RESEARCH REPORT

ENVIRONMENT

Title: Establishing Monarch Butterfly Breeding Habitat on Iowa Swine Production Sites, **NPB #18-132**

Investigator: Robert Hartzler, Ph.D.

Institution: Iowa State University

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revised

Industry Summary:
The goal of this research was to find cost-effective methods to establish and maintain monarch habitat – milkweeds and native wildflowers – on Iowa swine production confinement sites to support monarch butterfly conservation in Iowa. Results from the project were distributed through high-quality videos, print media, and other communications.

In 2016, twelve grass-dominated sites in four central Iowa counties were prepared for planting monarch butterfly habitat by applying glyphosate twice during the growing season. A diverse, native seed mix was planted in early December of 2016 and changes in plant density, plant diversity, and monarch utilization were monitored during the summer of 2017 and 2018. Data was collected three times each summer (June, July, August), beginning the summer before the habitat sites were planted with the native seed mix.

Survey teams recorded monarch presence (eggs, caterpillars, and adults), blooming plants, and vegetation growth and thickness. Increases in native flowers, native plant species diversity, and native milkweeds were recorded. Data analysis shows an increase in monarch eggs, caterpillars and adult butterflies using the new habitat from 2016 to 2018, as well as more blooms, more plant species, and more monarch activity.

The results show that hog confinement locations can provide suitable areas for monarch habitat conservation. This project appeared on the cover of Iowa Pork Producer magazine (May 2019) and farmers Ben Crawford and Tom Tiernan described what they have learned about monarch habitat in video interviews with ISU Extension (2018-2019), available to view at https://monarch.ent.iastate.edu/video.

Key Findings:

- Transitions from mowed turf to diverse native pollinator habitat require careful attention to site selection and site preparation to ensure successful establishment of native plant species at confinement facilities.

- Annual weeds are very common in the early years of site establishment, but the greatest concern is aggressive perennial or biennial weeds that can outcompete native species. For this reason, it helps to know the site's history and potential weed problems before converting from non-native, cool-season grasses to prairie pollinator habitat.

- Best practices include multiple applications of glyphosate (spring, summer and fall) prior to a no-till, dormant planting of native seed, ideally mid-Nov to mid-Feb.

- Successful establishment of monarch habitat at the swine production sites resulted in a quantifiable increase in adult and larval monarch and bee utilization.

- With proper site selection and pre-planting preparation and maintenance, high- to medium-quality habitat plots can be established, at a reasonable cost, within a few years of planting.

Key words: conservation, environment, pollinator, monarch, grass

Scientific Abstract:

Conservation practices for monarch and pollinator habitat can be co-located at hog production sites. Investing in monarch conservation may also be less expensive for owner-operators than maintaining cool-season sods that typically surround confinement sites.

Native pollinators are on the decline in Iowa and throughout the country. This includes the beautiful, iconic monarch butterfly known for its incredible journey migrating between over-wintering grounds in Mexico and breeding territory throughout Iowa and neighboring states. The decline of monarchs and other pollinators has been linked to loss of habitat and food sources, including milkweed, the monarch larvae's primary food.

Planting pollinator habitat in grass-dominated sites near livestock facilities can create multiple benefits. Improvements in monarch conservation can meet the resource needs of many pollinators, as well as other wildlife species, without negatively impacting livestock production. However, there may be challenges and requirements to achieve habitat goals for specific species, such as the monarch butterfly.

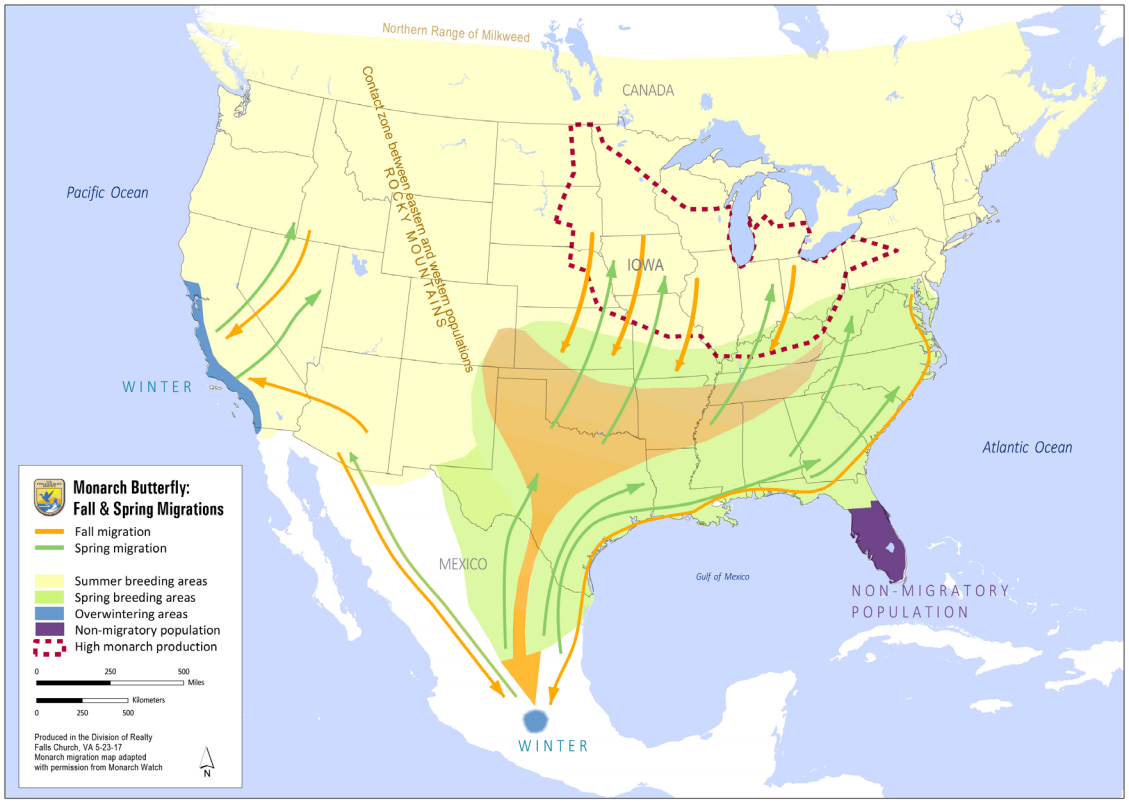
Twelve demonstration sites were selected to assess management practices to replace Kentucky bluegrass near confinement facilities with pollinator habitat in Dallas, Hamilton, and Marshall counties. Site preparation (mowing and one or two glyphosate applications) was undertaken in the summer and fall of 2016. In 2017, the sites were mowed three times at height of 6 inches to ensure optimal vegetation establishment. Sites were mowed once or twice in 2018 at a height of 10-12 inches to reduce seed set of biennial weeds. Sites were surveyed in June, July, and August each year during 2016-

2018 to assess the density and diversity of the native plant species and utilization of the habitat by monarchs.

To communicate the results of this project, one statewide monarch butterfly summit was hosted at the Field Extension Education Lab in Boone County in July of 2018. This project also appeared on the cover of Iowa Pork Producer magazine (May 2019) and farmers Ben Crawford and Tom Tiernan described what they learned about monarch habitat in video interviews with ISU Extension (2018-2019), available to view at https://monarch.ent.iastate.edu/video. Additional communications were distributed online via social media @IowaMonarchs on Twitter and Facebook, as well as digitally at https://www.extension.iastate.edu/news/ and www.iowamonarchs.info.

Introduction:

The monarch butterfly is perhaps the most recognizable and iconic insect in North America. The fact that their populations have declined approximately 80% over the past decade is a concern for environmental conservation. This decline in monarch butterfly populations has been attributed to loss of overwintering habitat in Mexico, climatic perturbations, and a greater than 50% reduction of milkweed (*Asclepias* spp) in the monarch's Midwestern breeding habitat (Pleasants, J.M. and K. S. Oberhauser. 2013). Fifty percent of overwintering monarch butterflies breed in the upper Midwest, and Iowa is in the heart of their summer breeding range (see below).



This project took an innovative approach to enhancing the environmental stewardship of the Iowa swine industry's current production sites. Iowa has more than 6,000 farms with

hogs, predominately in modern confinement sites near corn or soybean fields. The turf areas surrounding swine confinement barns are well-positioned for monarch butterfly habitat. This project evaluated the best practices for establishing monarch habitat and will provide swine producers with cost-effective, bio-secure means to further improve their environmental stewardship at swine production sites without negatively impacting production. This 'habitat-enhanced' approach can further benefit producers by adding a new environmental conservation technique for Iowa's swine production sites and, over time, an increase in monarch reproduction and pollinator diversity throughout the state.

Objectives:

Our goals are to develop and optimize cost-effective methods to establish and maintain milkweeds and companion plants on Iowa swine production confinement sites to support monarch butterfly conservation in Iowa and to communicate this information to producers and stakeholders of the IPPA. Specifically:

Objective 1) Develop cost-effective, bio-secure methods for establishing monarch habitat on Iowa swine production confinement sites.

Objective 2) Evaluate establishment and persistence of milkweeds and companion plants and monarch utilization on Iowa swine production confinement sites.

Objective 3) Extend best practices through field days, high-quality videos, and internet-based and hard copy publications of guidelines for monarch habitat establishment.

Materials and Methods:

Objective 1. *Site selection:* To identify cooperators, an announcement was sent to members of the Iowa Pork Producers Association describing the project and requesting interested parties to contact us. One integrator, Prestage Farms, responded to the request with multiple possible sites for monarch habitat demonstrations in Hamilton county. In addition, three individual producers, Ben Crawford, Appelgate G&L, and Tom Tiernan provided four demonstration sites in central Iowa. At each site, plot locations were determined based on producer preference and the suitability and/or potential planting area. In total, 12 habitat plots were established:

- four Prestage Farms locations with two plots each location (8)
- two sites provided by Ben Crawford with one plot at each location (2)
- Tom Tiernan and Appelgate G&L provided one plot each (2)

Figure 1. Proposed monarch habitat for Prestage Farms confinement site located on Wilson Ave. (Hamilton County).

Initial visits were made in early November of 2015 to evaluate the sites and follow-up visits were made in mid-March of 2016, to identify specific areas at the confinements where monarch habitat could be positioned (see Figure 1). A third visit was made to finalize locations of the plantings and confirm with the owner-operator that the position of the monarch habitat will not interfere with day-to-day operations at the facility.

Site preparation and planting: Plot areas were sprayed with glyphosate in early September of 2016 and a second time in mid-October 2016 to kill existing vegetation. A diverse native seed mix (Mesic 1.1 seed mix; see Appendix A) was frost-seeded in early December of 2016 with a Truax no-till drill. Across all sites, a total of 3.9 acres of monarch habitat were planted. During 2017, sites were mowed throughout the growing season to a height of six inches approximately every week. Frequent mowing (usually 3-5 times) in the first growing season is a standard practice for establishment of native vegetation. During 2018, the sites were mowed once (sometimes twice) at height of ten to twelve inches to reduce seed set of biennial weeds.

Objective 2. Monitoring of sites in 2016 (pre-site preparation), 2017, and 2018 included sampling of vegetation and monarchs once per month in June, July and August each year. Appendix B includes sampling protocols and example blank data entry sheets used in the monitoring surveys. Data collected from each site were logged in GitHub and made available to ISU colleagues for statistical analysis.

Objective 3. To communicate the results of this project, one statewide monarch butterfly summit was hosted at the Field Extension Education Lab in Boone County in July of 2018, with 50+ participants in attendance. This project also appeared on the cover of Iowa Pork Producer magazine (May 2019). ISU Extension staff interviewed farmers Ben Crawford (Hamilton county) and Tom Tiernan (Dallas county) to record they learned about monarch habitat on video, which was edited with assistance from Dal Grooms at IPPA in Des Moines and the North Central IPM

Center in Ames and published 2018-2019. Both interviews are available at https://monarch.ent.iastate.edu/video.

