The Insect Abundance and Diversity of Native, Invasive, and Agricultural Cover Crop Plots in Hilltop Hanover Farm and Environmental Education Center

by

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Abstract

Hilltop Hanover Farm and Environmental Center is a working farm and environmental educational center located in Yorktown Heights, NY. Native Mountain Mint, Native Swamp Milkweed, Native Monarda, Agricultural Cover Crop, and Invasive Mugwort sites were studied to measure diversity and abundance of insects. There were three plots in this study including the native plot (Mountain Mint, Swamp Milkweed, Monarda), invasive plot (Mugwort), and the cover crop plot. Insect surveying included visual search and sweep net methods. The most flower-visiting insects were observed on the native plants compared to Agricultural Cover Crop and Invasive Mugwort. There were 108 more flower-visiting insect observations on the native plants. The number of flower-visiting insect observations was lowest in August, and highest in July. There were 90 more flower-visiting insect observations in July than in August. I ran a post hoc Tukey's HSD test and found that there was a significant difference between the richness of the dates August-June when sites were pooled ($P = 0.036$). I ran a post hoc Tukey's HSD test and found that there was a significant difference between both richness and shannon diversity of the native-invasive plots when all dates were pooled (richness p-value= 0.0414, shannon diversity p-value=0.0372). The results highlight that the native plot on Hilltop Hanover farm was successful in supporting large flower-visiting insects, and a diverse insect population. The findings of this study are important because agricultural intensification and invasive plant species are significant causes of insect decline. It is important that land management groups prioritize the addition of native plots on farms.

Introduction

The urbanization of landscapes has a negative impact on biodiversity by increasing habitat loss and fragmentation of natural areas (Corcos et al., 2019). One of the added challenges of urbanization is the intensification of agriculture needed to support populations. Agriculture causes a decrease in global biodiversity because it leads to habitat loss (Montañez and Amarillo, 2014). Globally, agricultural intensification and habitat loss are the most significant causes of insect decline. Greater than 50% of land on the globe is agricultural, so it is important that farming practices incorporate sustainable habitats for insects (Busse et al., 2021).

Organic farming is an option that can increase insect populations and biodiversity (Mazed et. al, 2021). Beneficial pollinator diversity increases because of the higher abundance of flowering plants in organic farms. Organic farming increases biodiversity because pesticides and agro-chemicals are not used. The use of agro-chemicals in conventional farming can have negative effects on nontarget organisms, so the limited use of such agrochemicals in organic farming may contribute to higher insect diversity (Rundlöf et al., 2016). A combination of organic farming and an increase in floral resources benefits flower-visiting insect populations (Bengtsson et al., 2005). Organic farming has the potential to increase insect abundance and diversity (Samways et al., 2020).

Native insect diversity and abundance may change if the insects are unable to use invasive plants. Invasive plants impact insect populations because many species use specific plants for food and reproduction (Litt et al., 2014). Invasive plants impact insect resources, and larval development which leads to a decreased population (Cardoso et al., 2020). Native insects and native plants have an important ecological relationship. Native plants are a food source and habitat for insects, and insects are a food source for birds (Kawahara et al., 2021). Native flowering plants help sustain beneficial insects in agriculture such as pollinators, predators, and parasitoids (Isaacs et al., 2009). Insects can benefit from initiatives that conserve and restore native plants (Litt et al., 2014).

Hilltop Hanover Farm and Environmental Center is a working farm and environmental educational center located in Yorktown Heights, NY. Since Hilltop Hanover is an organic farm, it does not use toxic chemical pesticides and synthetic fertilizers. Flowering cover crops is a conservation practice that is valuable for flower-visiting insects such as wild bees (Cover cropping for pollinators and beneficial insects, 2021). The Agricultural Cover Crops studied on the farm included Clovers and Buckwheat. Hilltop Hanover Farm has a native plant nursery to help protect biodiversity and natural habitats. The three native plants studied on Hilltop Hanover Farm were *Asclepias incarnata* (Swamp Milkweed), *Pycnanthemum virginianum* (Virginia Mountain Mint), and *Monarda fistulosa* (Wild Bergamot). Invasive plant species present on the farm are normally removed, but there was a plot of *Artemisia vulgaris* (Mugwort) preserved for this study. The data collected from the Native Plants, Invasive Plants, and Cover Crop were compared to see if there is a difference in diversity and abundance of insects within study sites, plots, and dates. The hypothesis of the study was that diversity and abundance will be highest within the native plants and the month of peak bloom.

Materials and Methods

Native Mountain Mint, Native Swamp Milkweed, Native Monarda, Invasive Mugwort, and Agricultural Cover Crop sites were surveyed to compare diversity and abundance of insects (Figure 1). The insect survey was performed once in June 29, July 27, and August 31. There were two methods used to record and collect insects on the farm. Method 1 was a visual search to record larger flower-visiting insects such as Lepidoptera and Hymenoptera. Method 2 required a sweep net to collect the smaller insects that were more difficult to identify by sight such as Coleoptera and Hemiptera. The insects collected in Method 2 were brought into the lab for closer identification under a microscope.

Figure 1. Sites Surveyed: Native Mountain Mint, Native Swamp Milkweed, Native Monarda, Invasive Mugwort, and Agricultural Cover Crop.

Method 1 (visual search) consisted of timed observations of insects along a 15m transact and counting the number of visitors from each insect group. Three replicates were used for each study site at 0-5 m, 5-10 m, and 10-15 m along the measuring tape. For each replicate, the visual search was standardized at 10 seconds. Within 10 seconds, the largest number of insects in each family that visited the plant was recorded. This visual search method was repeated at all 5 sites. The site, replicate number, date, and number of insect observations in each family was recorded.

Method 2 (sweep net) consisted of a sweep-net to collect and study insects along a 15m transact. Easily identifiable large flower-visiting insects caught in the net were released, and smaller insects were collected with an aspirator for identification in the lab. Three replicates were used for each study site at 0-5m, 5-10m, and 10-15m along the measuring tape. For each replicate the top of the vegetation was swept with the net two times. An aspirator was used to transfer the insects from the sweep-net to the vial. Insects were preserved by applying pure ethanol to the aspirator vial with a wash bottle. Ethanol was applied until insects were fully submerged. This sweep-net method was repeated at all 5 sites.

The insects in each vial were identified under the microscope at 40X and 100X magnification. An Amscope microscope camera was used to photograph each insect collected. The images were uploaded to iNaturalist for identification. Shannon diversity and richness of insect families were calculated in Excel. The formula for shannon diversity is $H = -\sum (Pi * \ln Pi)$. To test for the effects of site, plot, and date, data were compared using R studio codes for Analysis of variance (ANOVA), and post hoc Tukey's HSD.

Results

There was a total of 45 samples, and 557 individual insects collected. A portion of the insect identifications are organized on an iNaturalist project.

