Short Communication

Arthropod Community in Hybrid Hazelnut Plantings in the Midwestern United States

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Abstract

There is a lack of knowledge of the arthropod communities in both wild hazelnut and cultivated hybrid hazelnut ecosystems in the Midwestern United States. Our goal was to characterize the composition of these arthropod communities in hazelnut plantings. We surveyed six experimental plantings of hazelnuts in Wisconsin and two in Minnesota during growing seasons, from May 2017 to August 2021. We used four methods to survey the arthropod community of these plantings: ad libitum survey of specimen observations and collection, dissection of hazelnut buds and nuts, cone traps placed on the ground, and beat sheet sampling of plants. We registered 116 different morphospecies of five classes and 83 families. Arthropods with known feeding habits were grouped into four guilds: 59 herbivores, 36 carnivores (predators, parasites, and parasitoids), 4 decomposers (detritivores and scavengers), and 4 omnivores. While we registered 12 herbivorous species that could potentially cause damage to hazelnuts, we directly observed nine of them feeding upon or damaging plant parts: Phytoptus avellanae s.l. Nalepa (Eriophyoidea: Phytoptidae), Curculio obtusus Blanchard and Strophosoma melanogrammum Förster (Coleoptera: Curculionidae), Popillia japonica Newman (Coleoptera: Scarabaeidae), Parthenolecanium sp. (Hemiptera: Coccidae), Euschistus servus euschistoides Say (Hemiptera: Pentatomidae), aphids (Hemiptera: Aphididae), Acleris sp., and Choristoneura rosaceana Harris (Lepidoptera: Tortricidae). We also registered eight species of parasites or parasitoids that could offer biocontrol services in the cropping system. These findings provide a foundation for future targeted studies on potential pests and beneficial arthropods, as well as ecological interactions within the hybrid hazelnut ecosystem in the Midwest.

Resumen

Hay una falta de información sobre las comunidades de artrópodos tanto en ecosistemas naturales como en cultivos de avellanas en la región Medio Occidental de los Estados Unidos. Nuestro objetivo fue caracterizar la composición de estas comunidades de artrópodos en plantaciones experimentales de avellanas. Muestreamos en seis plantaciones en Wisconsin y dos en Minnesota, durante el periodo de crecimiento de las plantas, desde mayo del 2017 a agosto del 2021. Usamos cuatro métodos de muestreo: relevamiento ad libitum de especímenes, disección de yemas de avellanas y nueces, trampas cono para gorgojos ubicadas sobre el suelo, y técnica del paño. Registramos 116 morfoespecies, de cinco clases y 83 familias. Las morfoespecies con hábitos alimentarios conocidos fueron agrupadas en 4 grupos: 59 morfoespecies de herbívoros, 36 de carnívoros (predadores, parásitos y parasitoides), 4 de descomponedores (detritívoros y carroñeros) y 4 de omnívoros. Si bien identificamos 12 especies que podrían causar daño a las avellanas, sólo observamos nueve especies alimentándose de o dañando plantas de avellanas: Phytoptus avellanae s.l. Nalepa (Eriophyoidea: Phytoptidae), Curculio obtusus Blanchard y Strophosoma melanogrammum Förster (Coleoptera: Curculionidae), Popillia japonica Newman (Coleoptera: Scarabaeidae), cochinillas Parthenolecanium sp. (Hemiptera: Coccidae), Euschistus servus euschistoides Say (Hemiptera: Pentatomidae), pulgones (Hemiptera: Aphididae), Acleris sp. y Choristoneura rosaceana Harris (Lepidoptera: Tortricidae). Registramos ocho especies de parásitos y parasitoides que podrían ser agentes de control biológico en estos ecosistemas.
Hazel plants (*Corylus avellana* Linnaeus) (Fagales: Betulaceae) are trees whose nuts have been prehistorically a source of food for humans (Holst 2010). They have been cultivated in Eurasia for hundreds of years. In the United States, the European hazelnut is mainly cultivated in the Pacific Northwestern (PNW) states of Oregon and Washington. About 99% of the hazelnut crop in the United States is produced in Oregon, setting this country in fourth place with about 5% of the world crop (Mehlenbacher and Olsen 1997, Oregon Department of Agriculture 2021). In the Midwestern region of the United States, the climatic conditions and presence of disease, like the Eastern Filbert Blight, are not suitable for the introduction of hazelnut plantings. In the Eastern and Midwest states, there is a growing initiative to develop hybrid hazelnuts (*C. avellana × C. americana* or *C. avellana × C. cornuta* Marshall). In the Eastern and Midwest states, there are two native *Corylus* species to this region, the American hazelnut (*Corylus americana* Marshall) and the beaked hazelnut (*Corylus cornuta* Marshall). In the Eastern and Midwest states, there is a growing initiative to develop hybrid hazelnuts (*C. avellana × C. americana* or *C. avellana × C. cornuta*) that combine the disease resistance and cold hardiness of the native species with yield and processing characteristics of nuts of *C. avellana* for production in these regions. The global demand for hazelnuts is rising, both for fresh eating and for oil because the nuts are high in vitamins and oil content (Molnar et al. 2005, Braun and Jensen 2015, Braun et al. 2019).