Additional deliverables, including a video with tips for planting monarch habitat, were published online [https://monarch.ent.iastate.edu/video/planting-monarch-habitat-iowa], via social media @IowaMonarchs on Twitter and Facebook, as well as digitally at https://www.extension.iastate.edu/news/ and www.iowamonarchs.info.

Results:

Objective 1. Preparation and planting complied with Spring 2016 NRCS recommendations for establishing pollinator habitat: mowing the existing vegetation after August 1 and subsequently spraying one to two applications of glyphosate in the fall. The native seed mix was planted in early December (dormant season) of 2016. This approach greatly reduced the dominance of existing non-native cool season grasses. This approach utilized half a growing season to prepare a site for planting. Visual qualitative results indicate that increased applications of herbicide, to improve weed suppression prior to planting of habitat, would have been beneficial to increasing overall establishment while also decreasing weed pressure. Visual appearance is vital to the success of these establishments due to social factors and human perception of what is weedy/messy and what is attractive/desirable. Some sites show robust stands of wildflowers, but at other sites, the wildflowers appear to be struggling to out-compete weeds and non-native cool season grasses. It should be noted that these plots are only in their second growing season and should continue to improve in visual attractiveness in following years as more native plants establish and increase in density. Diverse native plantings go through multiple stages of development with some species not appearing in significant numbers until 3-5 years after the initial planting. Generally, the native plant community density increases with time via vegetative spread and seedlings from seed production.

Objective 2. Vegetation and monarch utilization data were collected during monitoring surveys in 2016, prior to site preparation, and in 2017 and 2018. One survey in June, July, and August was conducted at each plot during 2016-2018. Consistent with site preparation and post-plant maintenance, there was a sharp increase in the yearly Robel height measurements from 2016 through 2018 were used to measure variation in height of the vegetation over time (Robel, 1970). In 2016 and 2017, Robel pole heights were approximately 10 to 25 cm and by 2018 ranged from approximately 45 to 125 cm. This sharp increase in vegetation height is consistent with establishment of the native forbs, as noted in the Daubenmire measurements during the course of the project. In 2016, cool season grasses comprised between approximately 60 to 90% of the ground cover, while introduced/weed forbs comprised approximately 0 to 35% of the cover. In 2017, cool season grass comprised approximately 0 to 10% of the cover, consistent with pre-plant herbicide treatments in the fall of 2016. By 2018, there was a modest recovery of cool season grasses (approximately 5 to 45% cover across all sites). During 2017 and 2018, annual average forb cover generally ranged from approximately 50 to 95%. Planted warm season grasses showed modest establishment of approximately 5% cover across all sites. Woody plants were rarely observed.

Appendix C provides a summary of nectar plant data from 2016 through 2018. Densities of nectar plants from 2016 through 2018 are summarized in Tables 1 – 6 and depicted in Figures 1 – 5. Figure 1 shows that in 2016, prior to mowing and herbicide treatments,

non-native weed species dominated the sites, including white clover, common dandelion, plantain, and, to a lesser degree, yellow-sweet clover and red clover. From 2017 through 2018, the number and density of native forbs increased (see Figures 2 and 3), with the dominant native forbs in 2018 including yellow coneflower, ox eye sunflower, hoary vervain, wild bergamot, and foxglove bread tongue. Modest establishment of blue vervain, black-eyed susan, partridge pea, pale purple coneflower was noted. Lower establishment of white heath aster, Virginia mountain mint, purple prairie clover, ironweed, golden alexanders, Canada milk vetch, stiff goldenrod, prairie cinquefoil were noted. While the establishment of these native forbs was encouraging, the number of introduced/weed species increased (e.g., smartweed, black medic, in addition to white clover, yellow sweet clover, and common dandelion; see Figures 4 and 5). The establishment of milkweed species (common, swamp and butterfly) are summarized in Tables 7 and 8 and Figure 6. These data show that butterfly milkweed and swamp milkweed had lower establishment rates than common milkweed.

During the course of the study, milkweed plants were monitored for monarch eggs and larvae. A Pollard Walk was used to record observations of adult monarchs in the sites (Pollard, 1977). In addition, other monarchs flying in or around the sites were recorded during the entire site visit. Over the course of the three-year period, the number of monarch eggs, larvae, and adults were generally constant in 2016 and 2017, but there was a modest, qualitative increase in counts throughout 2018, likely consistent with the increase in forbs and common milkweed.

One statewide monarch butterfly summit was hosted at the Field Extension Education Lab in Boone County in July of 2018, with 50+ participants in attendance. This project also appeared on the cover of Iowa Pork Producer magazine (May 2019) and farmers Ben Crawford and Tom Tiernan described what they learned about monarch habitat in video interviews with ISU Extension (2018-2019), available to view at https://monarch.ent.iastate.edu/video. Additional communications were distributed online via social media @IowaMonarchs on Twitter and Facebook, as well as digitally at https://www.extension.iastate.edu/news/ and www.iowamonarchs.info.

Discussion

Transitions from non-native cool season grasses to diverse native pollinator habitat require careful attention to site selection and site preparation to ensure successful establishment of native plant species. The commonly used site preparation approach of mowing in the summer with one or two fall applications of herbicide will not be successful in most situations. If increased site preparation is undertaken, anticipated issues with re-establishment of red and white clover and non-native cool season grass may be reduced or perhaps eliminated. Based on the results of this research project, the following guidance is recommended:

1. Kill existing grass cover: apply repeated broad spectrum herbicides (e.g. glyphosate)

- If possible, apply herbicides throughout an entire growing season (3 applications) and preceding fall (1 application).
- Late fall spray is the most effective time to kill cool-season grasses.

2. Plant in late fall/dormant season (mid-November – mid February)
3. Mow three times in Year 1 at height of 6" (standard procedure in all pollinator habitat establishments)
4. Potentially mow once (sometimes twice) in Year 2 at height of 10-12" to reduce seed set of biennial weeds.

Annual weeds are very common in the early years of site establishment, but normally don't affect forb establishment unless at high densities. The greatest concern is aggressive perennial or biennial weeds that can outcompete native species. For this reason, it helps to know the site's history and potential weed problems before converting from non-native, cool-season grasses to prairie pollinator habitat.

It is important to note that sites that were dominated by Kentucky bluegrass generally produced higher quality habitat patches. In sites with smooth brome or other perennial weeds, site preparation is more difficult. For example sites with scouring rush (*Equisetum arvense*) should be avoided when selecting sites for monarch habitat. Glyphosate and Crossbow herbicide (2,4-D + triclopyr) were ineffective in controlling scouring rush. Few herbicides provide consistent, effective control for this species and those that do have a residual effect in the soil for two years or more, which would limit establishment of native forbs in a seed mix for several years after application. Tillage also does not control scouring rush. Sites with reed canarygrass should also be avoided. A thick stand of reed canary grass will require multiple years of herbicide applications to provide, at best, partial control.

Finally, wild parsnip, Queen Anne's lace, and musk thistle are examples of biennial species that may require extra effort to control. Results from this project suggest that mowing for two consecutive years is an effective management strategy to reduce dominance of wild parsnip and musk thistle in pollinator habitat plantings. We expect this to be true for biennials in general as two years of mowing greatly reduces seed production.

Expect sites to require management in the long-term to maintain a competitive and balanced native plant community. Once a site has become established (3-4 years), a regular cycle of prescribed fire or baling should be carried out every three to five years. No increase in rodent activity was observed during this study, but following a standard baiting protocol would also address any potential biosecurity concerns regarding rodents.

Estimated costs for establishing monarch habitat are comparable to costs for implementing pollinator habitat in riparian buffer sites, as noted in Tables 1 and 2.

TABLE 1. Corn-soybean transition: estimated investment for establishment *	
Contracted	$312-$512/acre
Project planning and decision making	2 hours/project
Self	$324-$674/acre
Broadcast planting 4 mowing events	3 hours/acre total
Project planning and decision making	4 hours/project
*Estimated investment includes cost of pollinator seed mix.	

TABLE 2. Non-native cool-season grass transition: estimated investment for establishment *	
Contracted	$559-$909/acre
Project planning and decision making	4 hours/project
Self	$324-$674/acre
1 prescribed fire or baling event 4 broad spectrum herbicide applications Broadcast planting 4 mowing events	8 hours/acre total
Project planning and decision making	12 hours/project
*Estimated investment includes cost of pollinator seed mix.	

With proper site selection and pre-planting preparation and maintenance, high- to medium-quality habitat patches can be established within a few years of planting. Overall, a simple indicator of successful establishment for our plantings is the density of yellow coneflower and ox eye sunflower. These species reach reproductive maturity sooner than most forbs, typically within 1 to 2 years of planting. They bloom from July-September and can be used as a rough visual estimate of initial native plant establishment in the first three years post planting.

Successful establishment of native forbs at the swine production sites resulted in a quantifiable increase in adult and larval monarch and bee utilization. It is important to note that the monarch is a highly mobile species (Zalucki and Lammers, 2010; Grant et al., 2018). Consequently, observing monarchs in a given habitat is a function of the nature and extent of suitable breeding habitat in the surrounding landscape, as well as the quality of the monitored patch. Consequently, trends in monarch observations at the sites monitored in this study cannot be directly associated with the establishment of habitat patches. However, the finding that monarch utilization in 2017-2018 was qualitatively similar, if not higher, than what was observed in 2016 is encouraging and

suggests the milkweed species at the sites, combined with the establishment of nectar plants, has added viable monarch habitat within the respective landscapes surrounding the swine production facilities.

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App1, 2017

App1, 2018

Bcr1,  2017

Bcr1, 2018

Bcr2, 2016

Bcr2, 2017

Bcr2, 2018

Pre1, 2016

Pre1, 2017

Pre1, 2018

Pre2, 2016

Pre2, 2017

Pre2, 2018

Pre3, 2016

Pre3, 2017

Pre3, 2018

Pre4, 2016

Pre4, 2017

Pre4, 2018

Pre5, 2016

Pre5, 2017

Pre5, 2018

Pre6, 2016

Pre6, 2017

Pre6, 2018

Pre7, 2016

Pre7, 2017

Pre7, 2018

Pre8, 2017

Pre8, 2018

Tie1, 2016

Tie1, 2017

Tie1, 2018

Appendix A

Monarch Seed Mix

High Diversity

The Iowa State University Monarch Research Team developed this seed mix to benefit (1) monarch butterflies; (2) the rusty patched bumble bee; and (3) a wide variety of other native and non-native pollinators. The plant species were selected to perform in well-drained and moderately well-drained soils. The seed mix contains 37 species of nectar- and pollen-producing forbs (wildflowers). The diversity of forbs will provide floral resources throughout the entire growing season. The mix also contains four milkweed species as milkweed is the only host plant for monarch caterpillars. Grass species included are mostly short to medium height in order to reduce competition with forbs.

All 50 species in the mix are native to Iowa and available from commercial seed vendors. Purchasers are encouraged to collect seed bids from multiple dealers as prices and availability of specific species are often variable. This seed mix was developed for research purposes, and Iowa State reserves the right to alter this mix as needed depending on research results.

This seed mix meets requirements for a wide range of farm bill conservation programs in Iowa. The seed mix is eligible for use in CP42: CRP (Conservation Reserve Program) Pollinator Habitat; CP25: CRP Rare and Declining Habitat; EQIP (Environmental Quality Incentives Program) Monarch Habitat and many other CRP and conservation practices based on the clients objectives. This mix complies with Iowa Natural Resource Conservation Service (NRCS) Practice Standards 327 and 643. The common names used are from the Iowa NRCS Native Seeding Calculator.

