

# **Assessing Host Plant Suitability in Evergreen Bagworm (*Thyridopteryx ephemeraeformis*)**

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## **Abstract-**

A survey of the evergreen bagworm (*Thyridopteryx ephemeraeformis*) was conducted to evaluate possible differences between the suitability of host plants. The bagworm, while associated with evergreen trees, readily feeds on a variety of plants including deciduous trees, shrubs, and perennials. This project aimed to discern possible differences in host plant quality through various variables like pupal case size, rate of parasitism, rate of predation, and fecundity. While multiple factors can affect bagworm survival in the landscape, this project will focus on how host plants affect reproductive output and susceptibility to natural enemies.

## **Introduction-**

The evergreen bagworm, *Thyridopteryx ephemeraeformis* (Hawthorn) (Lepidoptera: Psychidae), as the common name suggests, is associated with evergreen trees and shrubs and can be a serious pest on those plants. However, evergreens are not the only plants at risk, as these bagworms have long been known to feed on a wide array of ornamentals, having been reported to feed on “apple, pear, plum, cherry, chokecherry, apricot, quince, linden, catalpa, maple, locust, oak, elm, poplar, sycamore, osage orange, willow, spruce, hemlock, larch, and white pine” (Felt, 1905). Little is known of the host selection for this species or requirements that might differentiate host suitability, and how differences in top down factors and bottom up factors interact with each other to influence host plant suitability.

All bagworms (Psychidae) have a somewhat unique lifestyle, building a case around themselves which they use for protection, from which the adult females never leave. While the adult males are mobile, females can only crawl a short distance, as evidenced by the lack of any functional appendages including mouthparts or wings, and the eggs are laid and develop in the female pupal case (Jones & Parks, 1928). This means that the adult females have no choice in host selection, leaving that duty to the neonatal larva themselves. This is different from many other Lepidopterans, where the female makes host assessment as a consequence of oviposition, solving many of the problems faced by neonatal larvae that need to disperse themselves.

Neonatal larvae of most flightless Lepidoptera balloon in order to colonize new plants (Mitchell 1979)(Mason and McManus 1981)(Cox and Potter 1986), but can also stay on the parent plant if the host is suitable and not overcrowded (Rhainds & Sadof 2008ab). Polyphagy is thus likely an important evolutionary trait to flightless females due to this constraint.

Work done on neonate dispersal has shown that the larvae are less selective the older they get— a matter of days— and that they preferred arborvitae over either juniper or maple (Moore & Hanks, 2004). This preference for an evergreen host differs from that of others who found a preference for black willow over red cedar in first instar larva, though adverse effects in switching host plants in later instars (Ward et al. 1989). Neonatal dispersal can also include the parent plant given low density of other bagworms (Rhainds & Sadof 2008a)(Rhainds & Sadof, 2008b), with evidence of inherited preference and proximity being some of the factors that influence dispersal or proliferation (Jones & Parks, 1927). Larval selection seems to suggest a preference for established hosts for all instars, and a preference for deciduous hosts in dispersed larva.

Nutritional selection is not the only variable affecting host suitability, and there are many variables which can influence the fitness of bagworms on various hosts. While there is little consensus in the literature as to what factors most influence host selection and suitability for bagworms, nutritional suitability, impacts of natural enemies, and overwintering temperatures have been the most explored to date. The relative importance of these factors on each host plant have yet to be investigated. For example, there have been no studies of how differences in foliar density and silhouettes could influence the capacity of a host to hide and protect bagworms. Similarly, there have been few studies of how tree shape can influence bagworm dispersal or overwintering insulation.

What is clear in the current literature are the selective processes and preferences of neonate larvae, the likely nutritional ‘superiority’ of certain deciduous genera, and the effects of temperature on overwintering success. All of these variables can be sorted as top down factors and bottom up factors. Top down factors can be described as factors which result from higher trophic level factors, such as predation or parasitization in the bagworm. Parasitism is the most studied top down factor, but entomopathic fungi and predation have also been reported. There are first hand documents reporting the efficiency with which bird flocks were able to consume the bagworms in a maple grove, suggesting that bare branches make for poor camouflage

(Haseman, 1912). Most of the literature agrees that predation is difficult to assess since it usually includes birds taking away the bags from their hosts, often destroying evidence of predation and making it difficult to record (Moore & Hanks 2000, Berisford & Tsao 1975). Parasitism and disease seem to have an inverse relationship based on weather conditions, dry conditions favoring parasitoids, wet conditions favoring fungi, and vice versa. Parasitoids are largely wasps (Hymenoptera), though some flies (Diptera) and even pyralid moths (Lepidoptera: Pyralidae) are reported as pupal parasites of the bagworm (Berisford & Tsao 1975). While no literature examines the relationship of host species and parasitism, there is some evidence that population density promotes parasitism, and bagworms escape parasitoids by colonizing new hosts (Barrows 1974, Cronin 1989, Rhainds & Sadof, 2008ab).

