F14AP00394
Final Report
on the Search for the
Rattlesnake Master Borer Moth
Papaipema eryngii Bird
(Lepidoptera: Noctuidae)
in the
State of Iowa

Papaipema eryngii
Male
St. Clair County, Missouri

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Submitted May10, 2017

Acknowledgments

I cannot begin to list all the people who have been of assistance in one way or another to this project, and it has truly been a pleasure working with all of them. My intense interest in moths in the genus *Papaipema* can be directly attributed to the field work I did over many years with Eric L. Quinter, retired from the American Museum of Natural History in New York, now of Connecticut. His thoughts, guidance and teaching have tested me throughout this lifetime of studying a small corner of the natural world, and I am better for it. I also thank Anthony E. McBride of New Jersey, my friend, editing consultant and field companion for the last decade in pursuit of these moths, and at times, the only person who truly understands me. The three of us constitute the major living information bank on this group of moths. My own part of our collective knowledge has not been gained without a lot of help. Tim Cashatt, retired from the Illinois State Museum, has guided me since I was seven years old; his mentoring has been priceless. The late Mogens C. Nielsen (who pushed me into moths decades ago), along with Ted Herig, both from Michigan, have contributed to the knowledge of the genus and to me personally. The late Bill Black of Kentucky and I studied the genus together for many years. Thanks to Vern LaGesse, who was with me on my early forays in studying *Papaipema eryngii*. Terry Esker, of the Illinois Department of Natural Resources, has provided in assistance for many years in Illinois. Many others too numerous to mention have helped me along the way.

The writing of this paper would not have been nearly as well done were it not for the time-consuming editing effort of my friend, microlepidopterist Terry Harrison of Charleston, IL, to whom I'm forever indebted on so many levels. A huge thank you to my friend and field colleague Paul McKenzie, USFWS, Columbia, MO; without his support, personal contacts, editing, advice and enthusiasm, this project never would have gotten off the ground. Steve Buback and Kelly Rezac of the Missouri Department of Conservation were both tremendously helpful and patient throughout this project, always at the ready if I needed something. They, along with a whole host of people from MDC, including Norman Murray, Chris Newbold, Andrea Schuhmann and Krista Noel were all helpful and supportive throughout this endeavor.

Thank you Dana Hoisington, the Naturalist at Prairie State Park, and Christopher Crabtree of Missouri Department of Natural Resources, for their efforts in locating a population of *Papaipema eryngii* in the park. Thanks to Katy Holmer, Site Superintendent, and "the Knox girls" at Prairie State Park, who took the time and interest to learn more about this moth. Thanks to Ken McCarty of Missouri State Parks, who kept things going smoothly, and to all others involved from MoDNR.

Thanks also to all who helped from The Nature Conservancy, and to the people of the Missouri Prairie Foundation, especially Bruce Schuette and Carol Davit, for their help, and for what they do to save prairie habitats.

To all the others who in some way, large or small impacted my time in Missouri and Iowa, I thank you as well.

Many private individuals shared their time, property or expertise over the course of this project, and I want to recognize them as well, in no particular order. All were gracious and helpful, and I thank them all, as they made this a better survey.

Garry and Larry Houf of the Houf Farm, Kingdom City, MO.
Tim and Trana Madsen, Kingdom City, MO.
Tom and Cathy Aley- Ozark Underground Laboratory, Protem, MO.
Henry and Lorna Domke of Prairie Garden Trust near New Bloomfield, MO.
Susan Lordi Marker and Dennis Marker from the Sedalia, MO area.
Jon Rapp, ambitious photographer from around Columbia, MO.
Donna Brunet, photographer and entomologist, Columbia, MO.
Susan Dees Hargrove, Springfield, IL.

Finally, thank you to my fellow lepidopterists from Missouri for their knowledge, companionship and hospitality throughout this project.

Rae Letsinger and his sister Joan of Sarcoxie, MO were wonderful during my time in southwestern Missouri. Rae has collected for many decades and has a grand representation of the fauna of that area of Missouri.

The late John Richard Heitzman, formerly of Independence, MO, mentored and assisted me for decades, and although he was gone before this project started, his impact has had a lasting effect on me that I'll carry throughout my life.