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Iowa State University	Bloom Month							Soil				
Common Name	APR	MAY	JUN	JUL	AUG	SEP	OCT	WET	WET-MESIC	MESIC	DRY-MESIC	DRY
Grasses/Sedges												
Prairie Junegrass		M	J	J								
Bicknell's Sedge			J	J								
Shortbeak Sedge			J	J								
Troublesome Sedge			J	J								
Bluejoint			J	J	A							
Big Bluestem			J	J	A	S						
Prairie Cordgrass				J	A	S						
Canada Wildrye				J	A	S	O					
Little Bluestem				J	A	S	O					
Sideoats Grama					A	S						
Indiangrass					A	S						
Prairie Dropseed					A	S	O					
Composite Dropseed					A	S	O					
Forbs	Colors represent bloom color											
Canadian Lousewort	A	M										
Golden Alexander's	A	M	J									
Common Spiderwort		M	J	J								
White Wild Indigo			J	J								
Foxglove Penstemon			J	J								
Pale Coneflower			J	J								
Leadplant			J	J	A							
Canadian Milkvetch			J	J	A							
Swamp Milkweed			J	J	A							
Common Milkweed			J	J	A							
Butterfly Milkweed			J	J	A							
Prairie Coreopsis			J	J	A							
Culver's Root			J	J	A							
White Prairie Clover			J	J	A	S						
Ox-Eye			J	J	A	S						
Prairie Cinquefoil			J	J	A	S						
Common Mountain Mint			J	J	A	S						
Hoary Vervain			J	J	A	S						
Black-Eyed Susan			J	J	A	S	O					
Showy Ticktrefoil				J	A							
Partridge Pea				J	A	S						
Purple Prairie Clover				J	A	S						
Whorled Milkweed				J	A	S						
Gray-Headed Coneflower				J	A	S						
Wild Bergamot				J	A	S						
Blue Vervain				J	A	S						
Ironweed				J	A	S						
Prairie Blazing Star				J	A	S						
Tall Blazing Star				J	A	S	O					
Great Lobelia				J	A	S	O					
Tall Thoroughwort					A	S	O					
Saw-Tooth Sunflower					A	S	O					
Stiff Goldenrod					A	S	O					
Showy Goldenrod					A	S	O					
White Heath Aster					A	S	O					
Skyblue Aster					A	S	O					
New England Aster					A	S	O					

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Grasses	Scientific Name	PLS: seeds/foot²*	PLS: pounds/acre*
Cool Season Grasses			
Bluejoint	*Calamagrostis canadensis*	0.75	0.007
Canada Wildrye	*Elymus canadensis*	0.25	0.131
Prairie Junegrass	*Koeleria macrantha*	1.50	0.020
Sedges			
Bicknell's Sedge	*Carex bicknellii*	0.20	0.032
Shortbeak Sedge	*Carex brevior*	0.30	0.028
Troublesome Sedge	*Carex molesta*	0.25	0.027
Warm Season Grasses			
Big Bluestem	*Andropogon gerardii*	0.05	0.014
Sideoats Grama	*Bouteloua curtipendula*	1.15	0.522
Little Bluestem	*Schizachyrium scoparium*	3.50	0.635
Indiangrass	*Sorghastrum nutans*	0.05	0.011
Prairie Cordgrass	*Spartina pectinata*	0.05	0.021
Composite Dropseed	*Sporobolus compositus*	1.75	0.159
Prairie Dropseed	*Sporobolus heterolepis*	0.20	0.034
		10.00	**1.641**

* *Pure Live Seed (PLS) indicates the amount of seed that is capable of developing into seedlings.*

Authors: Seth Appelgate, agricultural specialist in entomology; Sue Blodgett, professor in entomology; Steven Bradbury, professor in natural resource ecology and management; Robert Hartzler, professor in agronomy; John Pleasants, adjunct assistant professor in ecology; and Dana Schweitzer, program coordinator in entomology, Iowa State University. Diane Debinski, professor in ecology, Montana State University. Richard Hellmich, USDA-ARS.

Photo by Alec Euken, animal ecology, Iowa State University.

Forbs	Scientific Name	PLS: seeds/foot²*	PLS: pounds/acre*
Legumes			
Leadplant	*Amorpha canescens*	0.70	0.119
Canadian Milkvetch	*Astragalus canadensis*	1.00	0.160
White Wild Indigo	*Baptisia alba*	0.01	0.016
Partridge Pea	*Chamaecrista fasciculata*	0.25	0.252
White Prairie Clover	*Dalea candida*	1.00	0.143
Purple Prairie Clover	*Dalea purpurea*	2.50	0.378
Showy Ticktrefoil	*Desmodium canadense*	0.10	0.050
Non-Legumes			
Swamp Milkweed	*Asclepias incarnata*	0.24	0.136
Common Milkweed	*Asclepias syriaca*	0.23	0.146
Butterfly Milkweed	*Asclepias tuberosa*	0.08	0.051
Whorled Milkweed	*Asclepias verticillata*	0.05	0.012
Prairie Coreopsis	*Coreopsis palmata*	0.01	0.003
Pale Coneflower	*Echinacea pallida*	0.10	0.052
Tall Thoroughwort	*Eupatorium altissimum*	0.58	0.032
Saw-Tooth Sunflower	*Helianthus grosseserratus*	0.10	0.018
Ox-Eye Sunflower	*Heliopsis helianthoides*	0.50	0.216
Tall Blazing Star	*Liatris aspera*	0.15	0.026
Prairie Blazing Star	*Liatris pycnostachya*	0.35	0.087
Great Lobelia	*Lobelia siphilitica*	2.50	0.014
Wild Bergamot	*Monarda fistulosa*	2.00	0.078
Stiff Goldenrod	*Oligoneuron rigidum*	1.00	0.066
Canadian Lousewort	*Pedicularis canadensis*	0.20	0.017
Foxglove Penstemon	*Penstemon digitalis*	2.00	0.042
Prairie Cinquefoil	*Potentilla arguta*	2.00	0.024
Common Mountain Mint	*Pycnanthemum virginianum*	1.00	0.012
Grey-Headed Coneflower	*Ratibida pinnata*	1.00	0.091
Black Eyed Susan	*Rudbeckia hirta*	1.75	0.052
Showy Goldenrod	*Solidago speciosa*	1.25	0.036
White Heath Aster	*Symphyotrichum ericoides*	0.25	0.003
New England Aster	*Symphyotrichum novae-angliae*	1.00	0.041
Skyblue Aster	*Symphyotrichum oolentangiense*	1.00	0.034
Common Spiderwort	*Tradescantia ohiensis*	0.10	0.034
Blue Vervain	*Verbena hastata*	1.50	0.044
Hoary Vervain	*Verbena stricta*	0.50	0.049
Ironweed	*Vernonia fasciculata*	0.50	0.057
Culver's Root	*Veronicastrum virginicum*	2.00	0.007
Golden Alexander's	*Zizia aurea*	0.50	0.124
	TOTAL (grass)	**10.00**	**1.641**
	TOTAL (forb)	**30.00**	**2.722**
	GRAND TOTAL	**40.00**	**4.361**

* *Pure Live Seed (PLS) indicates the amount of seed that is capable of developing into seedlings.*

Appendix B

Environment Survey Protocol

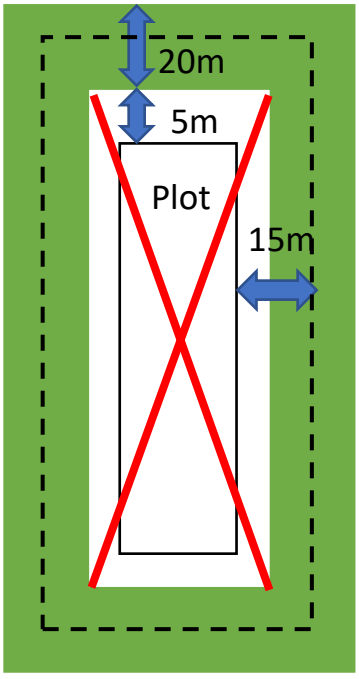
Weather data: collect when monarch survey begins

- Temperature: Record whole numbers. Hold anemometer at the base.
- Wind: Face anemometer into the wind. Hold anemometer away from your body and above your head to avoid obstructing the wind. Do not take anemometer readings directly next to a wind obstruction such as a vehicle, building, or tree. Record the approximate average wind speed after 30 sec. of observation. Record whole numbers.
- Sky
    - Clear: no clouds
    - Mostly clear: less than 50% cloud cover
    - Mostly cloudy: more than 50% cloud cover
    - Cloudy: full cloud cover
    - Rain: rain

Surrounding Landscape

Sample the green frame (see figure below). Don't sample area which is within 5m of plot. Sample area which is 5m away from plot but not further than 25m away. 10m to each side of walk line. A 20m wide band.

- Milkweed Ramet #
    - If green frame potentially contains milkweed, walk area along dotted line.
    - Line is 15m from plot edge (see below).
    - Count # of milkweed ramets 10m to each side of line
    - If area has no milkweed, walk around plot is not necessary
- Flowering plants
    - Estimate % of land cover in green frame which is covered by currently flowering plants.
    - In essence; a Daubenmire reading for % of cover of flowering plants across entire green frame.
- Dominant Flowering Species
    - Write in the dominant flowering species



Environment Datasheet **Site:** _____

Date: _____ **Transect:** _____

Observer: _____ **Round:** _____

Recorder: _____

Team lead: _____

Time arrived at site: _____

Time left site: _____

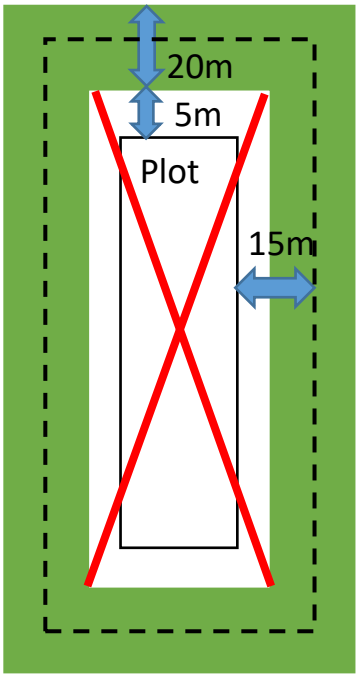
Temperature: _____ °F (whole number)

Wind: _____ mph (whole number)

Sky (check one box)		
	clear	no clouds
	mostly clear	<50% cloud cover
	mostly cloudy	>50% cloud cover
	cloudy	full cloud cover
	rain	rain

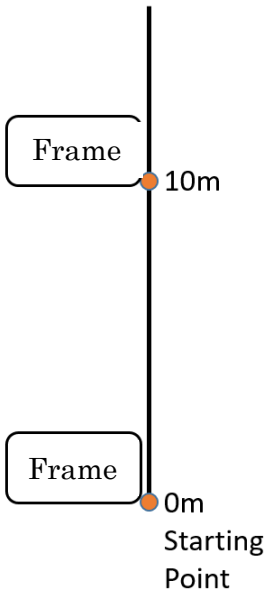
Surrounding Landscape: sample the green frame. Don't sample area which is within 5m of plot. Sample area which is 5m away from plot but not further than 25m away. A 20m wide band. Walk dotted line, 15m from plot edge.

	Milkweed Ramet #
Currently Flowering Plants (check one box)	
	0%
	0-5%
	5-25%
	25-50%
	50-75%
	75-100%
Dominant Flowering Species (write in)	



Daubenmire-Robel Survey Protocol

- Set up the 100m tape from the start point to the end point with flags placed *every 10 meters*.
- Do Daubenmire survey on left side of the transect
- Place frames with long axis perpendicular to the 100m tape with the bottom side of the frame lining up exactly with each flag every 10 meters
- Since you will record Daubenmire data at the 0m starting point, *do not* record Daubenmire data at the very end of the transect as that would give you 1 extra set of frame data that is not needed.