Like in other cropping systems, there is a diverse suite of arthropods associated with *Corylus* spp. Descriptions of arthropod communities associated with hazelnut ecosystems, including harmful pests, are mostly from plantings of European hazelnuts in the Eastern Hemisphere (Villaronga and Garcia-Mari 1988, Trevilla et al. 1997, Snare 2006) and the PNW region in the United States (AliNiazee 1980,1998; Brenner 1986; Walton et al. 2007, 2009; Wiman and Bell 2021). According to AliNiazee (1998), there are 280 species of insects and mites associated with hazelnuts plantings in Turkey, with approximately 150 species feeding on hazelnut plants, but only 47 species cause most of the damage. In the United States, AliNiazee (1998) identified about 150 species of insects and mites in hazelnut ecosystems in the PNW, with approximately half of those species being beneficial. AliNiazee (1980), Snare (2006), Walton et al. (2007, 2009), and Wiman and Bell (2021) mention 27 species of arthropods that cause damage to hazelnut cultivars in Oregon and Washington spanning both specialist and generalist feeding habits.

Arthropods associated with hazelnut plantings have never been surveyed in the Eastern or Midwest regions of the United States. Little is known about arthropod communities associated with native beaked hazelnut or American hazelnut other than the hazelnut weevil (*Curculio obtusus* Blanchard) (Coleoptera: Curculionidae) (Treadwell 1996). Our goal was to characterize the composition of arthropod communities present in hazelnut experimental plantings in the Upper Midwestern United States. Knowledge of potential arthropod pests and beneficial natural enemies is a crucial first step in ecological research needed to create pest management recommendations, should they become required.

### Methods

We surveyed arthropods in eight hybrid hazelnut research plantings throughout the Upper Midwestern United States, six in Wisconsin: Bayfield, Ashland, Hayward, Spooner, Tomahawk, and Stoughton; and two in Minnesota: Rosemount and Saint Paul (Table 1). In each of these locations, there are trials of hybrid hazelnut genotypes. Plantings’ ages varied from 12 yr to a few months; the latter where new plants were installed within the primary plantings. The weed control methods used varied among plantings (Table 1). No insecticide was used in any plantings.

We used four methods of arthropod sampling (with some variability across sites, described below): 1) ad libitum survey by species collection and visual observations while working in the field throughout each growing season at all locations (both on hazelnut plants and other vegetation within the plantings); 2) collection and dissection of hazelnut buds and nuts, both during the growing period and after harvest, at all locations; 3) four metal mesh cone entrapments; and 4) four metal mesh cone entrapments.

### Table 1. Location and characteristics of each experimental hybrid and American hazelnut planting in the Upper Midwest of the United States

