	Black cherry	1.0107
P122	21 July 1996	Black cherry	0.6728
P122	21 July 1996	Black cherry	0.8403
P122	22 July 1996	Black cherry	1.1753
P122	26 July 1996	Black cherry	0.9472
P122	19 July 1996	White ash	0.8815
P122	21 July 1996	White ash	0.8553
P122	21 July 1996	White ash	0.8541
P122	22 July 1996	White ash	0.8148
P122	22 July 1996	White ash	0.9564
P122	24 July 1996	White ash	0.9541
P122	25 July 1996	White ash	0.7182
P122	27 July 1996	White ash	0.7336
P122	21 July 1996	Quaking aspen	1.023
P122	24 July 1996	Quaking aspen	0.776
P122	27 July 1996	Quaking aspen	0.6973
P122	29 July 1996	Quaking aspen	1.1579
P123	18 July 1996	Black cherry	0.83
P123	19 July 1996	Black cherry	0.9868
P126	18 July 1996	Black cherry	0.7712
P126	18 July 1996	Black cherry	0.9377
P126	19 July 1996	Black cherry	0.794
P126	19 July 1996	Black cherry	0.9765
P126	19 July 1996	Black cherry	1.0115
P126	20 July 1996	Black cherry	0.7475

P126	20 July 1996	Black cherry	0.9053
P126	21 July 1996	Black cherry	0.9033
P126	21 July 1996	Black cherry	0.9417
P126	21 July 1996	Black cherry	0.8705
P126	22 July 1996	Black cherry	0.8657
P126	24 July 1996	Black cherry	0.7911
P126	26 July 1996	Black cherry	0.774
P126	9 July 1996	Black cherry	0.874
P126	18 July 1996	White ash	0.8107
P126	19 July 1996	White ash	0.8129
P126	20 July 1996	White ash	0.7642
P126	30 July 1996	Quaking aspen	1.1455
P129	18 July 1996	Black cherry	0.8382
P129	18 July 1996	Black cherry	0.8503
P129	18 July 1996	Black cherry	0.9062
P129	19 July 1996	Black cherry	0.8673
P129	19 July 1996	Black cherry	0.9903
P129	19 July 1996	Black cherry	0.9469
P129	20 July 1996	Black cherry	0.8315
P129	20 July 1996	Black cherry	0.8306
P129	21 July 1996	Black cherry	0.6912
P129	27 July 1996	Black cherry	0.5115
P129	9 July 1996	Black cherry	0.7542
P129	20 July 1996	White ash	0.7213
P129	20 July 1996	White ash	0.8384
P129	21 July 1996	White ash	0.7681
P129	21 July 1996	White ash	0.7262
P129	21 July 1996	White ash	0.9195
P129	21 July 1996	White ash	0.8699
P129	21 July 1996	White ash	0.7064
P129	25 July 1996	White ash	0.7674
P129	25 July 1996	White ash	0.693
P129	19 July 1996	Quaking aspen	0.9099
P129	22 July 1996	Quaking aspen	0.8305
P129	24 July 1996	Quaking aspen	0.7545
P129	25 July 1996	Quaking aspen	0.6899
P129	30 July 1996	Quaking aspen	0.5836
P129	30 July 1996	Quaking aspen	1.2542
P130	19 July 1996	Black cherry	0.814

P131	20 July 1996	Black cherry	0.7899
P131	30 July 1996	Quaking aspen	1.0976
P132	19 July 1996	Black cherry	0.9614
P132	19 July 1996	Black cherry	0.8591
P132	20 July 1996	Black cherry	0.9442
P132	20 July 1996	Black cherry	0.9758
P132	20 July 1996	Black cherry	1.0058
P132	20 July 1996	Black cherry	0.8695
P132	21 July 1996	Black cherry	0.772
P132	21 July 1996	Black cherry	0.8397
P132	23 July 1996	Black cherry	1.1059
P132	26 July 1996	Black cherry	0.9161
P133	18 July 1996	Black cherry	0.874
P133	20 July 1996	Black cherry	0.7992
P133	23 July 1996	Black cherry	0.7524
P137	18 July 1996	Black cherry	0.9572
P137	18 July 1996	Black cherry	0.9948
P137	18 July 1996	Black cherry	0.9695
P137	19 July 1996	Black cherry	0.9695
P139	22 July 1996	Black cherry	0.8531
P139	23 July 1996	Black cherry	0.7609
P139	19 July 1996	White ash	0.8314
P140	18 July 1996	Black cherry	0.9195
P140	18 July 1996	Black cherry	1.0151
P140	18 July 1996	Black cherry	0.8009
P140	19 July 1996	Black cherry	1.0164
P140	21 July 1996	Black cherry	0.9978
P140	24 July 1996	Black cherry	0.9075
P140	24 July 1996	Black cherry	0.7906
P140	24 July 1996	White ash	0.5654
P140	24 July 1996	White ash	0.5932
P147	26 July 1996	Black cherry	0.8296
P147	26 July 1996	Black cherry	0.7908
P147	27 July 1996	Black cherry	0.6991
P147	27 July 1996	Black cherry	0.619
P147	27 July 1996	Black cherry	0.6794
P147	30 July 1996	Black cherry	0.5899
P148	20 July 1996	Black cherry	0.853
P148	21 July 1996	Black cherry	0.8555