Variables in Data Sheet:

Percent Cover

CSG (Cool Season Grasses) – Includes sedges and equisetum
WSG (Warm Season Grasses)
Forbs – All non-grass herbaceous plants. Do not include milkweed.
Milkweed – Milkweed cover of all species of milkweed
Common ramet #, Swamp ramet #, Butterfly ramet # -- Total # of milkweed ramets by their species. **Count data, not %.**
Woody Species
Bare Ground – Includes tree roots, stumps, animal manure, mushrooms
Leaf Litter – All horizontal dead plant material that is no longer rooted: twigs, leaves, grass
Litter Depth (cm) – Depth of horizontal dead plant material on the soil surface **in cm, not %.**

Percent cover is measured in "cover classes" (these are approximate ranges, based off of Daubenmire 1959).

- Look from a top-down/birds eye view.
- Estimate the area of the frame that undisturbed plant material covers within the frame. Total percent cover of all cover classes combined *can* be greater than 100%.
    - Example: frame could potentially have 16% WSG, 86% CSG, 38% forbs, 16% milkweed, 3% woody vegetation, 16% bare ground, and 38% litter. When these percentages are added together, they exceed 100%. (A milkweed could be covering 16% of the frame and still have grasses taking up area underneath it.)

Coverage Classes

0	None
1	Trace
3	1-5%
16	5-25%
38	25-50%
63	50-75%
86	75-95%
98	95-100%

Warm Season Grasses

- Typically Native
- Stems are covered in fine hairs
- Often have a red, purple, or blue tint
- Often grow in a bunch or clump
- Common Examples:
    - **Big Bluestem** - straight and tall
    - **Little Bluestem** - straight and short
    - **Indian Grass** - straight and tall
    - **Prairie dropseed** - thin leaves that slowly taper to a very fine point and often fall over to the side
    - **Foxtail**
    - **Crabgrass:** mostly prostrate bunchgrass

Cool Season Grasses

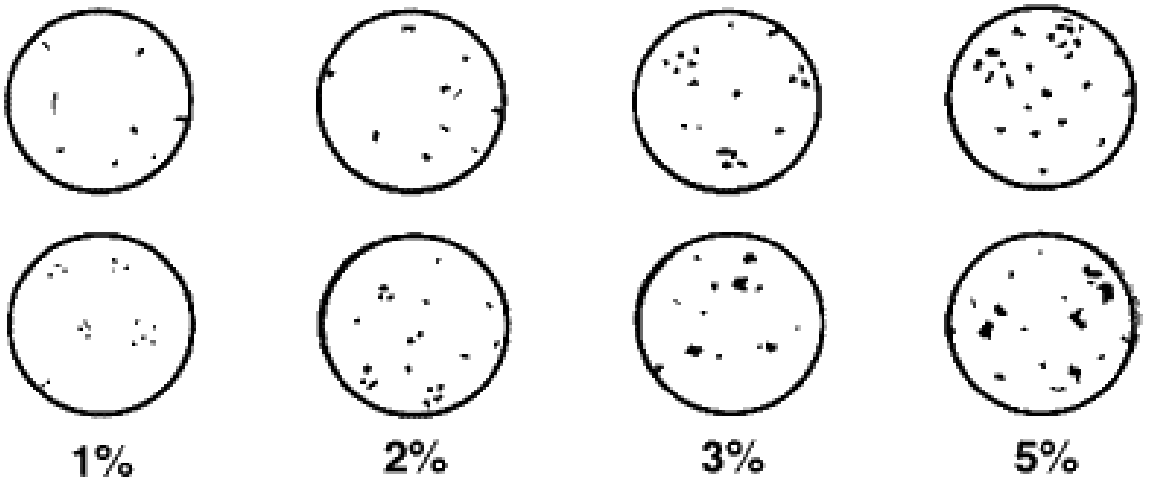
- Typically non-native (Canada or Virginia wildrye are an exceptions)
- Stems are usually bare and not covered in any hairs
- Undersides of leaves are often very rough
- Common Examples:
    - **Canada wildrye**
    - **Quackgrass**
    - **Orchardgrass-** ovalish flat stem
    - **Brome** - has the "M" or "W" marking on the blade, rough but not sharp
    - **Reed Canary Grass** - one of the largest grasses, often in low, wet places
    - **Kentucky Bluegrass** - small grass, most commonly seen as lawn grass
    - **Sedges** - look like typical grasses, but stems are triangular in shape, seed head usually compacted, composed of ball-like structures. Both seed head and leaves are chunkier than grasses

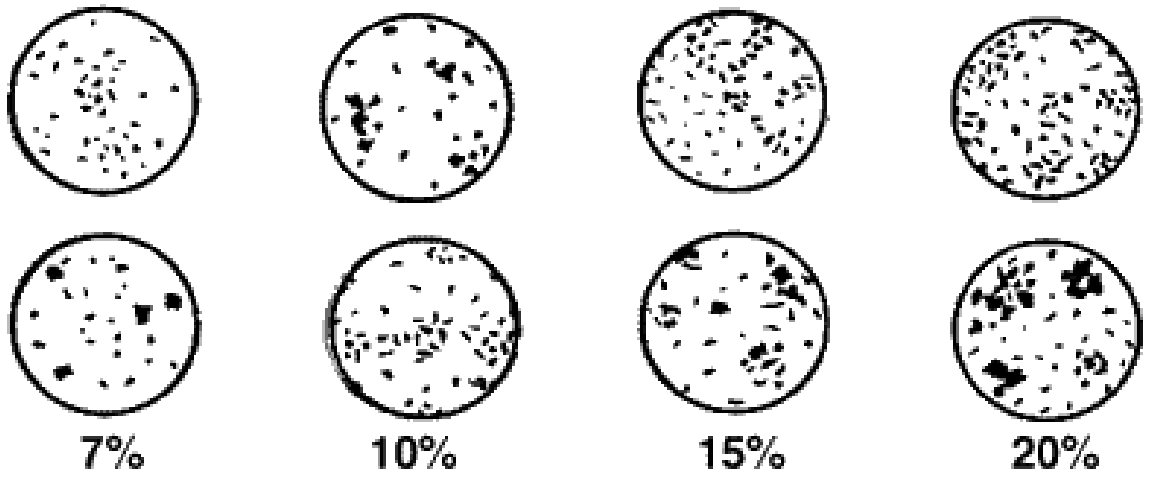
---

Visual Obstruction (Robel)

- Take Robel data at every point on transect that Daubenmire data is collected.
- Place pole in the bottom right corner of the frame next to the flag for each 10m point on the transect.
- Stand 4 meters away from pole with head at height of 1 meter above ground.
- Take robel reading in all 4 directions: N, S, E, W. Direction is in reference to the pole. Observer standing north of the pole is the N reading. It is not what direction the observer is facing.
- Robel reading is highest band on pole at which vegetation obscures ≥50% of band on pole.
    - Example: "4" is barely visible but "5" is unobscured, the reading is 4. Visual obstruction readings are allowed to be zero.

Take care not to trample taller vegetation around each 10m point so that the robel data is as accurate as possible.


1%
2%
3%
5%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10%
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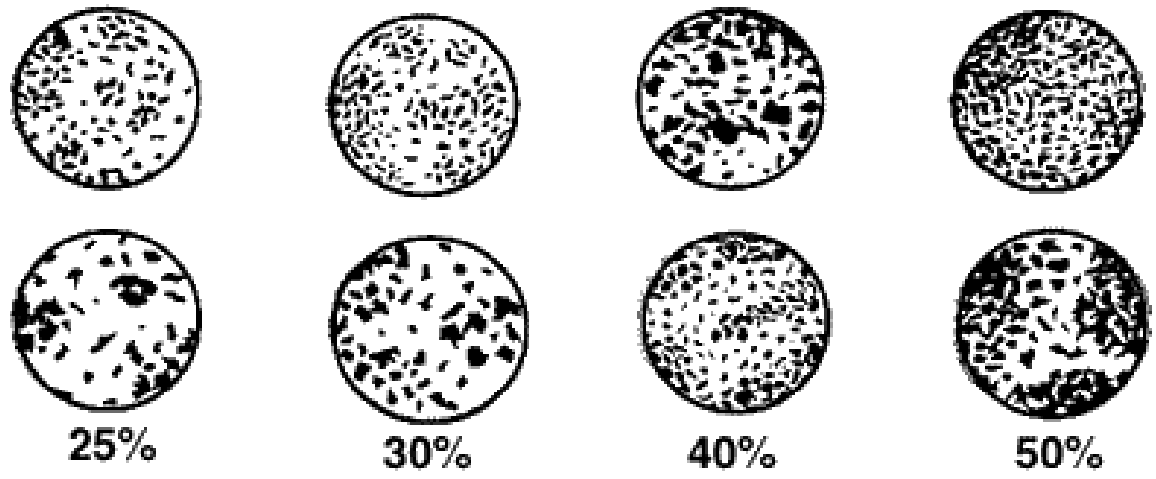
20%


25%
30%
40%
50%

Daubenmire Plant Datasheet

Site:_____

Date:_____

Transect: _____

Field Data Recorded by: _____

ROUND: _____

Team lead _____

Entered into PC by: _____ on this date:_____

Data Entry Checked by_____ on this date:_____

	CSG	WSG	Forbs	Milkweed			Woody Species	Bare Ground	Leaf Litter	Litter Depth	
0 m											
10 m											
20 m											
30 m											
40 m											
50 m											
60 m											
70 m											
80 m											
90 m											

Robel Pole:

	0 m	10 m	20 m	30 m	40 m	50 m	60 m	70 m	80 m	90 m
N										
E										
S										
W										

Transect length: 100 m or _____

Transect Direction N/S or _____

Categories: 0 - absent | 1 - trace | 3 - trace-5% | 16 - 5%-25% | 38 - 25%-50% | 63 - 50%-75% | 86 - 75%-95% | 98 - 95%-100%

CSG - cool season grasses (including sedges)
WSG - warm season grasses
Forbs - forbs not including milkweed
Milkweed

Wood - woody cover
Bare Ground - includes rocks, lichens, moss, branches, and cow pies
Leaf Litter (horizontal dead material),
Litter Depth - to nearest 0.25 cm

Nectar Survey Protocol

- Set up the 100m tape from the start point to the end point with flags placed every 10 meters.
- Do nectar survey on the right side of the transect, with the observer walking a line 1.5m to the right of the transect line.
- The individual recording the numbers should write their name down as 'recorder'. The individual counting the nectar species should write their name down as 'observer'.
- Using a 1 meter measuring device, walk the line 1.5m to the right side of the transect line surveying a 1 meter wide band.
- Count all flowers that are encountered within the 1 m band, identifying each species and their total number for every 10m section. For extremely abundant flowers, estimate by counting by 5's or 10's.

Refer to the 'nectar plant ID guide' documents.

- **record the species common name as it is listed in the 'nectar plant ID guide' documents**
- **use the correct counting method**

Unknown Plants

- Use the provided nectar plant ID resources.
- If plant can't be ID'd:
    - Write '<u>unknown</u> [description]' in data sheet.
    - Example: 'unknown- aster like ½" diameter yellow flower heads'
        - Use a counting unit which seems appropriate and record the counting unit (head, ramet, etc) to the right of the row in the margin
    - Take a quality photo of the flower, leaves, etc.
    - Upload 'unknown' pictures to box after finishing site survey
    - Text/email unknown nectar species picture with the relevant *transect ID, and date* to Seth after finishing site survey

On the data sheet:

- 'common milkweed ramet #', 'swamp milkweed ramet #', 'butterfly milkweed ramet #': count the # of milkweed **ramets** for each milkweed species within the 1m wide sampling area. **It does not matter if the milkweed is flowering or not.** Count milkweed ramets, regardless of flowers.
    - Flowering milkweed should also be recorded in their own row by their individual species (just the same as any other flowering plant).
    - Remember that flowering milkweed is counted by <u>umbels, not ramets</u>.