| Planting    | State       | Coordinates               | Size (ha) | Year planted | Weed control                                                                 |
|-------------|-------------|---------------------------|-----------|--------------|-------------------------------------------------------------------------------|
| Ashland     | Wisconsin   | 46°35′04″N, 90°57′56″W    | 0.19      | 2012         | Herbicide in early spring, weed-whipping and hand weeding as needed, and one mowing in late summer. |
| Bayfield    | Wisconsin   | 46°50′19″N, 90°50′02″W    | 1.53      | 2009         | Herbicide in early spring, weed-whipping and hand weeding as needed, and one mowing in late summer. |
| Hayward     | Wisconsin   | 45°59′47″N, 91°30′26″W    | 0.83      | 2014         | Herbicide in early spring, weed-whipping and hand weeding as needed, and two mowing or three times per season. |
| Spooner     | Wisconsin   | 45°49′22″N, 91°52′05″W    | 0.36      | 2011         | Herbicide in early spring, weed-whipping and hand weeding as needed, and mowing two or three times per season. |
| Stoughton   | Wisconsin   | 42°56′37″N, 89°09′41″W    | 0.35      | 2011         | Mowing once or twice per season. |
| Tomahawk    | Wisconsin   | 45°30′23″N, 89°32′59″W    | 0.21      | 2012         | Weed whipping once in late summer. |
| Rosemount   | Minnesota   | 44°43′36″N, 93°05′59″W    | 0.18      | 2011-2013    | Weed whipping and mowing as needed |
| Saint Paul  | Minnesota   | 44°59′53″N, 93°10′30″W    | 0.68      | 2009         | Weed whipping and mowing as needed |
weevil traps placed on the ground, each one under a different hazelnut plant in Bayfield only in 2019 and 2020, checked weekly with all arthropod specimens collected (Treadwell 1996 and Mulder et al. 2012); 4) beat sheet sampling done weekly from May to July of 2020 and 2021 in both Minnesota locations via beating 12 random hazel plants with a stick 10 times over a one square meter white canvas. Across all methods, the Bayfield planting was the most visited and intensely sampled planting in Wisconsin.

For Wisconsin locations, arthropods were collected or observed for 5 yr, from May to October 2017 to 2020, and May to July in 2021. Specimens were collected into sealable plastic bags or 7 ml plastic vials and stored in a refrigerator at ~4°C or in 70% isopropyl alcohol. Specimens representing new records for the state of Wisconsin were deposited in the Wisconsin Insect Research Collection. Specimens were identified to species level when possible. Some specimens, such as larvae, were identified to family or genus level based on the availability of taxonomic keys for those groups (MacKay 1962; McAlpine 1981, 1987; Vickery and Kevan 1986; Stehr 1987, 1991; Anderson and Howden 1994; Arnett and Thomas 2001, 2002; Wagner et al. 2001; Johnson and Triplehorn 2004; Wagner 2005; Packer et al. 2007; Bright and Bouchard 2008; Paiero et al. 2013; Hoebeke and Sprichier 2016; Whitehead et al. 2018).

For Minnesota locations, arthropods were observed or collected from April to August of 2020 and 2021. All weevils were collected into sealable plastic bags and frozen until they could be identified to species. Buprestid specimens were identified to genus by Patrick Perish (University of Minnesota). All other arthropods were identified by HNS and confirmed by uploading photographs to iNaturalist (www.inaturalist.org).

We organized all specimens or morphospecies into four guilds according to their feeding habits: carnivores (natural enemies such as predators, parasites and parasitoids), decomposers (detritivores and scavengers), herbivores, and omnivores. In the cases where the juveniles are carnivorous, but the adults are herbivorous, we placed the arthropod into the carnivore guild. When we could not identify the species, or the taxa has a wide spectrum of feeding habits, we elected not to assign a guild. We did not include ticks, some spiders, adult Lepidoptera, or common species of Diptera unless of natural enemy importance, such as syrphid flies.

Results

We recorded 116 morphospecies of 83 families, 18 orders, and five classes. One superfamily (Chalcidoidea; Hymenoptera), was included in our tally, as well as two of Odontata and Trichoptera that were not identified to family level. Of the 116 morphospecies, only 75 of them were identified to species or genera (Table 2). For the four guilds, we recorded 59 morphospecies of arthropods that are considered herbivores, 36 carnivores, 4 omnivores, and 4 decomposers.

Eight species of herbivores, C. obtusus, Phytoptus avellanae s.l. Nalepa (Eriophyoidea: Phytoptidae), Agrilus spp. (Coleoptera: Buprestidae), Strophosoma melanogrammum Förster (Coleoptera: Curculionidae), Popillia japonica Newman (Coleoptera: Scarabaeidae), Euschistus servus Say (Hemiptera: Pentatomidae), Parthenolecanium sp. (Hemiptera: Coccidae), and aphids (Hemiptera: Aphididae) were observed feeding on various parts of the hazelnut plants. Aderis sp. (Lepidoptera: Tortricidae) and Choristoneura rosaceana Harris (Lepidoptera: Tortricidae) larvae were collected from rolled hazel leaves on the plant. Larvae of two species of tent caterpillars (Malacosoma disstria Hübner and M. americanum Fabricius) (Lepidoptera: Lasiocampidae) and sawfly larvae (Craesus sp., (Lepidoptera: Tenthredinidae) were observed on hazelnut leaves with signs of herbivory; however, we did not directly see these larvae feeding on the plants. In 2017, we collected the first record of S. melanogrammum for Wisconsin.