Overall, I documented many different species. Not every insect was identified to species, but some were able to be identified that closely. Milkweed had 11 species identified including *Chrysoperla carnea, Lygaeus kalmii*, *Tetraopes tetrophthalmus*, *Harmonia axyridis*, *Aphis nerii*, *Saxinis saucia*, *Plagiognathus obscurus*, *Propylea quatuordecimpunctata*, *Diabrotica undecimpunctata*, *Lygus lineolaris*, and *Hippodamia variegata*. Mountain Mint had 5 species identified including *Chionomus puellus*, *Lygus lineolaris*, *Neortholomus scolopax*, *Propylea quatuordecimpunctata*, and *Myodocha serripes*. Monarda had 10 species identified including *Photinus pyralis*, *Lygus lineolaris*, *Micrutalis calva*, *Diachus auratus*, *Acalymma vittatum*, *Toxomerus marginatus*, *Psyllobora vigintimaculata*, *Myodocha serripes*, *Neortholomus scolopax*, and *Plagiognathus obscurus*. Cover Crop had 4 species identified including *Lygus lineolaris*, *Thaumatomyia glabra*, *Propylea quatuordecimpunctata*, and *Toxomerus marginatus*. Mugwort had 6 species identified *Harmonia axyridis*, *Plagiognathus obscurus*, *Lygus lineolaris*, *Propylea quatuordecimpunctata*, *Acanthocephala terminalis*, and *Graphocephala versuta* (Figure 2).

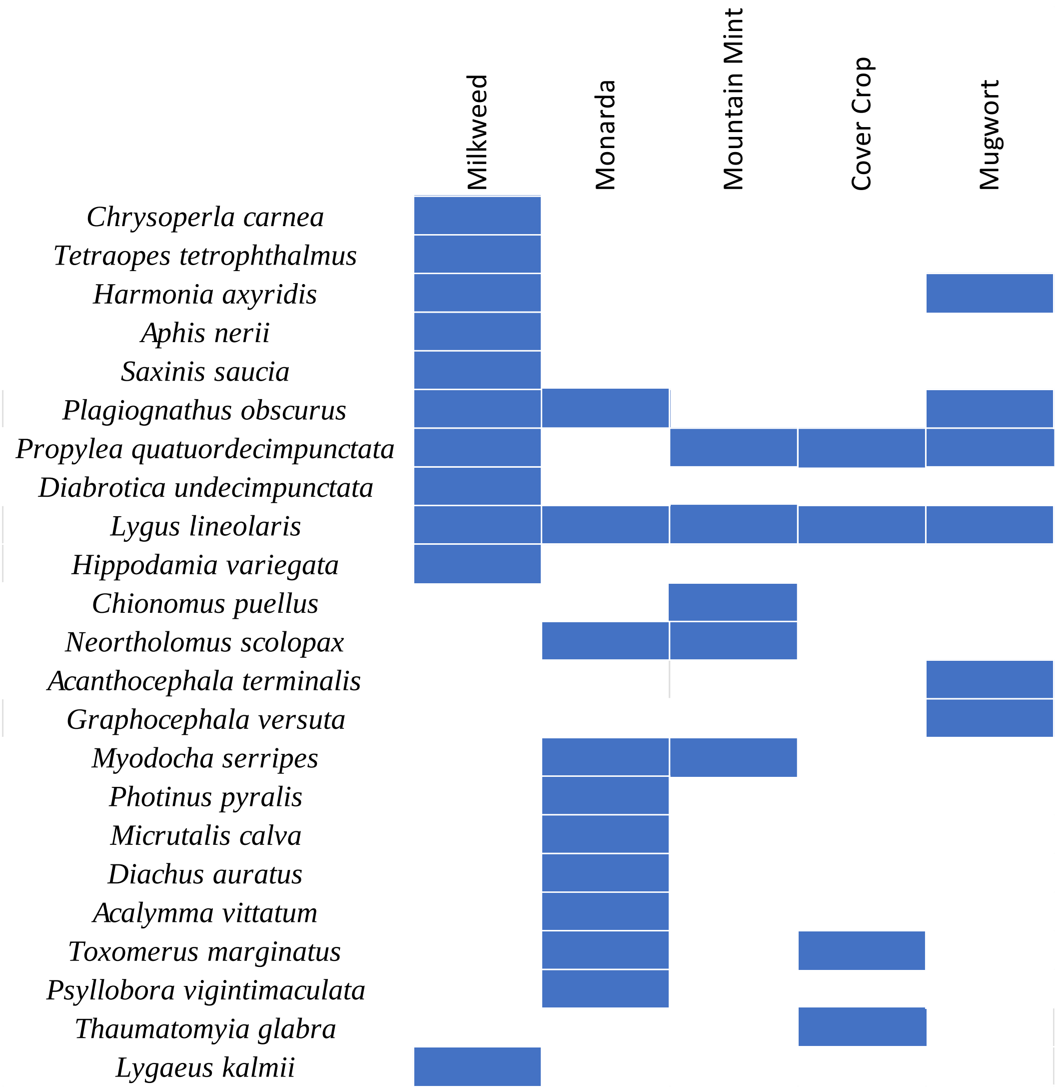

Figure 2. Insect species identified at the sites (Sweep Net Survey). Replicates and dates are pooled. Native plants (Milkweed, Monarda, Mountain Mint), Invasive plant (Mugwort), and Agricultural (Cover Crop).

Insect observations varied by date and site. In June there were 0 Cover Crop observations, 2 Apidae observations in Milkweed, 0 observations in Monarda, 16 Apidae observations in Mountain Mint, and 0 observations in Mugwort. In July there were 0 Cover Crop observations, 6 Apidae and 1 Nymphalidae observations in Milkweed, 21 Apidae, 7 Papilionidae and 9 Hesperiidae observations in Monarda, 46 Apidae observations in Mountain Mint, and 0 observations in Mugwort. In August there were 0 observations in Cover Crop, Milkweed, Monarda, Mounain Mint, and Mugwort (Figure 3).

Richness is an indication of overall different families found in each site; higher numbers mean more families. Cover Crop richness in June was 8, in July was 11, and in August was 7. Milkweed richness in June was 10, in July was 10, and in August was 7. Monarda richness in June was 15, in July was 12, and in August was 4. Mountain Mint richness in June was 8, in July was 7, and in August was 4. Mugwort richness in June was 8, in July was 5, and in August was 4 (Figure 4). When pooled together, Native richness in June was 25, in July was 19, and in August was 10 (Figure 5).

Shannon diversity considers richness and evenness to give an overall score for each site; higher numbers mean more diversity and more evenness. Cover Crop shannon diversity in June was 1.74, in July was 1.34, and in August was 1.65. Milkweed shannon diversity in June was 1.20, in July was 1.58, and in August was 1.95. Mountain Mint shannon diversity in June was 2.25, in July was 1.82, and in August was 0.90. Mountain Mint shannon diversity in June was 1.95, in July was 1.06, and in August was 1.33.