Nectar Datasheet **Site: _____**

Date: _____ **Transect: _____**

Observer: _____ **Round: _____**

Recorder: _____

Team lead: _____

☐ Survey completed. No milkweed or flowering plants detected

Nectar Plant Species	0-10m	10-20m	20-30m	30-40m	40-50m	50-60m	60-70m	70-80m	80-90m	90-100m
common milkweed ramet #										
swamp milkweed ramet #										
butterfly milkweed ramet #										

Monarch Survey Protocol

Monarch survey should be done first, before all other data is collected at the site. This is to prevent disturbing the habitat, resulting in inaccurate monarch count data.

Adult Monarchs

- Observe and record the number of monarchs seen both inside and outside the plot. This is a 1 person job.
- Only record monarchs which are seen in front of oneself. Don't turn around to attempt to spot monarchs. (Observe the 180° directly in front of oneself.)
- Observe for 20 minutes, walking at a pace of 2 minutes per 10m section.
    - Walk on the immediate right side of the transect
    - Use a stopwatch to time your pace.
    - If transect is shorter than 100m, repeat walk.
    - To repeat: stop the time, walk around plot, return to transect start.
    - Every site should be surveyed for 20 minutes. No more, no less.
- Record adult monarchs as inside or outside plot based on first sighting of monarch
- Extra Monarchs
    - Record number of monarchs observed outside 20 minute monitoring time; anywhere in the area.

Egg and Larvae Count #'s

- For each of the three milkweed species survey 10 randomly selected milkweed ramets (within the plot) to obtain a count of eggs and instars.
    - A running tally will help keep track of milkweed ramet # observed for each species.
- Record # of milkweed ramets surveyed. If no ramets observed, write '0'. If >10 milkweed are present for any specific species, only survey 10 milkweed.
    - 30 total milkweed ramets would be surveyed if all 3 species have 10 ramets
- If possible, survey milkweed ramets throughout the area of the plot (not simply in a few patches or just in one corner)
    - Survey a ramet, then walk 5-10 meters away and survey next closest ramet, generally traveling with the length of the plot.
    - Attempt to survey healthy and unhealthy ramets, tall and short ramets.
        - Do not be biased by selecting only the 'best' ramets
- Inspect the entire ramet for milkweed larvae/eggs
    - Eggs are most commonly found on undersides of younger, upper leaves and sometimes on the buds/flowers.

Palmer Amaranth

- Record total # of palmer amaranth found in plot.
- See "Palmer Amaranth" protocol sheet for protocols

Monarch Datasheet **Site: _____**

Date: _____ **Transect: _____**

Observer: _____ **Round: _____**

Recorder: _____

Team lead: _____

Adult Monarchs

☐ No survey. Reason: _____

Start Time: _____

# Inside Plot	# Outside Plot

Total # sighted in 20 minutes walking on right side of transect @ rate of 2 minutes per 10m section. Repeat walk as needed to reach 20 minutes. To repeat: stop the time, walk around plot, return to transect start.

	Extra Monarchs

Total # sighted outside of 20 minute transect monitoring time, anywhere in the area.

Egg and Larvae Count #'s (only inside plot area)			
	Common	Swamp	Butterfly
# milkweed ramets surveyed **(0-10)**			
eggs			
1instar			
2instar			
3instar			
4instar			
5instar			

Palmer Amaranth Scouting Protocol

Use Palmer ID guides: https://store.extension.iastate.edu/Product/14794
https://www.extension.purdue.edu/extmedia/ws/ws-51-w.pdf

Palmer Amaranth defining characteristics: hairless stems, leaves (palmer: wider ovate, waterhemp: long lanceolate), some petioles longer than leaves , more dense patterned rosette than waterhemp, long thick seed head, sharp bracts on female seed head

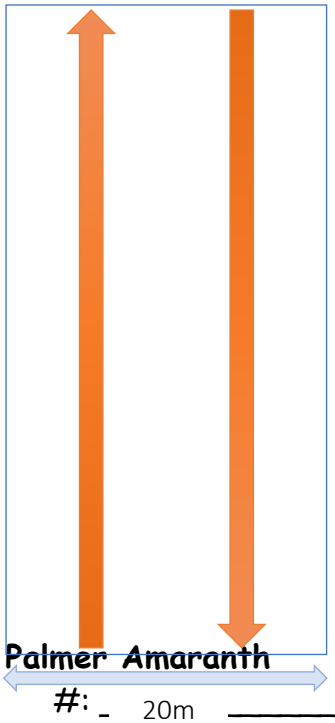
Protocol

Scout plot area by covering 10m swath every pass (observe 5m to each side). A single person would make two passes to scout a 20m wide plot, 3 passes for a 30m wide plot. Two people, each covering 10m swath can scout 20m wide plot in 1 pass or 40m wide plot in 2 passes. See diagram below.

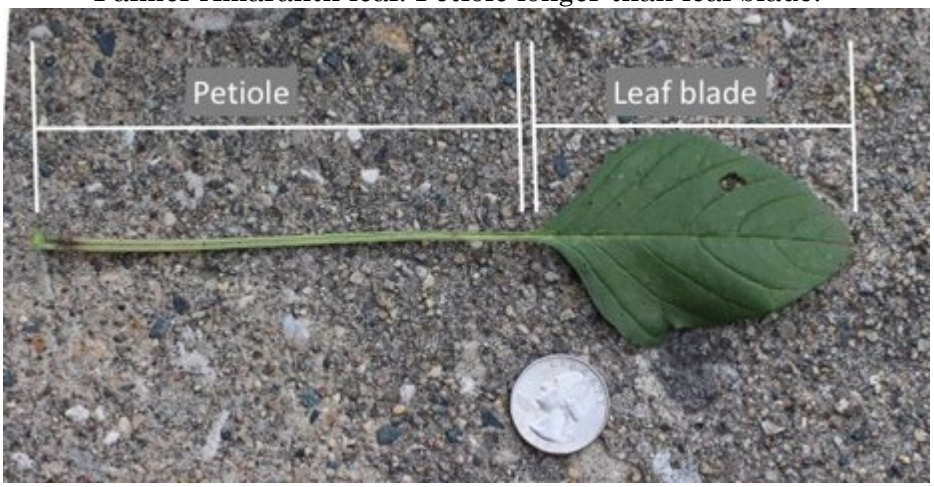
If palmer amaranth is found:

- Take ≥2 pictures and upload them to cybox:
  - Picture 1: the plant. Picture 2: a leaf with a petiole longer than the leaf (shown below)
  - Example cybox name: 'cra1_7-17-2017_palmer(1)'
- Seeds formed= pull it, put in paper bag, take bag to vehicle when finished scouting.
  - Remove and bag every palmer plant with seed formed
- Label paper bags with:
  - Transect ID
  - Date
  - Words "Palmer Amaranth"
- Record total number of palmer amaranth found on 'Monarch' data sheet
- Bring palmer amaranth paper bags back to campus and place them next to Seth's desk

Single person scouting a 20m wide plot



Palmer Amaranth leaf. Petiole longer than leaf blade.



Bee Survey Protocol

- Walk along the left side of the transect, 1.5m from the transect line at a rate of 2 minutes/10m section.
- Survey 3m wide strip.
- Conduct survey for 20 minutes.
    - Repeat walk as needed to reach 20 minutes.
    - To repeat: stop the time, walk around plot, return to transect start.
    - Use a stopwatch/phone to time
    - Avoid trampling: When finished with survey, walk around plot. Not through it.

On data sheet

- Always record the start time of the survey if a survey was completed
- In 'Bee Species Column' write the word 'honey bee', 'bumble bee', or 'solitary bee' when a bee is sited
    - Do not capture any bees
- Identify the plant that a bee is nectaring on when it is first sighted
    - Use the 'Nectar Plant ID Guide' resources to help ID the nectar species

Bee Datasheet **Site: _____**

Date: _____ **Transect: _____**

Observer: _____ **Round: _____**

Recorder: _____

Team lead: _____

☐ No survey. Reason: _____

☐ Survey Completed. No bees detected

Start Time: _____

Bee Species	Nectar Plant Species	0-10m	10-20m	20-30m	30-40m	40-50m	50-60m	60-70m	70-80m	80-90m	90-100m

Appendix C

Summary Statistics: Establishing Monarch Butterfly Breeding Habitat on Iowa Swine Production Sites

Jarad Niemi, Seth Appelgate, and Nehemias Ulloa

2019-04-01

Table 1, 2, and 3 provide mean count of nectar plant species averaged across all data collection events within a year. Values in table represent the specific floral counting unit for each species (flower head, ramet [stem], spike, or umbel) and is not associated with number of plants. Floral counting units differ between species. Table 4, 5, and 6 provide nectar plant species floral unit density (per m2) averaged across all data collection events within a year. Table 7 provides mean counts of milkweed ramets. This data is unavailable for 2016 therefore 2016 does not have an associated milkweed ramet table or figure. Table 8 provides mean density of milkweed ramets.

Figures 1, 2, 3, 4, and 5 are heatmaps which plot the log density of species floral counting units (planted as part of the seed mix and non-planted species) with transects on the columns and species on the rows; transects are sorted by average density and species are sorted by average presence. Figure 6 is a heatmap which plots the log density of milkweed ramets with transects on the columns and species on the rows; transects are sorted by average density and species are sorted by average presence.

Table 1: 2016 nectar plant species: mean count across all surveys

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
common dandelion	-	-	-	1.0	5.0	26.7	18.7	19.0	1.0	13.7	17.7	-
plantain	-	-	-	98.3	6.7	-	-	-	-	17.7	37.3	-
red clover	16.7	-	-	-	-	-	-	-	-	-	-	-
white clover	3.3	42.0	-	116.3	13.3	763.3	318.3	624.3	41.7	279.3	365.7	20.7
yellow sweet clover	-	-	-	-	-	-	-	1.3	-	-	-	-

Table 2: 2017 nectar plant species: mean count across all surveys

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
alfalfa	-	16.7	-	-	-	-	-	-	-	-	-	-
black eyed susan	10.7	-	-	0.3	1.7	1.7	0.3	-	1.7	0.3	-	0.3
black medic	1.0	102.0	1.3	10.3	-	8.3	0.7	6.7	0.3	-	2.0	-
blue vervain	1.0	-	-	-	-	-	-	-	-	-	-	-
common cinquefoil	-	-	-	-	-	-	5.3	-	-	-	0.3	-
common dandelion	3.0	5.7	1.7	1.0	6.0	6.0	1.3	2.0	-	-	-	1.0
compass plant	0.3	-	-	-	-	-	-	-	-	-	-	-
eastern daisy fleabane	-	-	-	-	33.3	-	-	-	-	-	-	-
marestail	20.3	-	-	-	-	-	-	-	-	-	-	-
musk thistle	-	-	-	-	1.0	-	-	-	-	-	-	-
ox eye sunflower	-	-	-	-	-	-	-	-	-	-	-	0.3
partridge pea	2.7	5.0	4.0	-	-	0.3	-	-	0.3	-	-	1.3
pineapple weed	-	-	-	-	10.7	-	-	-	-	-	-	-
prostrate vervain	-	70.0	-	-	-	-	-	-	-	-	155.0	-
queen annes lace	-	-	-	-	-	1.3	-	-	-	-	-	-
red clover	105.7	-	-	-	-	-	-	-	-	-	-	-
shepherds purse	-	-	-	-	-	-	-	-	-	36.7	-	-
smartweed	84.0	17.7	39.7	-	151.0	15.0	9.0	10.7	119.0	-	7.3	3.7
velvetleaf	0.7	-	-	-	-	-	-	-	-	-	-	-
white clover	249.0	33.7	-	9.0	3.3	18.0	32.3	49.3	3.0	11.0	22.3	-
yellow coneflower	-	-	-	-	-	1.7	-	-	-	-	-	-