Phillip E. Koenig of O'Fallon, MO, has created one of the finest Lepidoptera databases in the country. His generosity in sharing his knowledge of Missouri Lepidoptera, and in liberally allowing me open access to his massive database, was immeasurably helpful for this project, and to my personal awareness as well.

In Iowa, I spent much more time on my own than in Missouri, but there are people who made the Iowa project possible, and no one is more to thank for that than Aaron Brees of the Iowa Department of Natural Resources. Aaron and I spent several days in the field together, and he has an impressive knowledge of *Papaipema* moths in general and will continue to search areas that could potentially harbor a population of *P. eryngii*. I believe that if the moth is there to find in Iowa, Aaron will locate it. Matt Kenny is another who has taken a liking to the *Papaipema* moths; he too will be on the lookout. The enthusiastic Mary Jane Hatfield is another Iowa asset who is known across the country for seeking out hard-to-find or new species, and she has an educational flair that's infectious; she may well find *P. eryngii* if it is there to find. Thanks to Sara Jones, Iowa State University Lab Technician, Courtney Lab, for photographing the Iowa specimen and its data. And, thanks to John Pearson, Ecologist with the Iowa Department of Natural Resources, for putting this project together in Iowa and supplying site data.

Finally I want to thank my family, especially wife Tammy, for giving me the opportunity to run all over the Midwest in search of my little specialty in the natural world.

Contents

The Project

A total of over 3,000 miles were traveled directly in connection with this survey searching for *Papaipema eryngii* covering areas in 17 Iowa counties. About 25 areas were visited over the life of the project during 2015-2016, with field days totaling 12, most averaging 10 to 12 hours of search effort and data recording each. Countless hours were spent in the lab rearing larvae, curating specimens, literature searches and compiling reports. I was privileged to be able to spend time in the nicest prairies Iowa has to offer. I was in every corner of the state thoroughly enjoying my time there. To the people of the great state of Iowa Thank You.

James R. Wiker, May, 2017

Iowa sites surveyed for Papaipema eryngii 2015-2016

	County	Site	Date
1	Adams	Hamilton Prairie	7-22-16
2	Calhoun	Munson Prairie	7-12-16
3	Clay	Kichner Prairie	7-13-16
4	Dickinson	Caylor (East)	7-13-16
5	Dickinson	Caylor (West)	7-13-16
6	Dickinson	Santa Fe Prairie	7-13-16
7	Emmet	Anderson Prairie	7-13-16
8	Howard	Hayden Prairie	7-16-16
9	Kossuth	Area of Buffalo Center	7-14-16 7-15-16
10	Lucas	Cinder Path Trail	7-28-15 7-21-16
11	Mitchell	Crossman Prairie	7-16-16
12	Montgomery	Erickson Prairie	7-22-16
13	Pocahontas	Kaslow Prairie	7-12-16
14	Story	Doolittle Prairie	7-28-15
15	Wayne	Cinder Path Trail	7-28-15 7-21-16
16	Wayne	Along Route 2	7-21-16 7-22-16
17	Webster	Liska-Stanik Prairie	7-12-16
18	Winnebago	Area of Buffalo Center	7-14-16 7-15-16
19	Winnebago	Along Route 9	7-14-16 7-15-16
20	Winnebago	Farland Access	7-15-16
21	Worth	Along Route 9	7-14-16 7-15-16
22	Worth	Rt 9 and Nettle Rd	7-15-16

History of the current project:

The following study began as the result of conversations between the author and Dr. Paul McKenzie, Endangered Species Coordinator, Region 6, U.S. Fish and Wildlife Service, Columbia, Missouri. During several years of working together on mark/recapture surveys of Hine's emerald dragonfly, *Somatochlora hineana* Williamson, in Missouri, McKenzie noticed and inquired about this author's interest in and constant search for larvae of moths in the genus *Papaipema*. This genus is in the moth family Noctuidae, which in North America contains over 2500 named species, of which 46 are in the genus *Papaipema*, with several more waiting to be formally described. McKenzie's greatest interest was in acquiring information on what is known about a species of *Papaipema* which in the larval stage feeds as an internal borer in the plant known as rattlesnake master, *Eryngium yuccifolium* Michaux (Apiaceae). The species is the rattlesnake master borer moth, *Papaipema eryngii* Bird, which was discovered in prairies around Chicago, Illinois in 1915.