Bottom up factors result from lower trophic interactions, mostly nutritional ecology and food quality for the bagworms, but also any temperature differences. Work done looking specifically at host tree quality in bagworms compared size and fecundity. Research by Neal and Santamour (1990) shows a nutritional ‘superiority’ of the deciduous hosts; American sycamore, honey locust, and especially black locust, over evergreen hosts; eastern white pine, arborvitae, and Colorado blue spruce. This is similar to research done by Rhainds et al. (2008) showing honey locust, the deciduous host sampled, to be better than most deciduous hosts sampled, with the exception of arborvitae. While nutrition is an important bottom up factor, environmental factors can be just as important, especially when considering landscape ecology. There is evidence to show that the bags are the main line of defense against the cold and dehydration, as there are low levels of chemicals with antifreeze properties like glycerol and sorbitol (Rivers et al. 2002). Furthermore, work done by Smith and Barrows (1991) shows a favorable difference between pupal size and overwintering temperature in black locust (*Robinia pseudoacacia*) compared to various junipers (*Juniperus sp.*). Previous work has even created temperature ranges which are acceptable to overwintering bags and tolerance for extreme cold events (Rhainds et al. 2013), and how hardscape and other thermal trapping surfaces influence overwintering temperature and success (Dwadi, 2022).

Bagworm abundance can be explained by top down or bottom up factors, both of which will be examined with this survey. I will examine bottom up factors by comparing the reproductive capacity of female bagworms between hosts. Top down factors will be assessed by recording rates of parasitism and predation between hosts. This survey will discern if there is a

difference between host plants suitability and its interaction with these two factors. These two factors affect suitability through larval or growth success and pupal or overwintering success. Based on the literature, it is my hypothesis that deciduous trees will correlate with higher fecundity, though greater parasitism and predation than evergreen hosts. I think that deciduous trees represent a better food source, though less hospitable overwintering site than evergreen hosts, meaning that while more fecund, there will be greater rates of predation and parasitization.

## Methods-

### *Bagworm collection-*

In early fall, trees were identified around the Purdue University campus, taking note of trees with bagworms present. Early fall is ideal since foliage is still present, making tree identification much easier. In early spring, the week of March 14, 2022, bags were collected from the trees scouted in the fall and any additional trees that could be identified. Early spring is ideal since the cold has passed, giving an accurate assessment for viable eggs in any eggs collected, but before leaves start to grow and obscure the bags.