Table 3: 2018 nectar plant species: mean count across all surveys

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
alfalfa	0.3	-	-	-	-	-	-	-	-	-	-	-
black eyed susan	-	-	-	-	-	-	2.7	20.3	2.7	7.3	-	-
black medic	-	85.3	-	86.3	33.3	3.3	1.7	21.7	-	35.0	36.7	-
bladder campion	-	-	-	2.7	-	21.7	7.7	-	-	-	-	-
blue vervain	-	-	-	20.0	-	65.7	-	35.0	5.0	-	-	-
bog yellow-cress	-	-	-	7.3	-	0.7	-	38.0	-	-	-	-
butterfly milkweed	-	-	-	-	-	-	-	-	-	-	-	1.0
canada goldenrod	-	-	-	-	-	2.0	-	-	-	0.3	-	-
canada lettuce	-	-	-	-	-	-	-	-	-	-	-	21.7
canada milk vetch	-	-	-	-	-	-	0.7	-	-	-	-	1.0
canada thistle	8.3	-	-	12.3	5.3	1.7	-	-	-	-	-	23.3
catnip	-	-	-	-	-	10.7	-	-	-	-	-	-
common cinquefoil	3.0	23.0	-	94.3	119.3	273.0	205.0	35.3	236.7	153.3	264.0	16.7
common dandelion	-	5.0	2.3	6.7	12.0	2.0	2.0	6.0	0.7	1.0	8.7	7.0
common evening primrose	-	2.7	-	28.7	-	-	-	23.3	-	-	-	-
cup plant	-	-	65.0	-	-	-	-	-	-	-	-	-
eastern daisy fleabane	-	-	-	0.7	277.0	0.7	0.3	0.3	1.7	23.7	-	-
field pennycress	-	13.7	101.0	-	-	-	-	-	-	-	-	-
field thistle	-	-	-	2.3	1.0	-	0.7	-	-	-	-	-
foxglove beardtongue	-	-	-	10.7	25.3	25.7	1.0	31.0	38.3	-	0.7	16.0
golden alexanders	-	-	-	-	-	-	-	-	-	-	8.3	1.7
hoary vervain	4.0	1.0	0.3	5.7	18.7	24.0	5.7	6.7	3.3	-	0.7	10.7
ironweed	0.3	-	1.3	-	-	-	-	-	-	-	-	-
marestail	13.7	1.7	0.7	-	-	-	-	0.3	-	-	0.3	29.0
morning glory	-	1.3	-	-	-	-	-	-	-	-	-	-
musk thistle	-	-	-	-	44.3	3.3	-	-	-	-	-	-
nodding stickseed	-	-	-	3.0	26.3	-	-	-	-	-	-	-
ox eye sunflower	62.7	71.0	4.3	110.0	189.7	477.0	91.3	166.7	1.3	28.7	145.3	128.0
pale purple coneflower	-	-	1.3	-	0.7	-	-	-	-	-	-	2.3
partridge pea	-	-	-	1.3	1.3	-	-	-	-	-	2.3	-
pineapple weed	-	-	-	-	-	-	-	-	-	-	-	125.0
prairie cinquefoil	-	-	0.7	-	-	-	-	-	-	-	-	-
prickly lettuce	-	6.7	-	42.7	40.3	-	-	-	-	-	-	-
prostrate vervain	-	0.7	-	-	-	-	-	-	-	99.3	24.3	-
purple prairie clover	-	-	-	-	-	-	-	-	0.7	-	-	1.0
queen annes lace	-	-	-	-	-	-	-	-	-	8.3	-	-
red clover	290.7	176.3	-	16.7	1.7	-	-	-	-	-	-	-
rough cinquefoil	-	-	-	-	-	-	-	-	-	-	-	16.7

Table 3(cont'd): 2018 nectar plant species: mean count across all surveys

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
shepherds purse	-	4.3	68.3	-	-	-	-	-	-	-	-	-
smartweed	18.3	-	-	104.7	54.3	78.3	-	10.0	-	-	221.7	226.7
stiff goldenrod	-	-	-	-	-	1.0	-	-	-	-	-	-
velvetleaf	-	-	1.7	-	-	-	-	-	-	-	-	-
virginia mountain mint	-	-	-	9.3	-	-	-	-	22.7	-	-	-
white clover	51.3	717.0	1.7	793.0	109.0	1245.3	1210.0	1970.3	498.7	403.0	1373.3	4.7
white heath aster	-	-	-	-	-	-	-	-	0.3	37.0	-	-
white sweet clover	-	125.7	0.3	78.0	3.0	2.3	10.3	4.0	-	8.0	-	-
wild bergamot	0.7	-	-	39.7	71.7	50.7	36.0	31.7	-	18.7	53.0	81.0
wild mustard	-	-	-	-	-	-	-	-	-	3.7	13.3	-
wild parsnip	0.3	-	-	-	-	-	-	-	-	-	-	-
yellow coneflower	153.7	119.0	143.7	409.3	788.3	860.0	345.0	836.7	337.0	268.0	528.3	612.0
yellow sweet clover	58.0	-	-	6.7	4.3	1.3	14.7	23.7	-	11.0	12.3	-
yellow wood sorrel	2.0	-	-	-	-	-	-	-	-	-	-	2.0

Table 4: 2016 nectar plant species density: average density (count / m2) across all rounds

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
common dandelion	-	-	-	0.01	0.05	0.27	0.37	0.19	0.02	0.17	0.18	-
plantain	-	-	-	1.23	0.07	-	-	-	-	0.22	0.37	-
red clover	0.33	-	-	-	-	-	-	-	-	-	-	-
white clover	0.07	0.84	-	1.46	0.13	7.63	6.37	6.24	0.83	3.49	3.66	0.69
yellow sweet clover	-	-	-	-	-	-	-	0.01	-	-	-	-

Table 5: 2017 nectar plant species density: average density (count / m2) across all rounds

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
alfalfa	-	0.33	-	-	-	-	-	-	-	-	-	-
black eyed susan	0.21	-	-	0.00	0.02	0.02	0.01	-	0.03	0.00	-	0.01
black medic	0.02	2.04	0.03	0.13	-	0.08	0.01	0.07	0.01	-	0.02	-
blue vervain	0.02	-	-	-	-	-	-	-	-	-	-	-
common cinquefoil	-	-	-	-	-	-	0.11	-	-	-	0.00	-
common dandelion	0.06	0.11	0.03	0.01	0.06	0.06	0.03	0.02	-	-	-	0.03
compass plant	0.01	-	-	-	-	-	-	-	-	-	-	-
eastern daisy fleabane	-	-	-	-	0.33	-	-	-	-	-	-	-
marestail	0.41	-	-	-	-	-	-	-	-	-	-	-
musk thistle	-	-	-	-	0.01	-	-	-	-	-	-	-
ox eye sunflower	-	-	-	-	-	-	-	-	-	-	-	0.01
partridge pea	0.05	0.10	0.08	-	-	0.00	-	-	0.01	-	-	0.04
pineapple weed	-	-	-	-	0.11	-	-	-	-	-	-	-
prostrate vervain	-	1.40	-	-	-	-	-	-	-	-	1.55	-
queen annes lace	-	-	-	-	-	0.01	-	-	-	-	-	-
red clover	2.11	-	-	-	-	-	-	-	-	-	-	-
shepherds purse	-	-	-	-	-	-	-	-	-	0.46	-	-
smartweed	1.68	0.35	0.79	-	1.51	0.15	0.18	0.11	2.38	-	0.07	0.12
velvetleaf	0.01	-	-	-	-	-	-	-	-	-	-	-
white clover	4.98	0.67	-	0.11	0.03	0.18	0.65	0.49	0.06	0.14	0.22	-
yellow coneflower	-	-	-	-	-	0.02	-	-	-	-	-	-

Table 6: 2018 nectar plant species density: average density (count / m2) across all rounds

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
alfalfa	0.01	-	-	-	-	-	-	-	-	-	-	-
black eyed susan	-	-	-	-	-	-	0.05	0.20	0.05	0.09	-	-
black medic	-	1.71	-	1.08	0.33	0.03	0.03	0.22	-	0.44	0.37	-
bladder campion	-	-	-	0.03	-	0.22	0.15	-	-	-	-	-
blue vervain	-	-	-	0.25	-	0.66	-	0.35	0.10	-	-	-
bog yellow-cress	-	-	-	0.09	-	0.01	-	0.38	-	-	-	-
butterfly milkweed	-	-	-	-	-	-	-	-	-	-	-	0.03
canada goldenrod	-	-	-	-	-	0.02	-	-	-	0.00	-	-
canada lettuce	-	-	-	-	-	-	-	-	-	-	-	0.72
canada milk vetch	-	-	-	-	-	-	0.01	-	-	-	-	0.03
canada thistle	0.17	-	-	0.15	0.05	0.02	-	-	-	-	-	0.78
catnip	-	-	-	-	-	0.11	-	-	-	-	-	-
common cinquefoil	0.06	0.46	-	1.18	1.19	2.73	4.10	0.35	4.73	1.92	2.64	0.56
common dandelion	-	0.10	0.05	0.08	0.12	0.02	0.04	0.06	0.01	0.01	0.09	0.23
common evening primrose	-	0.05	-	0.36	-	-	-	0.23	-	-	-	-
cup plant	-	-	1.30	-	-	-	-	-	-	-	-	-
eastern daisy fleabane	-	-	-	0.01	2.77	0.01	0.01	0.00	0.03	0.30	-	-
field pennycress	-	0.27	2.02	-	-	-	-	-	-	-	-	-
field thistle	-	-	-	0.03	0.01	-	0.01	-	-	-	-	-
foxglove beardtongue	-	-	-	0.13	0.25	0.26	0.02	0.31	0.77	-	0.01	0.53
golden alexanders	-	-	-	-	-	-	-	-	-	-	0.08	0.06
hoary vervain	0.08	0.02	0.01	0.07	0.19	0.24	0.11	0.07	0.07	-	0.01	0.36
ironweed	0.01	-	0.03	-	-	-	-	-	-	-	-	-
marestail	0.27	0.03	0.01	-	-	-	-	0.00	-	-	0.00	0.97
morning glory	-	0.03	-	-	-	-	-	-	-	-	-	-
musk thistle	-	-	-	-	0.44	0.03	-	-	-	-	-	-
nodding stickseed	-	-	-	0.04	0.26	-	-	-	-	-	-	-
ox eye sunflower	1.25	1.42	0.09	1.38	1.90	4.77	1.83	1.67	0.03	0.36	1.45	4.27
pale purple coneflower	-	-	0.03	-	0.01	-	-	-	-	-	-	0.08
partridge pea	-	-	-	0.02	0.01	-	-	-	-	-	0.02	-
pineapple weed	-	-	-	-	-	-	-	-	-	-	-	4.17
prairie cinquefoil	-	-	0.01	-	-	-	-	-	-	-	-	-
prickly lettuce	-	0.13	-	0.53	0.40	-	-	-	-	-	-	-
prostrate vervain	-	0.01	-	-	-	-	-	-	-	1.24	0.24	-
purple prairie clover	-	-	-	-	-	-	-	-	0.01	-	-	0.03
queen annes lace	-	-	-	-	-	-	-	-	-	0.10	-	-
red clover	5.81	3.53	-	0.21	0.02	-	-	-	-	-	-	-
rough cinquefoil	-	-	-	-	-	-	-	-	-	-	-	0.56