This moth has for years been a topic of discussion, as it for some time has been a candidate for federal listing as threatened or endangered. The author has been able to find no historic records of *P. eryngii* from Missouri and only one (perhaps two) from Iowa. These Iowa records are the only known historic occurrences (i.e., records from before about 1990) of *P. eryngii* from outside of Illinois. Over time, the likelihood that this moth had viable populations in Missouri and was still extant in Iowa was the subject of several discussions, through which the idea of this project was born. Because this moth is truly a species of prairie areas, a conclusion of these discussions was that it certainly seemed possible that populations of *P. eryngii* could occur in Missouri and Iowa prairies in which *E. yuccifolia* was present.

The early stages of this project involved emails and conference calls between the author, the U.S. Fish and Wildlife Service, Missouri Department of Conservation, and the Iowa Department of Conservation. Once it was clear that there were potential habitat areas in both states, the process of moving forward began in 2014. Lists and maps of sites were provided, as well as any necessary permits and contacts that were needed to access areas to explore. Surveys of likely sites commenced in June of 2015 and were concluded in October of 2016. The end results were that no extant populations were found in the state of Iowa, in spite of searching quality areas that still support other species of habitat-restricted *Papaipema* moths. In Missouri, however, breeding populations of *P. eryngii* were found in a 250 mile swath from east-central Missouri (the Tucker Prairie) swinging to the west through the prairie region, down to southwestern Missouri (the

Diamond Grove Prairie), encompassing 9 counties. Iowa and Missouri will each have their own site reports, but the initiations, objectives and methods of this project were the same for both states.

Information on the genus *Papaipema*:

Continental North America supports a vast array of animal species, and among them are over 100,000 named species of insects. The importance and direct impact of these small creatures to human life, either as pollinators to our food supplies, food sources for animals that we in turn utilize as food, objects of pure aesthetic beauty, or bearers of undiscovered properties of which we have yet to recognize the importance, is immeasurable. This multitude of insect diversity also includes species that have an enormous negative effect on human endeavor, especially upon food production. Especially considering the advent of insecticide resistance, and the likelihood of inadvertent intercontinental transport of detrimental insect species (e.g., Asian longhorn beetle, emerald ash borer), we are now faced with the prospect that an insect species, whether native or introduced, can suddenly present us with a major problem. For all of these reasons, both positive and negative, it is therefore advisable to compile as much information as possible on the insect species that occur in a given area. Of the ca. 100,000 described North American insect species, about 13,000 belong to the order Lepidoptera (butterflies, skippers and moths). Though the state of taxonomy in these groups is in the process of conversion, Lepidoptera in North America currently contains 71 families of moths or closely-related groups, six families of butterflies, and one family of skippers. This paper concerns one of the largest moth families in North America, the Noctuidae, which is further divided into around 20 subfamilies, of which this paper will be concerned with Noctuinae, the group which now includes the genus *Papaipema*. This genus consists of 46 named species and at least five more yet to be described. *Papaipema* moths and their most closely allied genera are internal plant feeders as larvae, boring into the stems and/or roots of their particular host plants. This is an entirely North American genus with no representatives in the Old World and at this time, nothing recorded from Mexico, although it is likely that at least a few species occur south of the border. All species are single brooded and reach the adult reproductive stage in late summer and fall.

The first moth named in what was later to become the genus *Papaipema* was *Gortyna leucostigma*, now *Papaipema leucostigma* (the columbine borer) (Harris 1841). Harris referred to the larva of this moth as a “whitish” caterpillar with “black dots” feeding internally in the roots of a “fine double Columbine in my garden.” Smith (1899) proposed the genus name *Papaipema*, in which he included moths from the genera *Ochria, Apamea, Gortyna,* and *Hydroecia*; later, some species of *Emboloecia* would also be transferred into the genus.