P148	23 July 1996	Black cherry	0.7682
P148	23 July 1996	Black cherry	0.9635
P148	25 July 1996	Black cherry	0.9231
P148	25 July 1996	Black cherry	0.9446
P148	25 July 1996	Black cherry	0.9016
P148	26 July 1996	Black cherry	0.906
P148	27 July 1996	Black cherry	0.57
P148	27 July 1996	Black cherry	1.072
P148	29 July 1996	Black cherry	0.842
P149	27 July 1996	Black cherry	0.8799
P149	27 July 1996	Black cherry	0.906
P149	28 July 1996	Black cherry	0.7628
P155	21 July 1996	Black cherry	0.8922
P155	25 July 1996	Black cherry	0.7661
P157	01-Aug-96	Black cherry	0.9034
P157	29 July 1996	Black cherry	0.9206
P165	24 July 1996	Black cherry	0.7673
P165	19 July 1996	White ash	0.8785
P165	27 July 1996	White ash	0.7019

Table 25: 1997 *P. canadensis* pupal weight data

Host Plant	Larvae Set Up	Larvae Survived	Percent Survival	
Black cherry	303	100	33.00330033	
Paper birch	23	0	0	
White ash	411	30	7.299270073	
Basswood	32	0	0	
Quaking aspen	141	19	13.4751773	
Mother #:	Plant reared on:	Days Until Pupation:	Pupal weight:	Sex:
P201	Prunus serotina	30	0.8002	female
P205	Fraxinus americana	31	0.6355	male
P205	Populus tremuloides	24	0.6016	female
P205	Prunus serotina	30	0.9168	female
P205	Prunus serotina	30	0.9332	female
P205	Prunus serotina	27	0.8407	female
P205	Prunus serotina	29.5	0.937	female
P207	Populus tremuloides	27	0.6104	female
P213	Prunus serotina	21	0.7944	female
P213	Prunus serotina	27	0.5901	male
P213	Prunus serotina	33	0.5529	male
P213	Prunus serotina	33	0.7299	male
P213	Prunus serotina	26	0.9407	female
P213	Prunus serotina	25.5	0.5592	female
P215	Populus tremuloides	24	0.6466	female
P215	Populus tremuloides	27	0.5983	male
P215	Prunus serotina	27	0.842	male
P215	Prunus serotina	28.5	0.6456	
P215	Prunus serotina	34	0.847	female
P219	Fraxinus americana	21	0.666	female
P219	Fraxinus americana	24	0.587	male
P219	Fraxinus americana	30	0.7114	male
P219	Fraxinus americana	31	0.6786	female
P219	Fraxinus americana	30	0.7375	male
P219	Prunus serotina	33	0.4497	male

P222	Fraxinus americana	29	0.5738	female
P222	Populus tremuloides	20	0.6008	male
P222	Populus tremuloides	28.5	0.5796	female
P222	Prunus serotina	24	0.6272	male
P222	Prunus serotina	25.5	0.5458	male
P222	Prunus serotina	25.5	0.6245	male
P227	Fraxinus americana	25	0.5838	female
P227	Populus tremuloides	24	0.6108	female
P227	Prunus serotina	27	0.8723	female
P227	Prunus serotina	33	0.82	male
P227	Prunus serotina	54	0.8182	male
P227	Prunus serotina	28.5	0.8533	female
P228	Fraxinus americana	33	0.563	male
P228	Prunus serotina	24	0.6487	male
P228	Prunus serotina	33	0.94	female
P230	Fraxinus americana	21	0.6742	male
P230	Fraxinus americana	24	0.7182	male
P230	Fraxinus americana	29	0.6496	male
P230	Prunus serotina	21	0.6998	male
P230	Prunus serotina	24	0.7516	male
P230	Prunus serotina	27	0.635	female
P230	Prunus serotina	27	1.0046	female
P230	Prunus serotina	57	0.43	female
P230	Prunus serotina	26	0.6401	female
P230	Prunus serotina	27	0.5186	dead
P230	Prunus serotina	28.5	0.4607	female
P230	Prunus serotina	30	0.6931	male
P230	Prunus serotina	30	0.7546	male
P231	Prunus serotina	26.5	0.5075	male
P232	Prunus serotina	28.5	0.4275	male
P234	Prunus serotina	27	0.5042	female
P234	Prunus serotina	22.5	0.7002	male
P234	Prunus serotina	27	0.7212	male
P235	Fraxinus americana	27	0.6299	female
P239	Prunus serotina	27	0.5796	male
P239	Prunus serotina	22.5	0.5624	male
P239	Prunus serotina	28.5	0.573	male
P241	Prunus serotina	25.5	0.7706	female
P242	Fraxinus americana	24	0.601	male