Mugwort shannon diversity in June was 1.11, in July was 1.44, and in August was 1.09 (Figure 6). Native shannon diversity in June was 2.29, in July was 2.06, and in August was 1.57 (Figure 7).

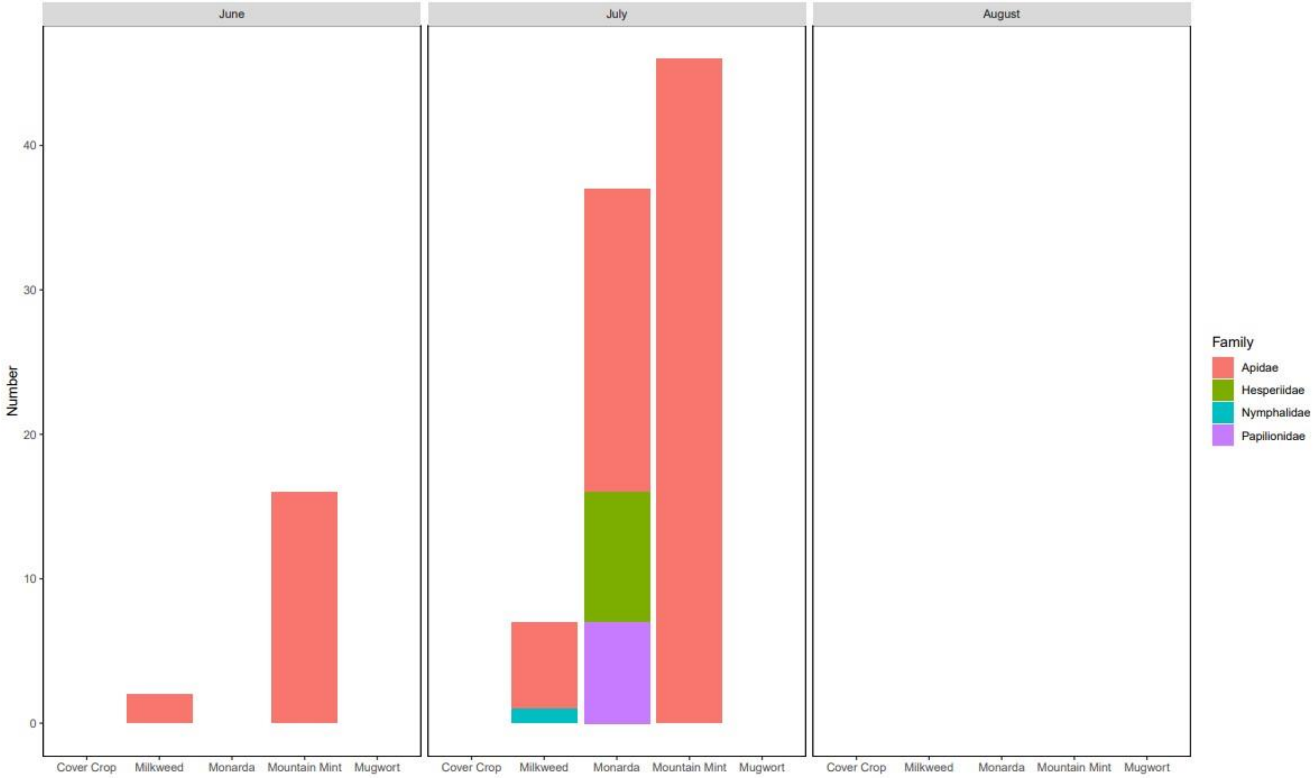

Figure 3. The number of insects of each insect family at site and date (Visual Survey). Replicates are pooled in each site. Native (Milkweed, Monarda, Mountain Mint), Invasive (Mugwort), and Agricultural (Cover Crop).

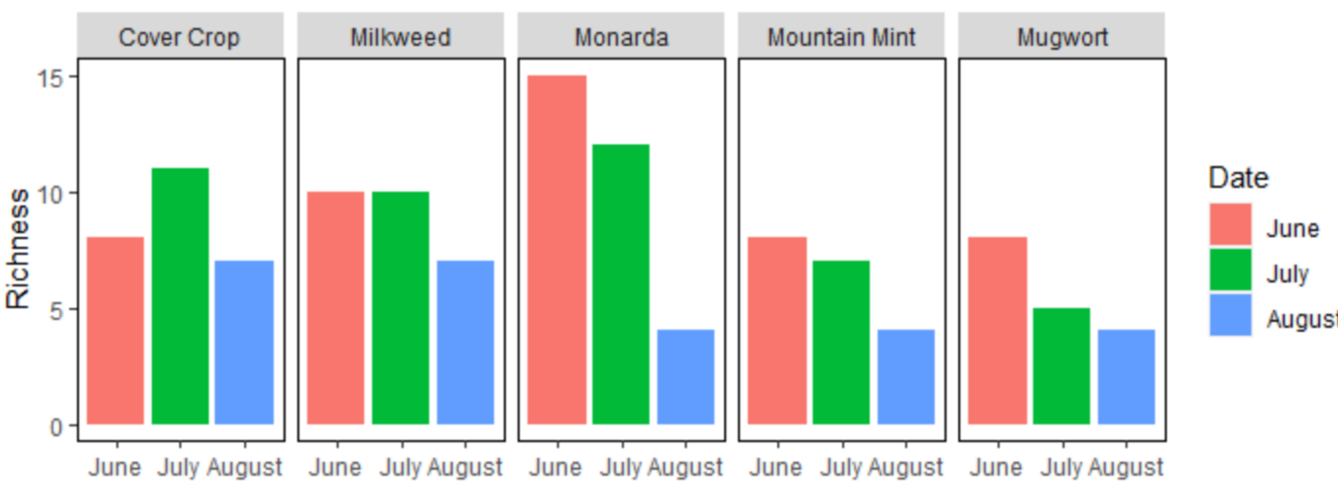

Figure 4. The richness of insect families at date and site (Sweep Net Survey). Replicates are pooled in each site. Native plants (Milkweed, Monarda, Mountain Mint), Invasive plant (Mugwort), and Agricultural (Cover Crop).