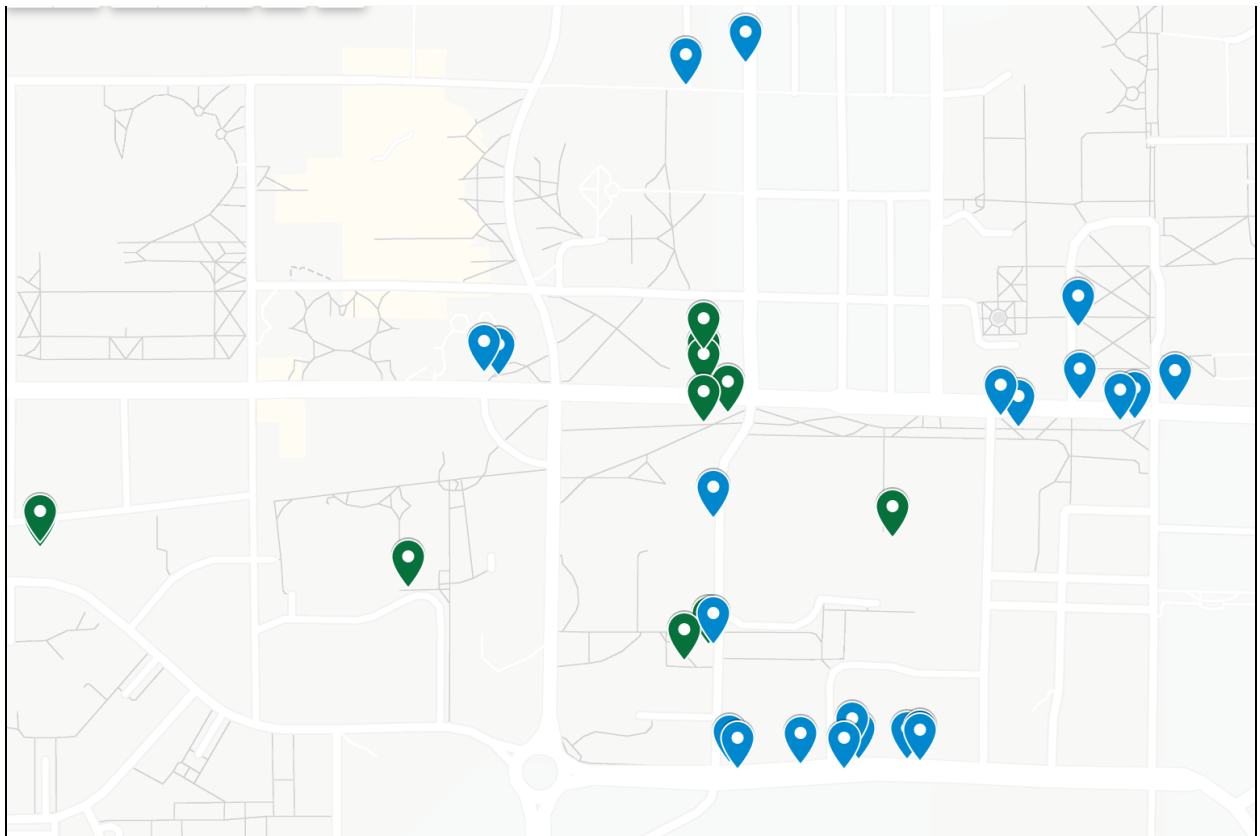
Collecting the bags was relatively simple, as a pair of pole pruners and twig pruners was sufficient. I simply collected as many bags per tree that I could see and reach, as some trees were too tall to collect all the bags. The bags were collected in a Ziploc™ (Bay City, MI) bag alongside a tag with a tree number, coordinates, and measurement of chest height circumference. Bags were stored in the fridge until dissection could be completed, about 1-3 weeks.

*Below is a list of the trees sampled*

Tree Type:	Number Sampled:
Sweetgum ( <i>Liquidambar</i> ; Altingiaceae)	4
American Sycamore ( <i>Platanus</i> ; Platanaceae)	4
Honey Locust ( <i>Gleditsia</i> ; Fabaceae)	1
Maple ( <i>Acer</i> ; Sapindaceae)	5
Oak ( <i>Quercus</i> ; Fagaceae)	1
Hackberry ( <i>Celtis</i> ; Cannabaceae)	1
Elm ( <i>Ulmus</i> ; Ulmaceae)	5

Crab Apple ( <i>Malus</i> ; Rosaceae)	1
Douglas Fir ( <i>Pseudotsuga</i> ; Pinaceae)	1
White Fir ( <i>Abies</i> ; Pinaceae)	1
Juniper ( <i>Juniperus</i> ; Cupressaceae)	2
Colorado Blue Spruce ( <i>Picea</i> ; Pinaceae)	3
White Pine ( <i>Pinus</i> ; Pinaceae)	4

Below is a Map of the sites:



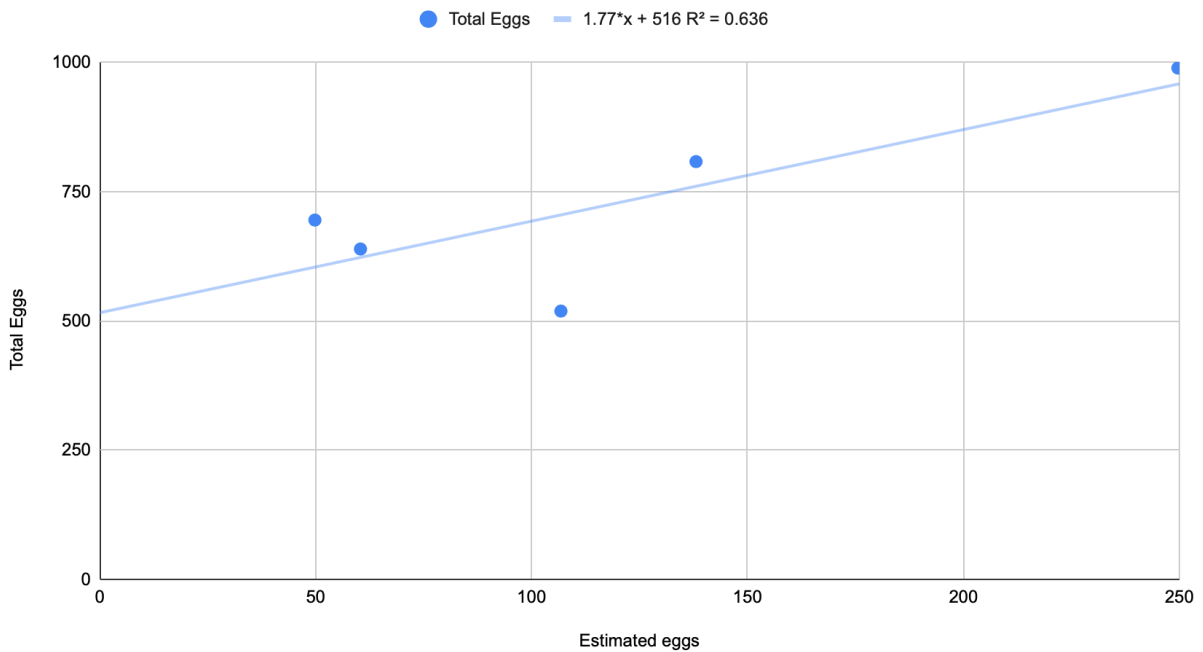
### *Assessing Bagworm Reproductive Capacity*