Among the carnivores, we identified eight species of spiders, and eight parasites and parasitoids. We found two natural enemies inside galls formed by P. avellanae: a predatory mite (Mesostigmata: Phytoseiidae) and a tube-tailed thrips (Thysanoptera: Thripidae). We also found a tachinid fly larva (Diptera: Tachinidae) inside a slug moth caterpillar (Lathicidae sp.) (Lepidoptera: Limacodidae) and a mummy wasp, Aleiodes sp. (Braconidae: Hymenoptera), parasitizing an unidentified caterpillar.

Discussion

Hazelnut planting ecosystems in the Midwestern United States have a richness of species close to that described by AliNiazee (1998) for the PNW, with about half of the species known as, or with the potential, to be beneficial arthropod species. Of the two species of filbert bud mites (Eriophyoidae) reported causing bud galls in hazelnuts, only P. avellanae was present in our eight plantings. This mite is an exotic species, that arrived in the United States most likely from the introduction of European hazelnut cultivars (Ourecky and Slate 1969). Other pest arthropods reported by AliNiazee (1980, 1998), Treadwell (1996), Snare (2006), Walton et al. (2007), and Wiman and Bell (2021) present in our hazelnut plantings are C. rosaceana, Parthenolecanium sp. scales, M. disstria and C. obtusus. This latter mentioned species is the only one found inside the hazelnut shell feeding on the kernel. Except for P. avellanae and C. obtusus, none of the other herbivorous species or morphospecies observed were seen in quantities that sparked concern of economically damaging levels. The Japanese beetle (P. japonica), present in Minnesota and Wisconsin, was abundant, although it is not known to what extent it may cause damage of economic consequence to hazelnut.

Strophosoma melanogrammum and Otiorynchus ovatus Linnaeus (Coleoptera: Curculionidae) are two introduced and invasive species from Europe observed and collected in abundance in Bayfield. Based on reports from Alford (2014), Nielsen et al. (2004), and Urban (1999), S. melanogrammum is considered a pest on oaks, hazels, and greenery plantations in Europe as it feeds on hazelnut vegetative and floral buds, among other vegetative parts. Strophosoma melanogrammum is a parthenogenetic species that may have the potential to become a pest to hazelnut plantings in the Midwestern region. This species was only recorded in Bayfield. We do not know how or when it arrived at the area.

Natural enemies found in Oregon hazelnut orchards that we also observed in our plantings included one species of Chrysopidae, Forficula auricularia Linnaeus (Dermaptera: Forficulidae), ladybird beetles (Coleoptera: Coccinellidae), and syrphid flies (Diptera: Syrphidae) (Walton et al. 2009). We also noted several species of ground beetles (Coleoptera: Carabidae) and spiders. Collectively, none of these natural enemies likely have large impacts on hazelnut pests such as C. obtusus. The two predatory morphospecies we detected inside the galls formed by P. avellanae, a predatory mite and a tube tailed thrips, may be natural enemies of the harmful filbert bud mites and warrant future studies. Other important beneficial morphospecies recorded were tachinid flies and two families of parasitoid wasps, Braconidae and Ichneumonidae, that were quite abundant. Some species found were beneficial for reasons other than biological control of hazelnut pests, such as Larinus obtusus Gyllenhal (Coleoptera: Curculionidae). The latter insect aids in the control of the spotted knapweed (Centaurea stoebe Linnaeus).
Table 2. Arthropods observed and collected in hybrid hazelnut experimental plantings in six Wisconsin locations (A=Ashland, B=Bayfield, H=Hayward, S=Spooner, St=Stoughton, T=Tomahawk), and two in Minnesota (R=Rosemount, and SP=Saint Paul). Feeding habits (D=detritivore, H=herbivore, Pr=predator, Ps=parasite or parasitoid, O=omnivore, S=scavenger) separated by commas include habits of different spp. within the group, separated by hyphen are habit of immature vs adult individual within the species.