Table 6 (cont'd): 2018 nectar plant species density: average density (count / m2) across all rounds

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre6a	tpre7a	tpre8a	ttie1a
shepherds purse	-	0.09	1.37	-	-	-	-	-	-	-	-	-
smartweed	0.37	-	-	1.31	0.54	0.78	-	0.10	-	-	2.22	7.56
stiff goldenrod	-	-	-	-	-	0.01	-	-	-	-	-	-
velvetleaf	-	-	0.03	-	-	-	-	-	-	-	-	-
virginia mountain mint	-	-	-	0.12	-	-	-	-	0.45	-	-	-
white clover	1.03	14.34	0.03	9.91	1.09	12.45	24.20	19.70	9.97	5.04	13.73	0.16
white heath aster	-	-	-	-	-	-	-	-	0.01	0.46	-	-
white sweet clover	-	2.51	0.01	0.97	0.03	0.02	0.21	0.04	-	0.10	-	-
wild bergamot	0.01	-	-	0.50	0.72	0.51	0.72	0.32	-	0.23	0.53	2.70
wild mustard	-	-	-	-	-	-	-	-	-	0.05	0.13	-
wild parsnip	0.01	-	-	-	-	-	-	-	-	-	-	-
yellow coneflower	3.07	2.38	2.87	5.12	7.88	8.60	6.90	8.37	6.74	3.35	5.28	20.40
yellow sweet clover	1.16	-	-	0.08	0.04	0.01	0.29	0.24	-	0.14	0.12	-
yellow wood sorrel	0.04	-	-	-	-	-	-	-	-	-	-	0.07

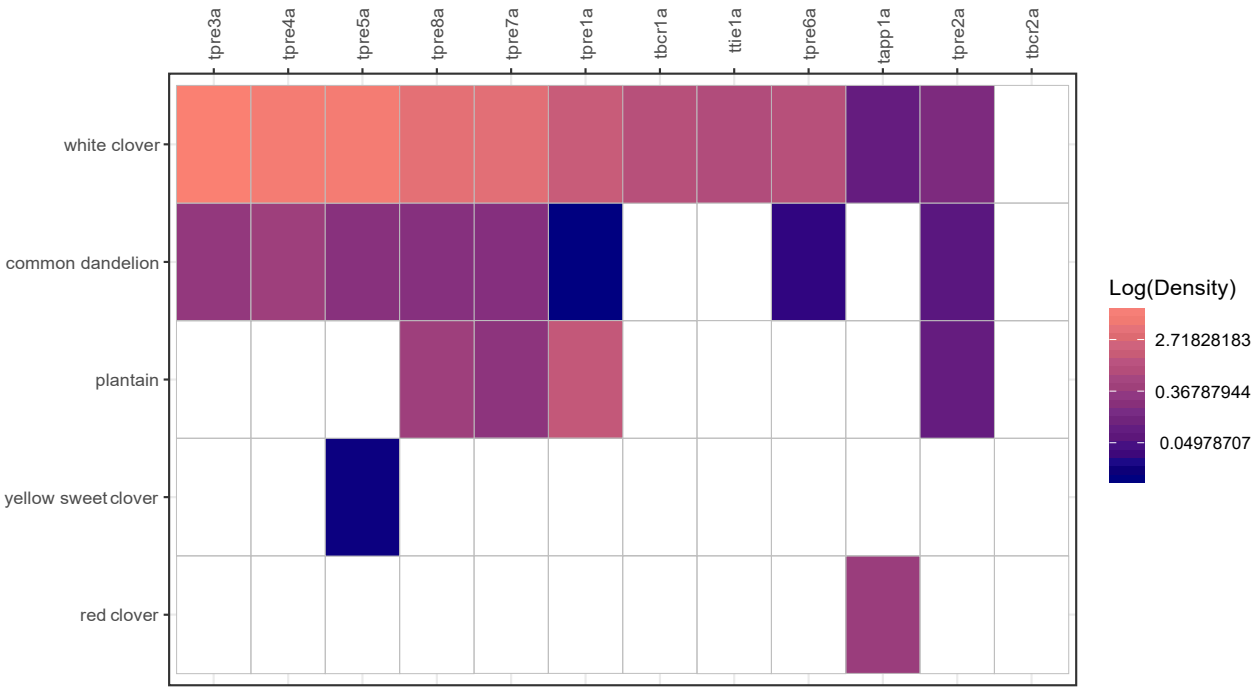


Figure 1: This plot is a heatmap for density of nectar species planted and non-planted with transects on the columns and species on the rows sorting transects by average density and sorting species by avg presence for year 2016.

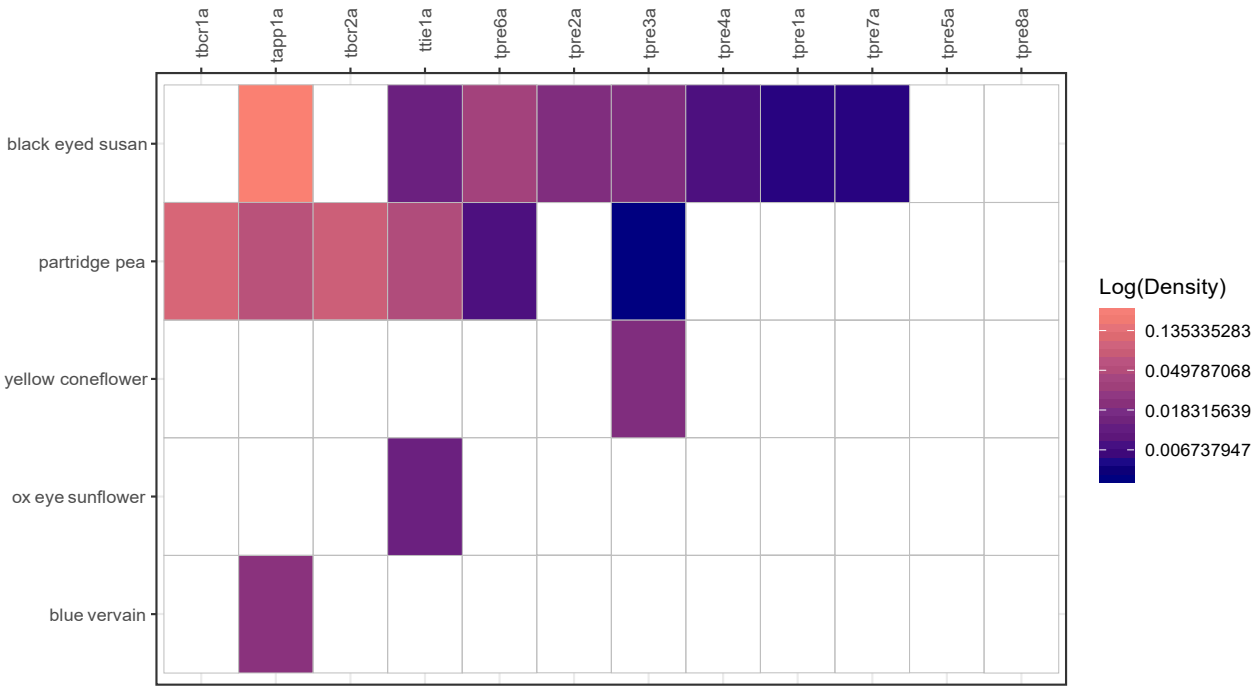


Figure 2: This plot is a heatmap for density of nectar species planted with transects on the columns and species on the rows sorting transects by average density and sorting species by avg presence for year 2017.

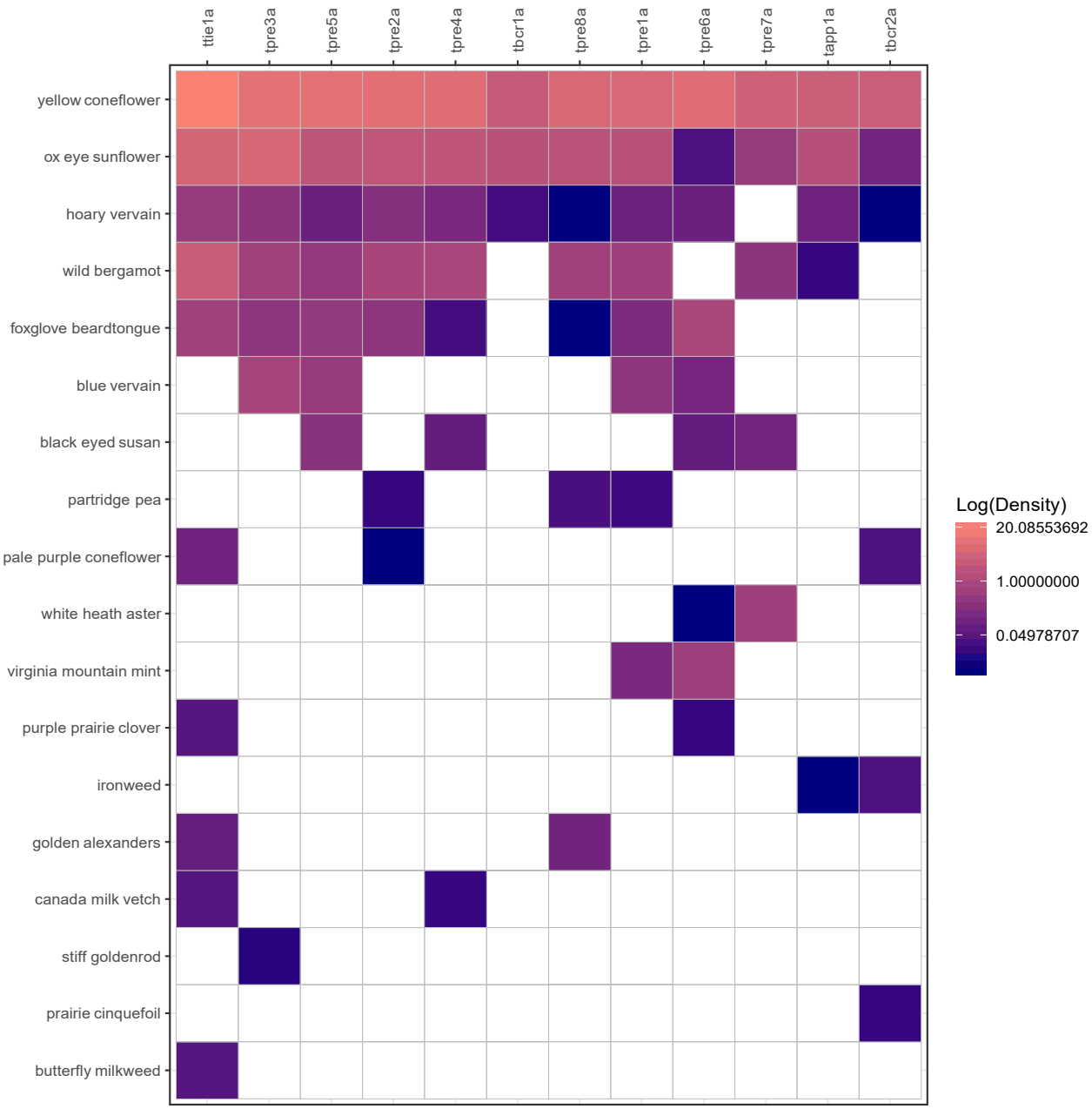


Figure 3: This plot is a heatmap for density of nectar species planted with transects on the columns and species on the rows sorting transects by average density and sorting species by average presence for year 2018.