Once the bags were collected and opened up, sex was easily determined through characteristics of the pupa, if present. Female pupal cases lack any obvious appendages, more or less looking like the larva with a reduced head and no legs. Male pupae, if still in the bag (often due to parasitism) will have obvious wings and antenna developing, which is absent in the female. Past work has found a positive correlation between pupal volume and female fecundity,

regardless of plant genus. Pupal volume can reliably be estimated using length (a) and width (b) calculated with the volume equation of a prolate ellipsoid:  $v = \frac{2}{3} \pi a b^2$  (Rhains et al. 2008). Pupal cases were mostly empty, so the length and width were most reliably recorded, though any female pupal cases with live eggs were weighed and later used to count the eggs. Using female measurements taken in this survey, and past work done by Rhains et al. (2008), we can by proxy estimate a relative fecundity by comparing pupal volume/size. This relationship can be described using the two linear equations to discern weight (y) from volume (x) ( $y = -0.069 + 0.217X$ ), then weight(x) and number of eggs laid(y) ( $y = 2405x - 59x$ ).

The egg count included simply opening up the pupae and counting each of the eggs individually. The Rhains equation underestimated the amount of eggs per bag, but when compared to the true amount of eggs counted the  $R^2$  indicated the equation explained approximately 64% of the variation in fecundity.

Total Eggs vs. Estimated eggs



*Determining Bagworm Predation and Parasitism-*

Each bag was assessed for parasitization and predation before being dissected. Dissection would help confirm these assessments, as well as allow me to judge the sex of the caterpillar inside, if the pupal case was still present and intact, and make measurements. Parasitism is consistent with small ‘pinholes’ in the bag and pupae, alongside direct evidence like larva, dead

parasitoids, and pupa. Predation is consistent with large holes or even completely missing parts in the bag and pupa, though not reliably sampled due to predator habits which often remove bags from the trees.

**Results-**

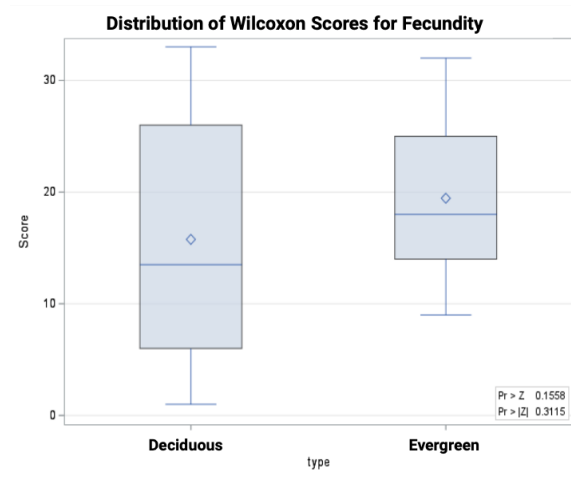
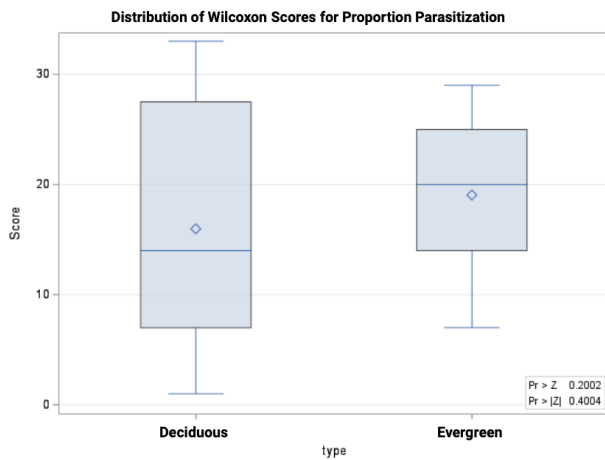
I used a Kruskal-Wallis One Way ANOVA to test two samples with different sample sizes, deciduous vs evergreen. The rates of parasitism were compared between tree types deciduous and evergreen, as well as fecundity. Using a statistics software, distribution plots were generated, shown below:

*Fecundity-*

Tree Type	Sample Size (n)	Mean (Number of predicted eggs)	Standard Deviation	Standard Error
<b>Deciduous</b>	22	84.23	56.20	11.98
<b>Evergreen</b>	11	92.69	43.09	12.99

*Proportion Parasitized-*

Tree Type	Sample Size (n)	Mean (Proportion Parasitized)	Standard Deviation	Standard Error
<b>Deciduous</b>	22	0.39	0.20	0.04
<b>Evergreen</b>	11	0.41	0.11	0.03



These results indicate no statistical difference in either fecundity or parasitism between the two tree types.

*Note-*

During dissection, many arthropods were found inhabiting the bags aside from the bagworms. Spiders, particularly jumping spiders, were the most abundant, though one interesting observation was the presence of elm flea weevil (*Orchestes steppensis*)(Korotyaev) inside 3 out of 5 of the elm tree Ziploc bags.

**Discussion-**

There were no clear differences observed between the deciduous and evergreen from the perspective of fecundity and parasitism. In the bagworm, growth rate can afford additional protection with the bag (Sugiura 2016), meaning that there is likely a relationship between growth rate, a bottom up factor, and predation, a top down factor. Parasitism is also shown to be density dependent (Barrows 1974, Cronin 1989, Rhains & Sadof, 2008ab), meaning that the variable to test for top down factors between host types would have been predation. This was difficult to survey for due to the predation habits which remove bags from the trees. More comprehensive experimental design can aid in making up for the limitations of the survey.

The results suggest that there is no difference between deciduous and evergreen hosts for both top down, parasitism, and bottom up factors, fecundity. This is not inconsistent with the literature, as there is no real consensus for fecundity and parasitism being largely density dependent. While one would expect a slight nutritional superiority for deciduous trees, though that was largely true for larva (Ward et al. 1989, Neal & Santamour, 1990), but the study that looked at fecundity only didn't find a strong superiority for the deciduous host tested (Moore and Hanks 2004). As for the lack of difference for parasitism, this is likely explained due to the dependence of parasitism on density (Barrows 1974, Cronin 1989, Rhains & Sadof, 2008ab).

Predation would have been a better variable to test, but due to the nature of the sampling and predation habits, it is difficult to survey for (Moore & Hanks 2000, Berisford & Tsao 1975). Anecdotally, it could be that deciduous hosts, particularly those with dense or particularly prickly needles offer protection against predation, as while collecting the bags it was difficult to collect bags on the spruce trees. Given that deciduous trees leave the bags unprotected from both being seen and grabbed, it could be that evergreen are superior overwintering sites, but without knowing the amount of bags before and after winter, that would be hard to test from the data I collected. A study where bags are put onto evergreens of various foliage conditions, like no



needles (bald cypress, defoliated evergreen), soft needle (white pine, arborvitae), and hard needles (spruce, Austrian pine), could test this hypothesis between needle camouflage and physical protection.

Worth noting is the observation of bags as overwintering sites for other arthropods. Spiders were consistently in each Ziploc containing a tree's bagworms, alongside mites, beetles, and exuvia of various arthropods. One particularly interesting observation was the presence of elm flea weevil (*Orchestes steppensis*) (Korotyaev) in several, 3 of 5, of the ziplock bags containing bagworms collected from elm trees. This is interesting considering work done in the past had trouble figuring out where to treat the overwintering adults (Is there a citation for the work you mentioned).

The survey limits the amount of testable variables, particularly when dealing with larval mortality, as only pupae are counted. A summer long observational study assessing the condition of growing larva is one way to better test bottom up factors like nutrition. A manipulative study putting live female bags on various trees, like with the evergreens of various foliage, or just evergreen vs deciduous in general, can identify a more clear relationship between tree type and predation. While a survey was sufficient for the scope of this capstone project, further work would need to fully explore the ecology of the evergreen bagworm, especially given the lack of research present in the literature.

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