| Class          | Order       | Family         | Scientific name                  | Common name                  | Feeding habits | Location       | Life Stage                  |
|----------------|-------------|----------------|----------------------------------|------------------------------|----------------|-----------------|-----------------------------|
| Arachnida      | Eriophyoidea| Phytoptidae    | *Phytoptus avellanae s.l.* (Nalepa) | Filbert bud mite            | H              | A, B, H, S, T, R, SP | Immature and adult          |
| Mesostigmata   | Phytoseiida  | Araneidae      | *Araneus trifolium* (Hentz)       | Shamrock orbweaver           | Pr             | B               | Adult                      |
| Araneae        | Phytoseiida  | Araneidae      | *Argiope sp.*                     | Yellow garden spider         | Pr             | B, S            | Adult                      |
| Araneae        | Phytoseiida  | Araneidae      | *Argiope annanta* (Lucas)         | Whitebacked garden spider    | Pr             | S               | Adult                      |
| Araneae        | Mesostigmata | Mesostigmata   | *Thanatus sp.*                    |                              | Pr             | B               | Adult                      |
| Salticidae     | *Dendryphantina* sp. | Salticidae | *Phidippus sp.*                  | Bold jumper spider           | Pr             | R, SP           | Adult                      |
| Thomisidae     | Mesostigmata | Mesostigmata   | *Meconema sp.*                   | Crab spiders                 | Pr             | S               | Adult                      |
|               | Entomobryomorpha | Entomobryidae | *Biresia caudata* urina* (Fabricius) | Spring tail                 | D, Pr           | B               | Adult                      |
| Insecta        | Coleoptera   | Buprestidae    | *Agrilus spp.*                   | Jewel beetles                | H              | R, SP           | Adult                      |
| Diplopora      | Polyxenida   | Polyxenidae    |                                | Bristle millipedes           | D, Pr           | B               | Adult                      |
| Carabidae      | *Harpalus sp.*| *Anomoa latexata* (Forster) | Claycolored leaf beetle         | H                            | T               | Adult                      |
| Chrysomelidae  | *Diachus annatus* (Fabricius) | *Pachybrachis sp.* | Bronze leaf beetle               | H                            | B               | Adult                      |
| Chrysomelidae  | *Trichocoma sp.* | *Trichocoma sp.* | *Chrysomelidae*                  | Scriptured leaf beetle       | H                            | B                           |
| Coccinellidae  | *Braconica arbusta* (Fabricius) | *Braconica septemonticata* (Linnaeus) | Weevil                       | Pr                            | SP                          |
| Coccinellidae  | *Braconica sp.* | *Braconica sp.* | *Coccinella coturnix* (Linnaeus) | Sevenspotted lady beetle     | Pr                            | B                           |
| Leptinidae     | *Hypena sp.* | *Anomoa latexata* (Forster) | Claycolored leaf beetle         | H                            | R               | Adult                      |
| Curculionidae  | *Barphetes pellucidus* (Bohemian) | *Laterna carinata* (Schoenherr) | Imported long-horned weevil    | H                            | R                           | Adult                      |
| Curculionidae  | *Laterna obtusata* (Blanchard) | *Laterna obtusata* (Schoenherr) | Canada thistle bud weevil       | H                            | R, S             | Adult                      |
| Lixus conicus  | *Lixus conicus* (Suy) | *Lixus conicus* (Schoenherr) | Canada thistle bud weevil       | H                            | B, H             | Adult                      |
| Olotrochystus otusius  | *Olotrochystus otusius* (Linnaeus) | *Phyllobius oblongus* (Linnaeus) | Strawberry root weevil        | H                            | R               | Adult                      |
| Phyllobius oblongus | *Phyllobius oblongus* (Linnaeus) | *Phyllobius oblongus* (Linnaeus) | European snout weevil         | H                            | B               | Adult                      |
| Polydrusus formosus  | *Polydrusus formosus* (Mayer) | *Polydrusus formosus* (Mayer) | Green immigrant leaf weevil    | H                            | B, H, R, SP, T | Adult                      |