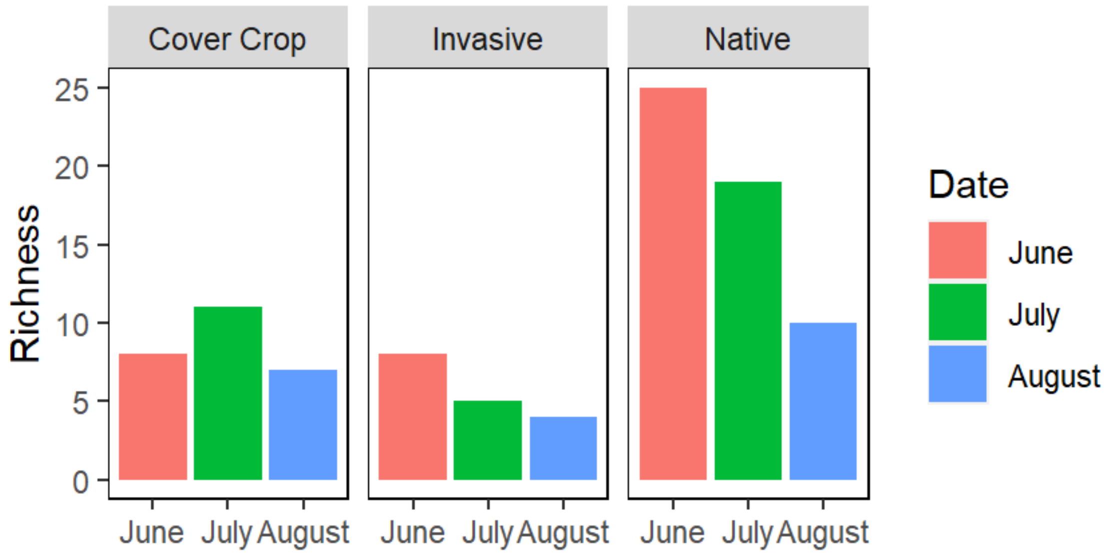

Figure 5. The richness of insect families at date and plot (Sweep Net Survey). Replicates are pooled. Native plot (Milkweed, Monarda, Mountain Mint), Invasive plot (Mugwort), and Agricultural (Cover Crop).

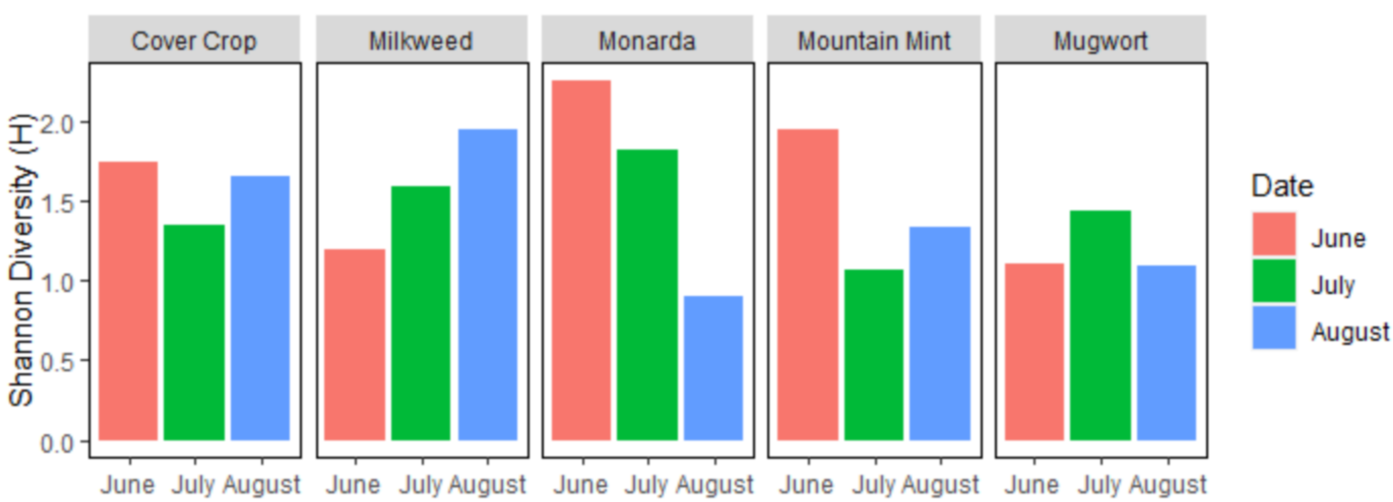

Figure 6. Shannon diversity of insect families at date and site (Sweep Net Survey). Replicates are pooled in each site. Native plants (Milkweed, Monarda, Mountain Mint), Invasive plant (Mugwort), and Agricultural (Cover Crop).

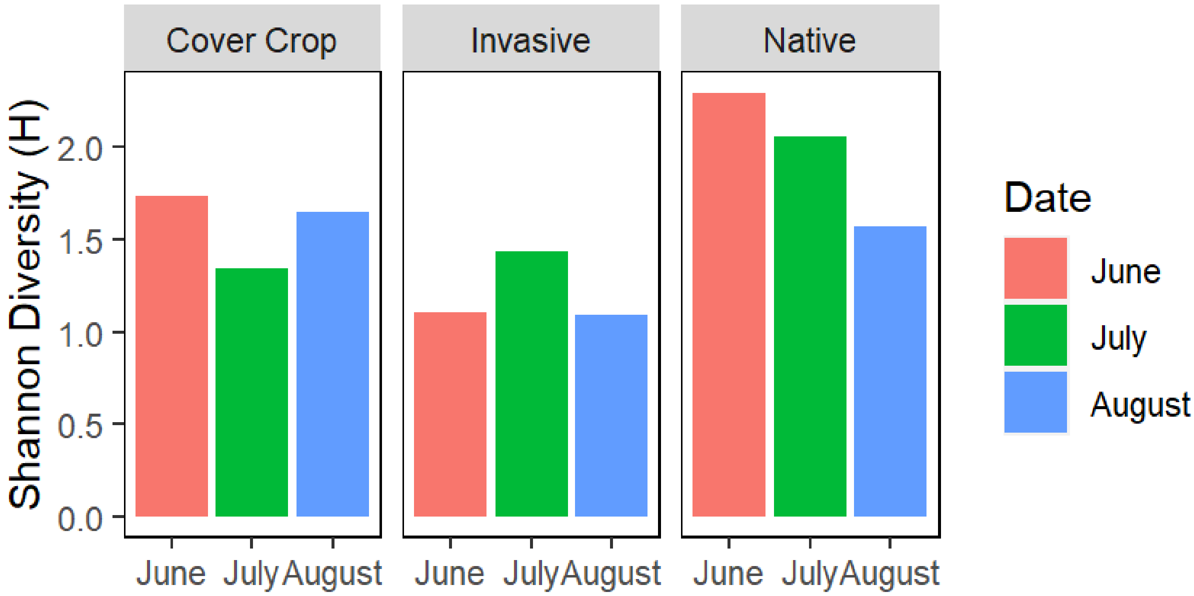

Figure 7. Shannon diversity of insect families at date and plot (Sweep Net Survey). Replicates are pooled. Native plot (Milkweed, Monarda, Mountain Mint), Invasive plot (Mugwort), and Agricultural (Cover Crop).