P242	Fraxinus americana	24	0.6589	female
P242	Fraxinus americana	24	0.7566	male
P242	Fraxinus americana	27	0.6346	female
P242	Fraxinus americana	30	0.579	male
P242	Fraxinus americana	28.5	0.6547	female
P242	Populus tremuloides	20	0.623	male
P242	Populus tremuloides	24	0.6333	male
P242	Prunus serotina	27	0.6297	male
P242	Prunus serotina	27	0.6702	male
P242	Prunus serotina	28.5	0.781	female
P244	Populus tremuloides	27	0.5173	female
P250	Fraxinus americana	27	0.7652	male
P250	Populus tremuloides	30	0.6238	male
P250	Prunus serotina	27	0.6427	male
P250	Prunus serotina	31	0.5075	female
P250	Prunus serotina	25.5	0.6318	male
P250	Prunus serotina	26.5	0.7273	male
P250	Prunus serotina	27	0.7778	female
P251	Fraxinus americana	29	0.8041	female
P251	Fraxinus americana	28.5	0.7627	female
P251	Populus tremuloides	27	0.6197	female
P251	Prunus serotina	24	0.8864	female
P251	Prunus serotina	29	0.8083	male
P251	Prunus serotina	26	0.7154	female
P251	Prunus serotina	27	0.7543	female
P262	Fraxinus americana	24	0.6487	female
P262	Fraxinus americana	33	0.5454	female
P262	Populus tremuloides	28.5	0.697	female
P262	Prunus serotina	21	0.5431	female
P262	Prunus serotina	25.5	0.5991	male
P262	Prunus serotina	25.5	0.6194	male
P262	Prunus serotina	27	0.616	male
P262	Prunus serotina	27	0.7278	male
P262	Prunus serotina	28.5	0.5998	male
P262	Prunus serotina	27.255	0.5939	male
P264	Fraxinus americana	33	0.7065	male
P264	Populus tremuloides	24	0.5521	male
P264	Populus tremuloides	24	0.7596	male
P264	Populus tremuloides	27	0.8329	female

P264	Populus tremuloides	27.5	0.737	male
P264	Prunus serotina	24	0.6792	male
P264	Prunus serotina	27	0.7715	female
P264	Prunus serotina	29	0.9045	female
P264	Prunus serotina	26	1.0159	female
P264	Prunus serotina	27	0.6203	male
P266	Fraxinus americana	31	0.62	female
P266	Populus tremuloides	24	0.5656	male
P266	Populus tremuloides	27	0.5592	male
P273	Prunus serotina	25	0.5896	female
P276	Prunus serotina	21	0.9503	female
P276	Prunus serotina	24	1.0205	female
P276	Prunus serotina	25	0.845	female
P276	Prunus serotina	25.5	0.8073	male
P276	Prunus serotina	28.5	0.7073	female
P277	Populus tremuloides	21	0.7641	male
P279	Fraxinus americana	24	0.614	female
P279	Prunus serotina	20	0.8971	female
P279	Prunus serotina	27	0.7442	male
P279	Prunus serotina	27	0.6308	female
P283	Prunus serotina	24	0.5499	male
P287	Prunus serotina	28.5	0.6337	female
P302	Prunus serotina	27	0.7286	female
P310	Prunus serotina	22	0.8907	female
P310	Prunus serotina	27	0.897	female
P310	Prunus serotina	29.5	1.0245	male
P331	Prunus serotina	27	0.7608	female
P331	Prunus serotina	33	0.761	female
P331	Prunus serotina	26	0.9043	male
P331	Prunus serotina	31	0.738	female
P331	Prunus serotina	25.5	0.9119	male
P331	Prunus serotina	27	0.7365	female
P331	Prunus serotina	34	0.869	male
P332	Prunus serotina	25	0.7633	male
P340	Prunus serotina	24	0.7473	female
P340	Prunus serotina	24	0.7463	female
P342	Fraxinus americana	27	0.8372	female
P342	Fraxinus americana	28	0.8067	female
P342	Prunus serotina	25.5	0.6427	female

P342	Prunus serotina	25.5	0.6604	female
P342	Prunus serotina	27	0.6694	female
P342	Prunus serotina	28.5	0.6731	female
P345	Prunus serotina	22.5	0.7774	male
P345	Prunus serotina	24	0.6817	female
P345	Prunus serotina	25.5	0.6868	female
P346	Fraxinus americana	22.5	0.498	male
P346	Prunus serotina	25	0.6343	female
P346	Prunus serotina	26	0.7142	female
P347	Prunus serotina	24	0.7717	male
P349	Prunus serotina	27	0.9674	male

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