| Class       | Order            | Family   | Scientific name                                      | Common name                        | Feeding habits | Location | Life Stage |
|------------|------------------|----------|------------------------------------------------------|------------------------------------|----------------|----------|------------|
|            |                  |          | *Polydrusus impressifrons* (Gyllenhall)               | Pale green weevil or leaf weevil   | H              | R, SP    | Adult      |
|            |                  |          | *Romualdis scaber* (Linnaeus)                        | Crusted root weevil                | H              | B        | Adult      |
|            |                  |          | *Systobosma melanogramma* (Forster)                  | Nut leaf weevil                    | H              | B        | Adult      |
| Elaterida  |                  |          | *Tychus sp.*                                          | Alfalfa weevil                     | H              | B        | Adult      |
|            |                  |          | *Aeolus sp.*                                          | Click beetle                       | H              | B        | Adult      |
|            |                  |          | *Melanotus spp.*                                      | Click beetle                       | H              | B        | Adult      |
| Lampyridae |                  |          | *Photinus sp.*                                         | Firefly                            | Pr             | B        | Adult      |
|            |                  |          | *Corticaria sp.*                                      | Minute brown scavenger beetle      | S              | B        | Adult      |
| Latridiida |                  |          | *Calopetron reticulatum* (Fabricius)                 | Banded net-wing beetle             | Pr-H           | B        | Adult      |
|            |                  |          | *Typhaea stercorea* (Linnaeus)                        | Hairy fungus beetle                | B              |          |            |
|            |                  |          | *Phalacrisidae*                                       | Shining flower beetle              | H              | B        | Adult      |
|            |                  |          | *Ptinidae*                                             | Primit or Anobiid beetle           | H, O, S        | B        | Adult      |
| Scarabeida |                  |          | *Popelis japonica* (Newman)                          | Japanese beetle                    | H              | R, SP    | St         |
|            |                  |          | *Isomera sp.*                                          | Comb-clawed beetle                 | S              | B        | Adult      |
|            |                  |          | *Forficula auricularia* (Linnaeus)                    | European earwig                    | O              | B, S     | Adult      |
| Hemiptera  |                  |          | *Alydus sp.*                                           | Broad headed bug                   | H, S           | B, S     | Adult      |
|            |                  |          | *Alyrdae*                                              | Broad headed bug                   | H, S           | B, S     | Adult      |
|            |                  |          | *Aphidae*                                              | Aphids                             | H              | B        | Immature and adult |
|            |                  |          | *Caliscelidae*                                         | Piglet bug                         | H              | B        | Adult      |
|            |                  |          | *Cercopidae*                                           | Spittle bug                        | H              | B        | Immature and adult |
| Class          | Order       | Family                   | Scientific name | Common name       | Feeding habits | Location          | Life Stage       |
|---------------|-------------|--------------------------|-----------------|-------------------|----------------|--------------------|------------------|
|               |             | Cicadellidae             | Parthenolecanium sp. | Leafhopper        | H              | B                  | Adult            |
|               |             | Coccidae                 | Lecanium scales   | Leafflower        | H              | B, H, S            | All stages       |
|               |             | Dictyopharidae           | Planthopper       | Planthopper       | H              | B                  | Adult            |
|               |             | Lygaeidae                | Milkweed bug      | Milkweed bug      | H              | B                  | Immature         |
|               |             | Pentatomidae             | Euschistus servus| Brown stink bug   | H              | B, S, A, SP        | Immature and adult|
|               |             |                         | euschistodes (Say) |                  |                |                    |                  |
|               |             |                         | Euschistus tritigm| Dusky stink bug  | H              | SP                 |                  |
|               |             |                         | us (Say)          |                   |                |                    |                  |
|               |             |                         | Podisus maculiventris| Spined soldier bug | H              | SP                 | Adult            |
|               |             | Reduviidae (Lateille)    | Slaterohiis insignis (Uhler) | Dirt-colored seed bug | H              | B                  | Adult            |
| Hymenoptera   |             | Andrenidae               | Mining bees      | Mining bees      | H              | B                  | Adult            |
|               |             | Apidae                   | Apid bees        | Apid bees        | H              | B, S               | Adult            |
|               |             | Braconidae               | Parasitoid wasp  | Parasitoid wasp  | Ps             | B                  | Adult and mass of cocoons |
|               |             |                         | Ps. B Adult      |                  |                |                    |                  |
|               |             | Superfam:                | Aleiodes sp.     | Mummy-wasp       | Ps             | H, S               | Paraisotid in a caterpillar |
|               |             | Chalcidoidea             | Crabronid wasp   | Crabronid wasp   | Pr             | B                  | Adult            |
|               |             | Crabronidae (Latreille)  |                 |                  |                |                    |                  |
|               |             | Eupelmidae               | Chalcid wasp     | Chalcid wasp     | Ps             | B                  | Adult            |
|               |             | Formicidae (Santschi)    | Field ants       | Field ants       | Pr             | B, S               | Adult            |
|               |             | Hylaeidae                | Formica sp.      | Pavement ant     | O              | B                  | Adult            |
|               |             |                              | Lasioglossum sp. |                  |                |                    |                  |
|               |             | Ichneumonidae             | Sphecodes sp.    | Cuckoo bee       | Ps-H            | B                  | Adult            |
|               |             | Megachilidae             | Lasius sp.       | Sweat bee        | H              | B                  | Adult            |
|               |             | Pompilidae (Lateille)    | Osmia sp.        | Mason bee        | H              | B                  | Adult            |
|               |             | Tenthrediniida           | Craesus sp.      | Sawfly           | H              | R, S               | Immature         |
| Lepidoptera   |             | Sphiceida                | Threaded-waist wasp | PS-H             | B              | Adult             |
|               |             | Vespidae                 | Polistes sp.     | Paper wasp       | Pr-H            | S                  | Nest and adult   |
|               |             | Coleophoridae            | Casebearer        | Pale or banded tussock moth | H | B, S, SP | Cocoon |
|               |             | Erebididae               | Hylidsota tessellaris (J. E. Smith) |                  |                |                    |                  |
|               |             | Geometridae              | Lymantria dispar (Linnaeus) | Gypsy moth     | H              | B                  | Immature         |
|               |             | Lasiocampidae            | Enamis tiliares (Harris) | Linden looper caterpillar | H | S | Immature |
|               |             | Limacodidae              | Malacosoma americanum (Fabricius) | Eastern tent caterpillar | H | T | Immature |
|               |             |                              | Malacosoma disstria (Hubner) | Forest tent caterpillar | H | B, S | Immature |
|               |             |                              | Lithacodes sp. | Yellow-shouldeered slug moth | H | S | Immature |