I found no significant statistical difference in richness among the insect family richness of the sites (ANOVA, F = 1.172, p = 0.38). There is no significant difference between sites in terms of richness (Figure 8).

I found a significant statistical difference in richness among the insect family richness of the dates (ANOVA, F = 4.441, p = 0.036). I ran a post hoc Tukey's HSD test and found that there a significant difference between August-June (P= 0.0403613). There was no significant difference between July-June (P=0.8796157), and August-July (P= 0.0937127). There is a significant difference between dates in terms of richness (Figure 9).

I found a significant statistical difference in richness among the insect family richness of the plots (ANOVA, F = 5.67, p = 0.0414). I ran a post hoc Tukey's HSD test and found that there a significant difference between Native-Invasive (P= 0.0411012). There was no significant difference between Invasive-Cover Crop (P= 0.7249638), and Native-Cover Crop (P= 0.1097349). There is a significant difference between plots in terms of richness (Figure 10).

I did not find a significant statistical difference in richness among the insect family richness of the dates (ANOVA, F = 0.681, p = 0.541). There is no significant difference between dates in terms of richness (Figure 11).

I found no significant statistical difference in shannon diversity among the shannon diversity of the sites (ANOVA, F = 0.508, p = 0.731). There is not a significant difference between sites in terms of shannon diversity (Figure 12).

I found no significant statistical difference in shannon diversity among the shannon diversity of the dates (ANOVA, F = 0.573, p = 0.579). There is not a significant difference between dates in terms of shannon diversity (Figure 13).

I found a significant statistical difference in shannon diversity among the shannon diversity of the plots (ANOVA, F = 5.985, p = 0.0372). I ran a post hoc Tukey's HSD test and found that there a significant difference between Native-Invasive (P= 0.0311895). There was no significant difference between Invasive-Cover Crop (P= 0.2977662), and Native-Cover Crop (P= 0.2449568). There is a significant difference between plots in terms of shannon diversity (Figure 14).

I did not find a significant statistical difference in shannon diversity among the shannon diversity of the dates (ANOVA, F = 0.3, p = 0.751). There is no significant difference between dates in terms of shannon diversity (Figure 15).

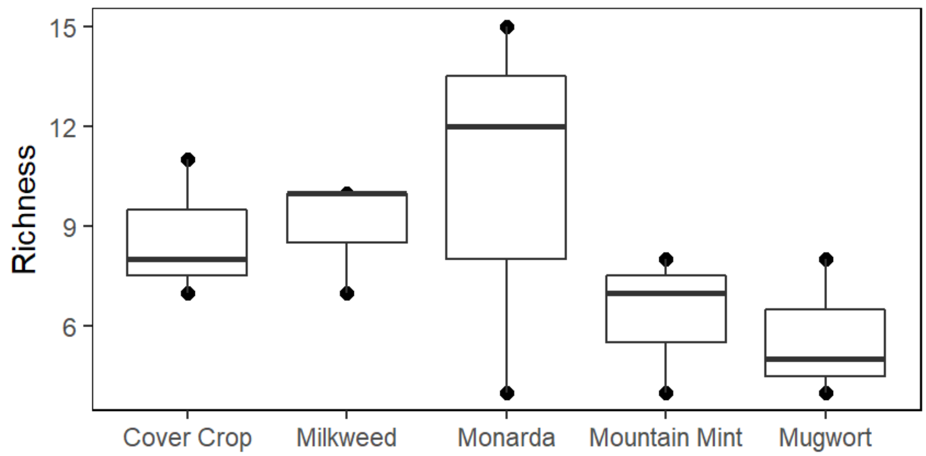

Figure 8. The distribution of insect family richness in each site (Sweep Net Survey). Replicates and dates are pooled. Native plants (Milkweed, Monarda, Mountain Mint), Invasive plant (Mugwort), and Agricultural (Cover Crop).

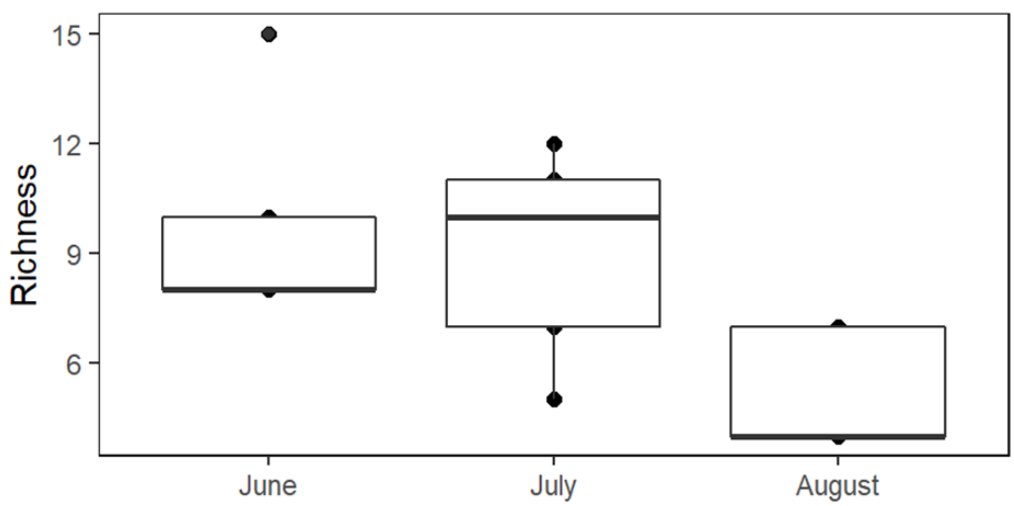

Figure 9. Distribution of insect family richness in each date (Sweep Net Survey). Replicates and sites are pooled