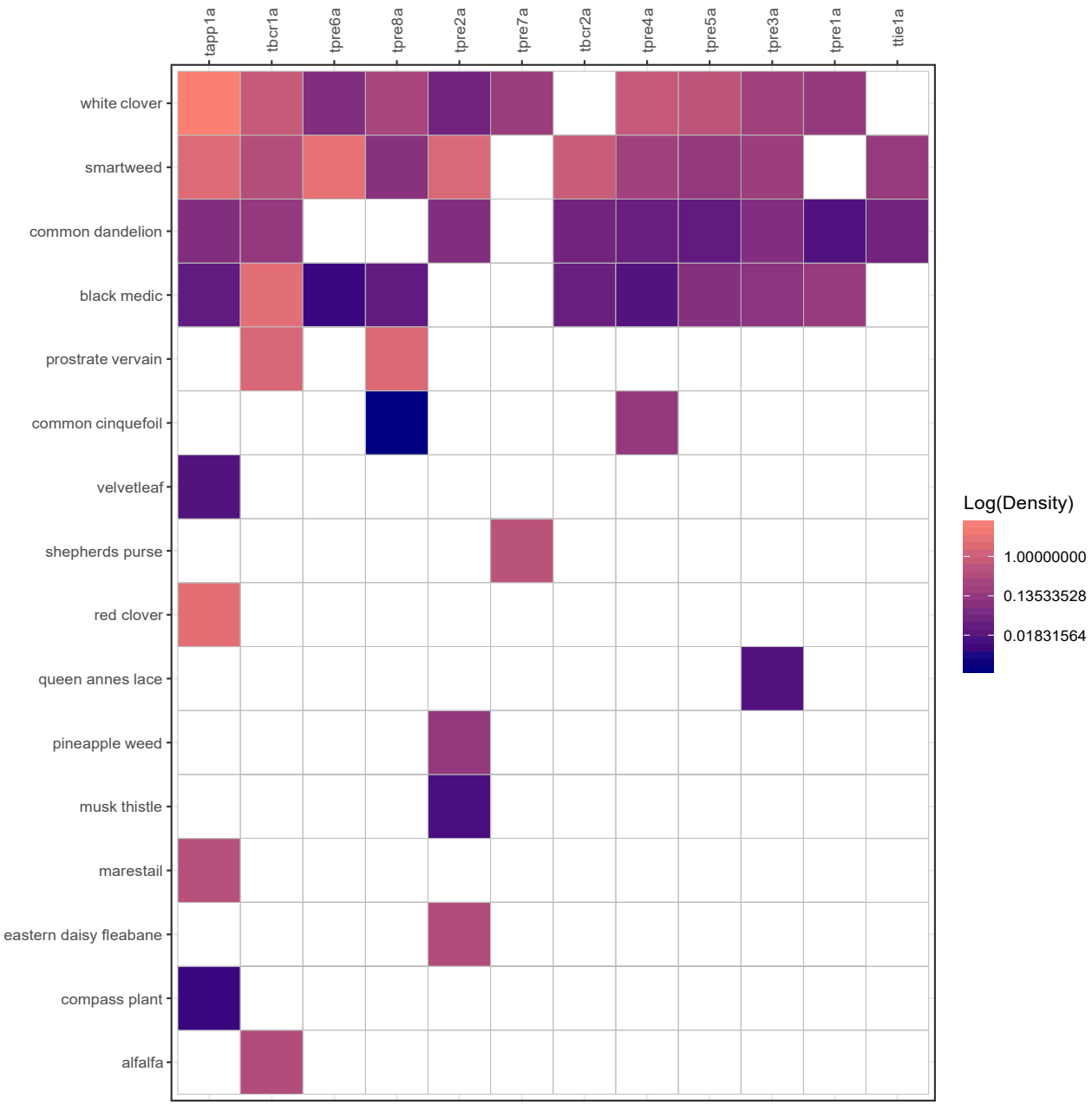


Figure 4: This plot is a heatmap for density of nectar species non planted with transects on the columns and species on the rows sorting transects by average density and sorting species by average presence for year 2017.

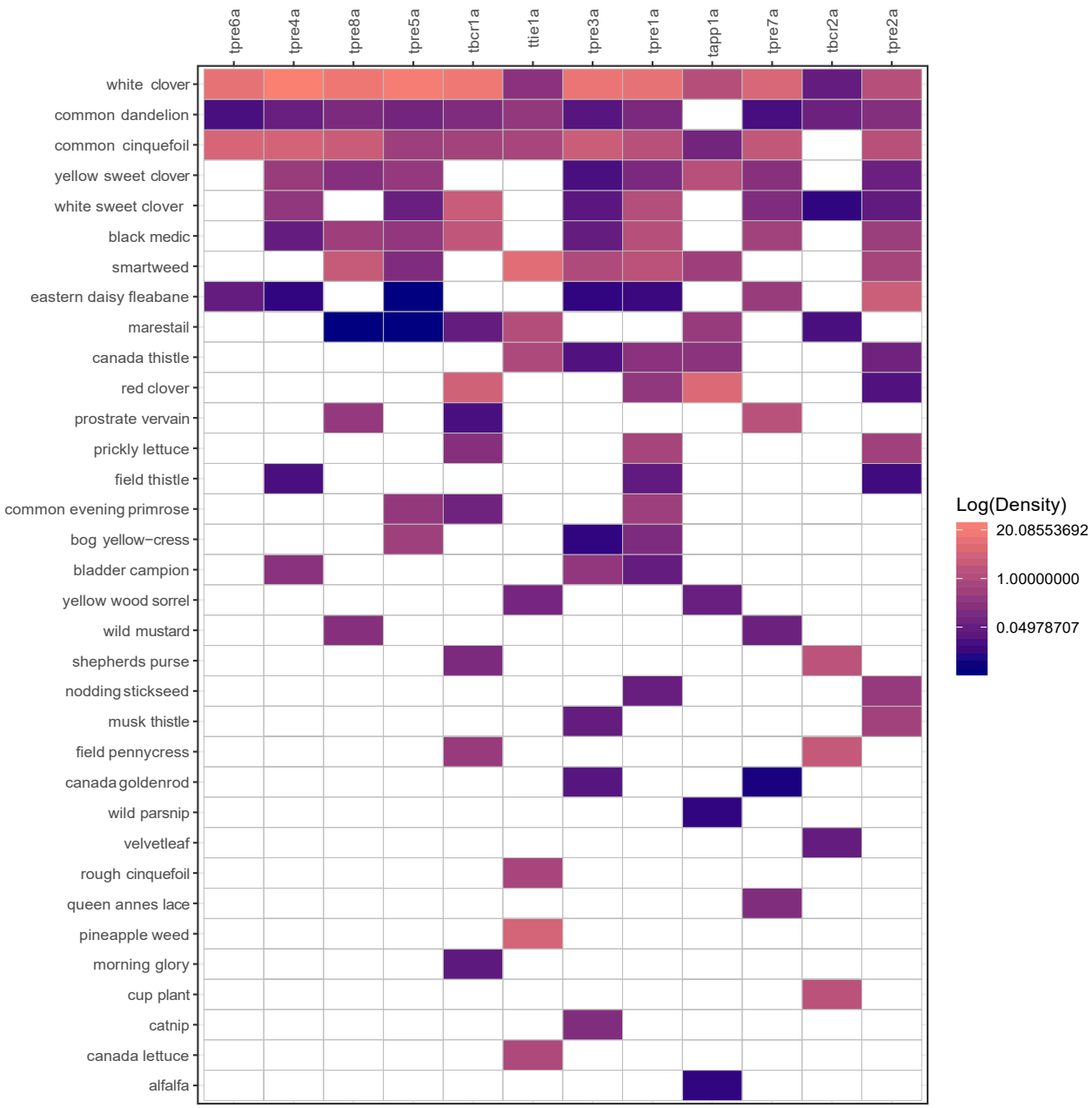


Figure 5: This plot is a heatmap for density of nectar species non planted with transects on the columns and species on the rows sorting transects by average density and sorting species by average presence for year 2018.

Table 7: 2018 ramet plant species: mean count across all surveys

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre8a	tpre7a	tpre6a	ttie1a
butterfly milkweed ramet	-	0.3	-	-	-	-	-	-	-	-	-	0.3
common milkweed ramet	0.3	1.3	0.3	0.7	1.0	8.3	0.3	0.7	1.0	-	0.7	0.7
swamp milkweed ramet	0.3	-	-	-	-	0.3	-	-	-	0.3	-	-

Table 8: 2018 ramet plant species density: average density (count / m2) across all rounds

Nectar Plant Species	tapp1a	tbcr1a	tbcr2a	tpre1a	tpre2a	tpre3a	tpre4a	tpre5a	tpre8a	tpre7a	tpre6a	ttie1a
butterfly milkweed ramet	-	0.01	-	-	-	-	-	-	-	-	-	0.01
common milkweed ramet	0.01	0.03	0.01	0.01	0.01	0.08	0.01	0.01	0.02	-	0.01	0.02
swamp milkweed ramet	0.01	-	-	-	-	0.00	-	-	-	0.00	-	-

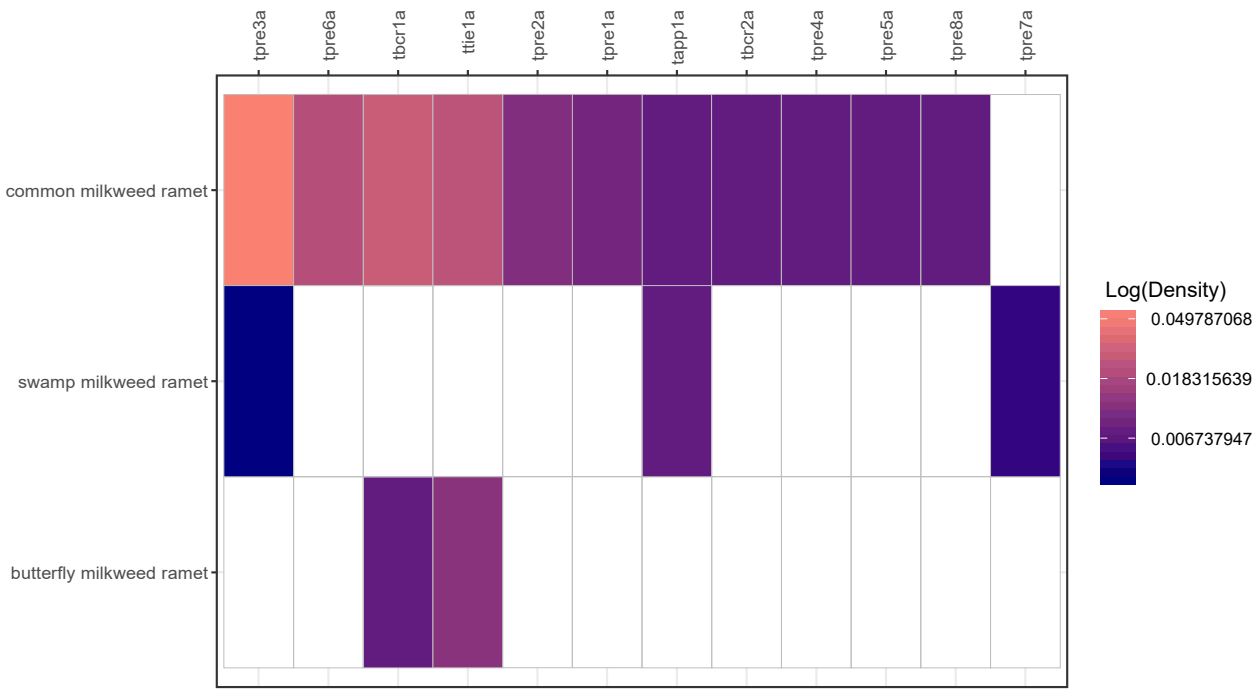


Figure 6: This plot is a heatmap for density of ramet species with transects on the columns and species on the rows sorting transects by average density and sorting species by average presence for year 2018.