Table 2. Continued
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| Class | Order | Family | Scientific name | Common name | Feeding habits | Location | Life Stage |
|-------|-------|--------|-----------------|-------------|---------------|----------|------------|
| Noctuidae | | | Schizura unicornis (J.E. Smith) | Unicorn moth | H | B | Immature |
| Notodontidae | | | Danaus plexippus (Linnaeus) | Monarch | H | B, H | Adult |
| Psychidae | | | Psycha casta (Pallas) | Bagworm | H | B | Adult and cocoons |
| Saturniidae | | | Antheraea polyphemus (Cramer) | Polyphemus moth | H | B, R, S, SP | Immature, cocoon, and adult |
| | | | Hydophora cecropia (Linnaeus) | Cecropia moth or giant silk moth | H | H, S | Immature |
| Sphingidae | | | Poxus excaciata (J.E. Smith) | Blind sphinx moth | H | B, H, S | Immature |
| Tortricidae | | | Adelis sp. | Leafroller | H | B | Immature |
| | | | Obstronomyrosaceana (Harnis) | Oblique banded leafroller | H | B | Immature and adult |
| Neuroptera | | | Chrysopidae | Green lacewing | Pr | B | Adult |
| | | | Mantispidae | Brown mantid fly | Pr | R | Adult |
| | | | Odonata | Dragonflies | Pr | A, B, H, S | Adult |
| | | | Orthoptera | Two-striped grasshopper | H | A, B, S | Immature and adult |
| | | | Acrididae | Slanted faced grasshopper | H | B | Immature |
| Phasmatodea | | | Diapheromera femorata (Say) | Northern walkingstick | H | S | Adult |
| | | | Diapheromera femorata | Slanted faced grasshopper | H | B | Immature |
| | | | Tubetailed thrips | Pr | B | Adult, in hazelnut bud infested with filbert bud mites |
| Trichoptera | | | Phlaeothripidae | Caddisfly | B | Adult |
| Malacostraca | | | Isopoda | Sowbugs | D | B | Adult |
(Asterales: Asteraeaceae) (Panke et al. 2012, WSU 2021), which is an introduced aggressive invasive plant species. Many other species found that were either assigned a decomposer guild or not assigned a guild could provide other essential services to the hazelnut ecosystem such as carbon cycling and serving as alternative food sources for natural enemies.

This base line list of species or morphospecies present in hybrid hazelnut plantings in the Upper Midwest provides a foundation for future research on possible pests, beneficial arthropods, and ecological interactions which are needed to understand the complexity of these ecosystems, and to develop pest management plans for this novel crop.

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