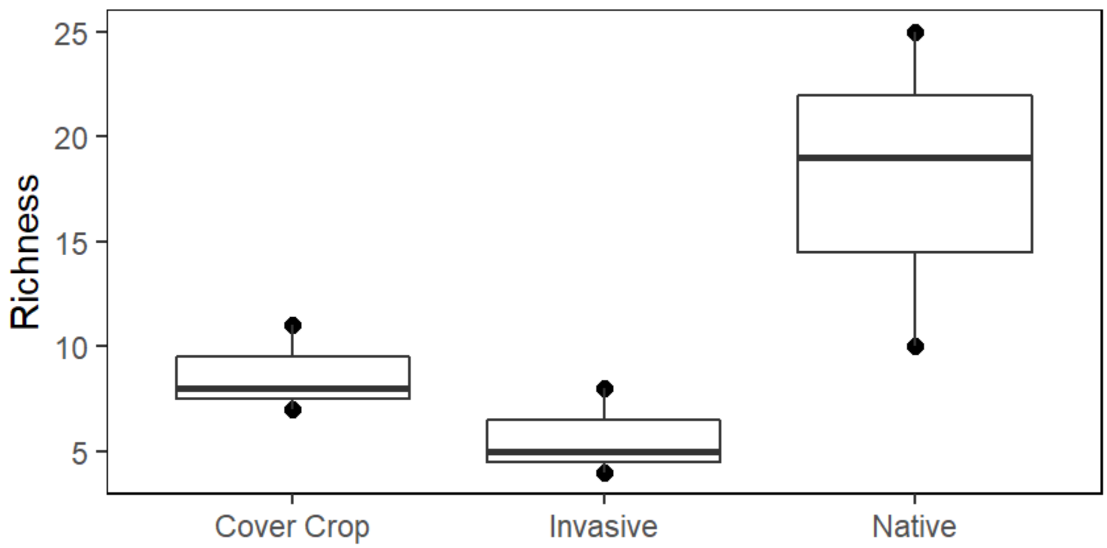

Figure 10. The distribution of insect family richness in each plot (Sweep Net Survey). Replicates and dates are pooled. Native plot (Milkweed, Monarda, Mountain Mint), invasive plot (Mugwort), and Agricultural cover crop plot (Buckwheat and Clover).

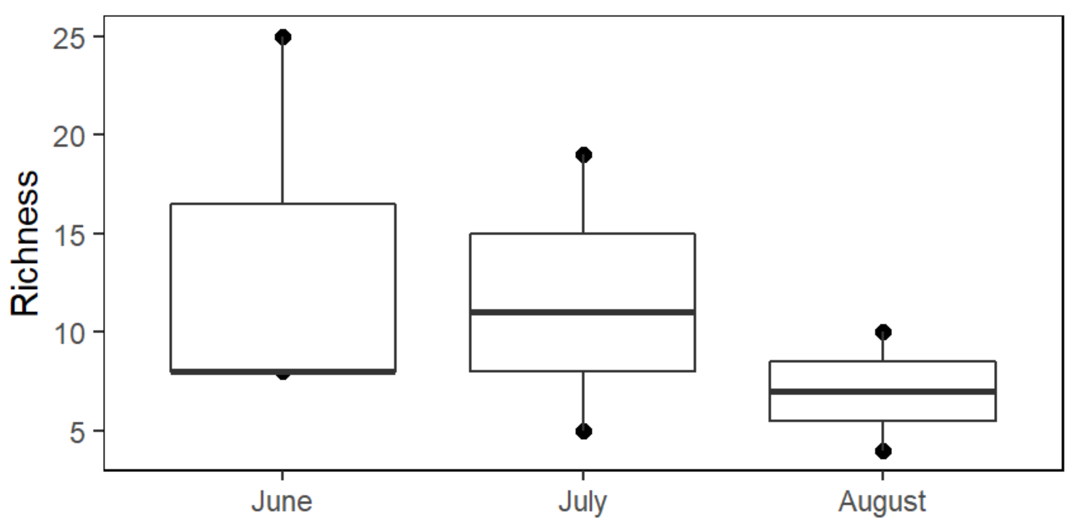

Figure 11. The distribution of insect family richness in each date (Sweep Net Survey). Replicates and plots are pooled. Native plot (Milkweed, Monarda, Mountain Mint), invasive plot (Mugwort), and Agricultural cover crop plot (Buckwheat and Clover).

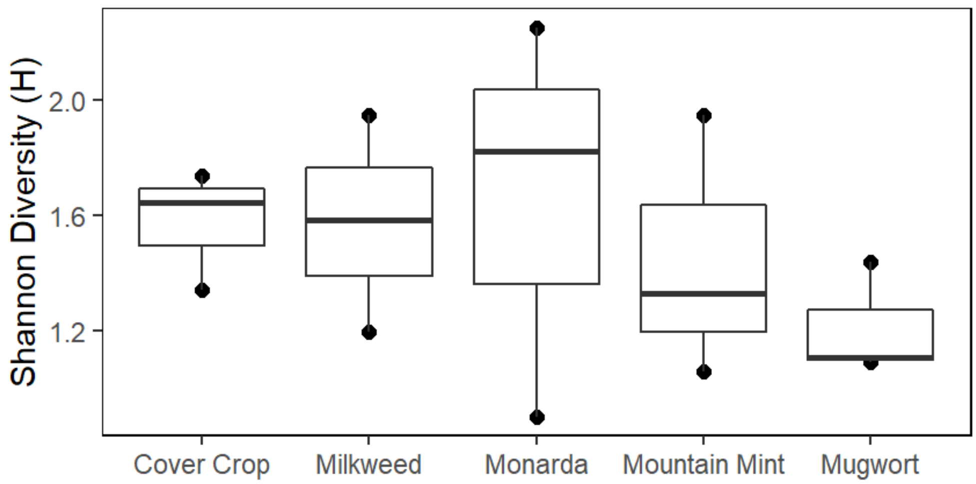

Figure 12. The distribution of insect family shannon diversity in each site (Sweep Net Survey). Replicates and dates are pooled. Native plants (Milkweed, Monarda, Mountain Mint), Invasive plant (Mugwort), and Agricultural (Cover Crop).

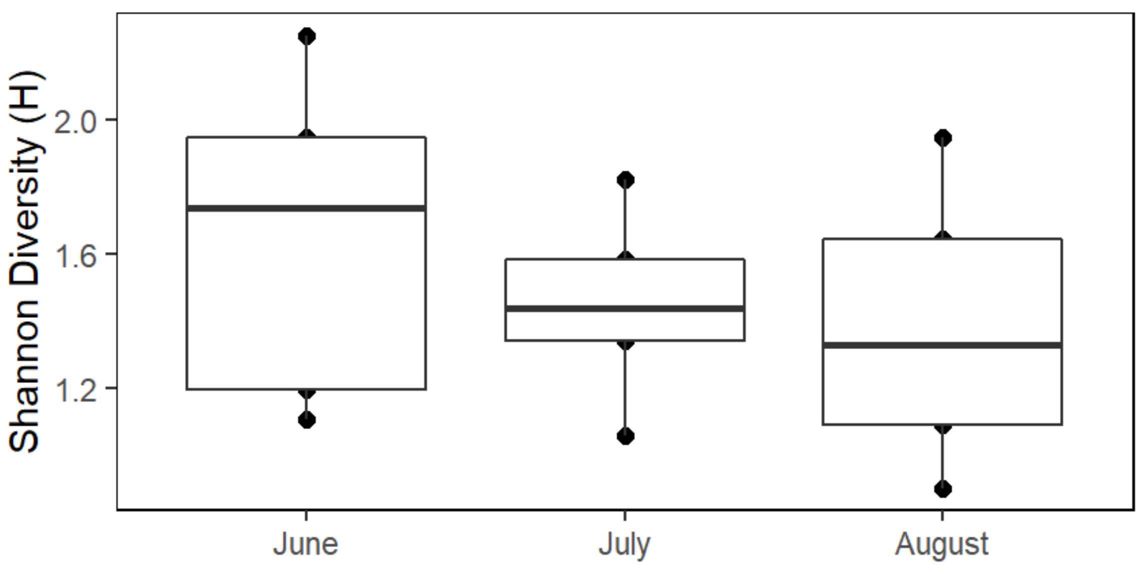

Figure 13. The distribution of insect family shannon diversity in each date (Sweep Net Survey). Replicates and sites are pooled.

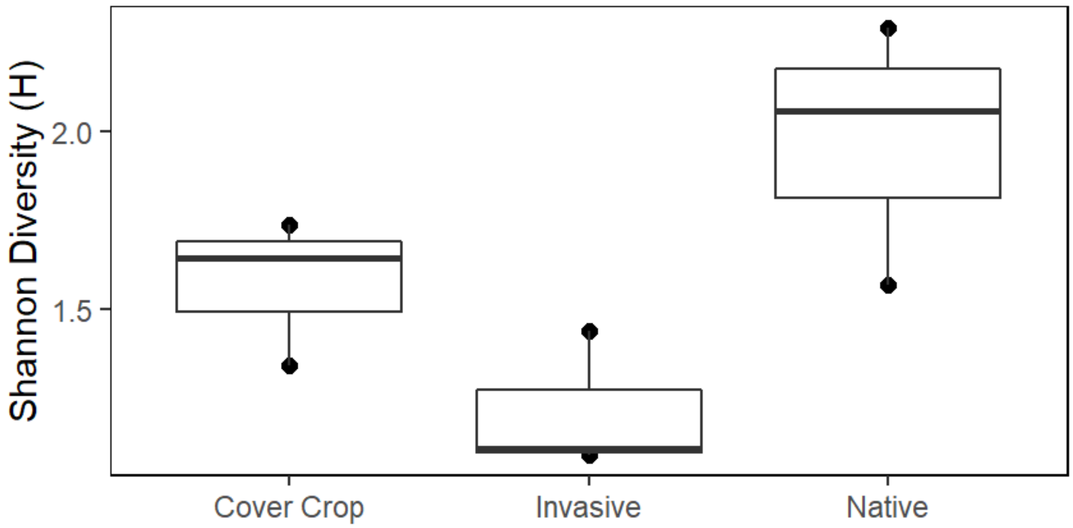

Figure 14. The distribution of insect family shannon diversity in each plot (Sweep Net Survey). Replicates and dates are pooled. Native plot (Milkweed, Monarda, Mountain Mint), invasive plot (Mugwort), and agricultural cover crop plot (Buckwheat and Clover).

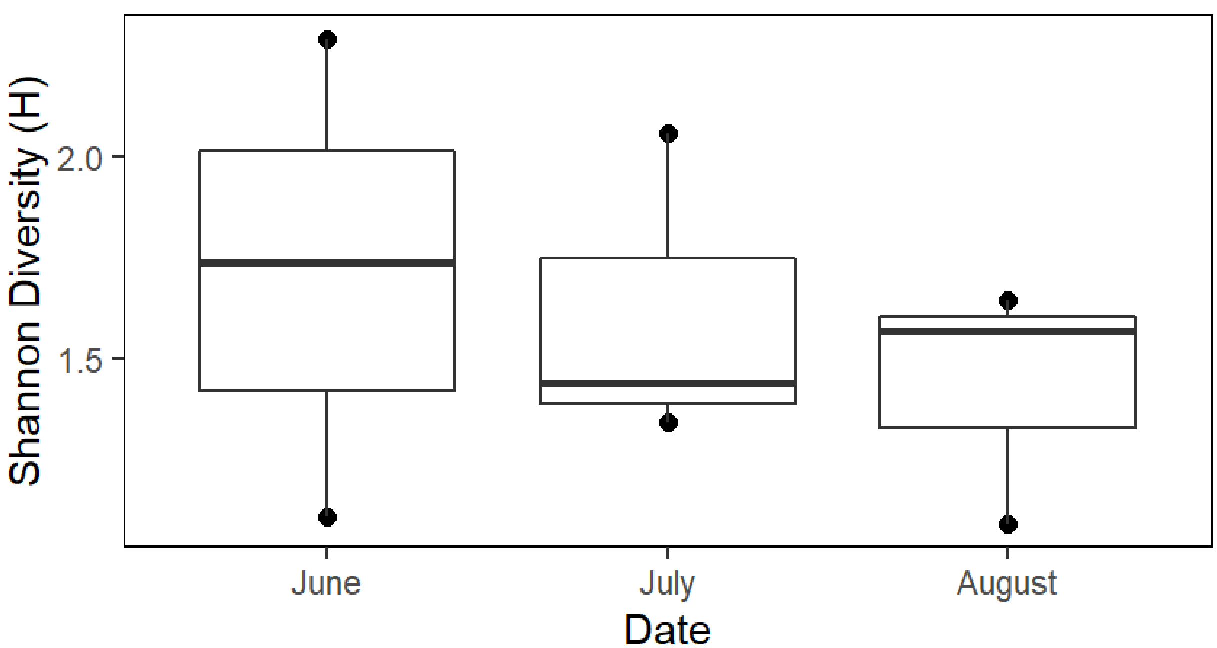

Figure 15. The distribution of insect family shannon diversity in each date (Sweep Net Survey). Replicates and plots are pooled. Native plot (Milkweed, Monarda, Mountain Mint), invasive plot (Mugwort), and agricultural cover crop plot (Buckwheat and Clover).

Discussion

Native sites had 180 more large flower-visiting insects than the agricultural cover crop, and invasive Mugwort. The number of large flower-visiting insect observations was highest at 90 in July, and lowest in August at 0. There was a significant difference in richness between August-June among the sites. There was a significant difference in shannon diversity and richness between Native-Invasive plots.

The results suggest that a greater number of large flower-visiting insects such as Hymenoptera and Lepidoptera visit native plants compared to agricultural cover crop and invasive Mugwort. Mugwort is wind-pollinated (Garnock-Jones1986). Mugwort and other angiosperms are wind pollinated and have reduced flowers, because flowers are not needed for pollinator attraction (GHAZOUL, 2004). Buckwheat is one of the best cover crops for bees and other large flower-visiting insects. However, Buckwheat must flower for up to 20 days to support pollinators and other beneficial insects (Cover cropping for pollinators and beneficial insects, 2021). The Buckwheat did not flower until after this study was completed, so there were no observations in the visual search method. Many Clover cover crops are beloved by bees and beneficial insects, but the Clover cover crop was not in bloom during this study (Cover cropping for pollinators and beneficial insects, 2021). The largest number of large flower-visiting insect observations was in July because the native flowers were in peak bloom. Based on the results of the study, organic farms could increase biodiversity by planting native flowers along fields. Other farms in the area should consider incorporating native plants adapted to Ecoregion 59, the Northeastern Coastal Zone. The addition of native plants that bloom when cover crops are not yet blooming helps support insect populations and local natural habitat.

The results suggest that there was no difference in abundance and diversity of insects between sites, but there was a difference between plots. There was no difference found in insect diversity and abundance among sites because of a low sample size. The results suggest that there was a difference in abundance and diversity of insects between plots. The native plot was a significantly more abundant and diverse habitat for insects than the invasive plot. This result highlights the value of native plants for insect communities compared to invasive plants. Native flowering plants benefit insect populations in an agricultural landscape (Isaacs et al., 2009).

There was no significant difference found in insect diversity between dates among the sites, but there was a difference in insect richness. This result highlights that what month it was did not influence insect diversity, but it did influence insect richness. The month influenced insect richness because certain taxa are present at different times of the year (Scriven et al., 2013). There may have been fewer taxa present in August because the native plants were not flowering.

It was unexpected that cover crop had zero observations from June to August. Ensuring flowering cover crop was available would have been important for calculating insect observations, richness, and diversity. The availability of flowers may result in an increase in insect observations, richness and diversity within the agricultural cover crop plot. Flower density is an important factor in changes between months and is important to a site for insect diversity (Scriven et al., 2013). Knowing the flower density of the plants studied in each month is important when calculating insect observations, diversity, and richness. In a future study the agricultural cover crop site could be revisited while it is flowering.

Conclusion

Understanding the abundance and diversity of insects on native plants, agricultural cover crop, and invasive plants in the agricultural landscape could help mitigate the impact of agricultural intensification on insect populations. The native plot on Hilltop Hanover farm was successful in supporting beneficial flower-visiting insects, and in supporting an abundant and diverse insect population. The future of agriculture can include a variety of native plants for the conservation of insects. The findings of this study are important because agricultural intensification is a significant cause of insect decline.

There should be further research on this topic at Hilltop Hanover Farm and Education Center. Future studies should include sampling cover crop during the month it flowers. Adding a sample in a later month such as September could show an increase in insect abundance and diversity within the agricultural cover crop plot. It is also important to note that sampling the cover crop at peak bloom could result in an increased number of large flower-visiting insects. It is important that a further study highlights the benefits of flowering cover crop on beneficial insects such as pollinators.

It is important that land management groups prioritize the addition of native plots on farms. The conservation and maintenance of native plant communities through land management can contribute to an increased abundance and diversity of insects. Land management groups should incorporate native plants from the ecoregion in which a farm is located. Native plants on the agricultural landscape provides food and shelter for beneficial insects and supports pollinators significantly more than invasive plant species.

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Bengtsson, Ahnstrom, J., & Weibull, A. . (2005). effects of organic agriculture on biodiversity and abundance: a meta-analysis. *The Journal of Applied Ecology*, *42*(2), 261–269. https://doi.org/10.1111/j.1365-2664.2005.01005.x

Busse, Zoll, F., Siebert, R., Bartels, A., Bokelmann, A., & Scharschmidt, P. (2021). How farmers think about insects: perceptions of biodiversity, biodiversity loss and attitudes towards insect-friendly farming practices. *Biodiversity and Conservation*, *30*(11), 3045–3066. https://doi.org/10.1007/s10531-021-02235-2

Cardoso, Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Fukushima, C. S., Gaigher, R., Habel, J. C., Hallmann, C. A., Hill, M. J., Hochkirch, A., Kwak, M. L., Mammola, S., Ari Noriega, J., Orfinger, A. B., Pedraza, F., Pryke, J. S., Roque, F. O., … Samways, M. J. (2020). Scientists' warning to humanity on insect extinctions. *Biological Conservation*, *242*, 108426–. https://doi.org/10.1016/j.biocon.2020.108426

Carrié, Ekroos, J., & Smith, H. G. (2018). Organic farming supports spatiotemporal stability in species Richness of bumblebees and butterflies. *Biological Conservation*, *227*, 48–55. https://doi.org/10.1016/j.biocon.2018.08.022

Forister, Pelton, E. M., & Black, S. H. (2019). Declines in insect abundance and Diversity: We know enough to act now. *Conservation Science and Practice*, *1*(8). https://doi.org/10.1111/csp2.80

Garnock-Jones PJ 1986. Floret specialization, seed production and gender in *Artemisia vulgaris* L. (Asteraceae, Anthemideae). *Botanical Journal of the Linnean Society* 92: 285–302.

GHAZOUL. (2004). ECOLOGY | Reproductive Ecology of Forest Trees. In Encyclopedia of Forest Sciences (pp. 63–68). https://doi.org/10.1016/B0-12-145160-7/00020-X

Gomiero T, Pimentel D, Paoletti MG. Environmental impact of different agricultural management practices: Conventional vs. organic agriculture. Critical Reviews in Plant Sciences. 2011;30:95-124

Isaacs, Tuell, J., Fiedler, A., Gardiner, M., & Landis, D. (2009). Maximizing Arthropod-Mediated Ecosystem Services in Agricultural Landscapes: The Role of Native Plants. Frontiers in Ecology and the Environment, 7(4), 196–203. https://doi.org/10.1890/080035

Kawahara, Reeves, L. E., Barber, J. R., & Black, S. H. (2021). Eight simple actions that individuals can take to save insects from global declines. *Proceedings of the National Academy of Sciences - PNAS*, *118*(2). https://doi.org/10.1073/pnas.2002547117

Mazed, Afroz, M., & Rahman, M. M. (2021). Global Decline of Insects: A Review from Agricultural Perspective. *Agricultural Reviews (Karnal, India)*, *Of*. https://doi.org/10.18805/ag.RF-223

Samways, Barton, P. S., Birkhofer, K., Chichorro, F., Deacon, C., Fartmann, T., Fukushima, C. S., Gaigher, R., Habel, J. C., Hallmann, C. A., Hill, M. J., Hochkirch, A., Kaila, L., Kwak, M. L., Maes, D., Mammola, S., Noriega, J. A., Orfinger, A. B., Pedraza, F., … Cardoso, P. (2020). Solutions for humanity on how to conserve insects. *Biological Conservation*, *242*, 108427–. https://doi.org/10.1016/j.biocon.2020.108427

Scriven, Sweet, M. J., & Port, G. R. (2013). Flower Density Is More Important Than Habitat Type for Increasing Flower Visiting Insect Diversity. International Journal of Ecology, 2013, 1–12. https://doi.org/10.1155/2013/237457

Sustainable Agriculture Research and Education. (2021, January 19). Cover cropping for pollinators and beneficial insects. SARE. Retrieved from https://www.sare.org/resources/cover-cropping-for-pollinators-and-beneficial-insects/