A remarkable aspect in the life histories of these moths is the wide range of plants that they utilize as larvae. From one species to the next they run the gamut of larval host plants from monocots to dicots, including grasses, trees, shrubs, many prairie forbs and some even utilize ferns. In the world of Lepidoptera, having such an extremely wide variety of larval hosts in a closely related moth group is an unusual situation. Most species of *Papaipema* moths appear to be very closely tied to a particular plant genus, and often to only one species within that genus, although when larvae are faced with starvation and death, especially when older, they will often move to a completely different food source on which they continue to develop normally. This does seem to be somewhat rare in nature, and it can usually be traced back to a normal host plant that was insufficient for the needs of the larvae. The female moths appear to be much more specific in their choice of oviposition sites and will very carefully place their eggs on the appropriate host, even when it is senesced away and not readily apparent. An example is mayapple, *Podophyllum peltatum* Linnaeus, and the mayapple borer moth, *Papaipema rutila* (Guenee), in September. The eggs are placed in natural folds or crevices in the leaves or stems, or sometimes the female will make a fold in the leaf herself and seal the edge with a spumaline type adhesive. The eggs are laid mostly in rows, with a number of eggs in each group. Females seldom if ever lay one egg by itself but seem to group them from just a few to dozens together. Then they tend to "sew" the area loosely shut with this self-made adhesive that is somewhat like extruded foam. These ova will overwinter and hatch in April and May, depending on the species and locality.

Upon emerging in the spring, the larvae, which are less than a millimeter in length, will feed on what plant material they can manage to chew at such a small size. This often happens behind new growth of a stem or leaf where they can remain hidden until they are capable of chewing into the harder growth and then enter the stem. In the case of a plant like rattlesnake master, they can proceed right down the center of the plant in the new unfurling leaves and work their way to the root. Arboreal species, such as *Papaipema* n.sp #5, which as larvae feed on wooly pipevine, *Aristolochia tomentosa* Sims (Aristolochiaceae), a vine that can grow 10 to 15 meters up into a tree, have been noted to disperse when newly hatched by ballooning. When freshly emerged in groups they will slide down on self-produced silken threads and the wind will blow them across the habitat, spreading them out away from each other. This strategy is generally associated with species that produce a large number of eggs, with the likelihood of high caterpillar loss due to not finding the appropriate food plant, and species that do not get along well in groups. Many species of *Papaipema* will become cannibalistic, in cases where there are multiple larvae in a single plant. This is particularly true of *P. eryngii*, in

which the author has noted finding as many as six larvae in various places in a single rattlesnake master plant early in the season. By early June however, there is usually only one larva remaining in each plant. The other larvae are killed and at least partially eaten by the remaining larva, or if they manage to escape they move to another plant. This is likely how some larvae end up being located in unusual host plants. They wander around looking for food, manage to find something they can tolerate and continue on with their life cycle. It would appear that again, with *P. eryngii*, this is seldom the case, and most battles for plant ownership end in death or they are just not able to tolerate many other plant species. The only other plant that has ever produced a *P. eryngii* larva besides *E. yuccifolium* was at Diamond Grove Prairie in Newton County, Missouri in 2015. The author reared one individual of *P. eryngii* from a larva found in the root of a species of *Arnoglossum* (Asteraceae), probably *A. atriplicifolium* (L.) H. Rob. This is the only time a *P. eryngii* larva has been recorded feeding in the wild in any species of plant other than *E. yuccifolium*.

In the laboratory, *Papaipema* larvae of most species are easy to rear to adult. They will usually take to feeding on carrots or potatoes. A hole can be made with a drill bit into either of these substitute hosts and the larva is gently encouraged to enter it. Often within a short time frass will begin to appear out of the top of the hole, indicating the larva has accepted its new surroundings and will proceed with development (**Fig. 1**).

Figure 1 *Papaipema* rearing setup with larva in carrot.

The larvae of many species of *Papaipema* moths, aside from their host plant associations, can be easier to identify than the adults and can be roughly grouped into four categories. Most larvae in the genus have a standard coloration of purplish brown with white stripes running laterally down the body and a dark band around the first four abdominal segments (A1 to A4) of the body (**Fig. 2**).

Figure 2 Typical *Papaipema* larva.

The variations, which can be diagnostic with these larvae, are the combination of whitish stripes that continue through the dark band, in conjunction with the plant species in which the larva is found feeding. The three main types of striped larvae are:

1. No stripe crossing through the dark band . (No Striper) (**Fig. 3)**

2. Only the dorsal stripe crossing the dark band. (One Striper) (**Fig. 4**)

3. Dorsal and subdorsal stripes cross the dark band. (Three Striper**)** (**Fig. 5**)

Added to this, there are a few species that have unique larvae; these encompass only about three species, none of which should be confused with *P. eryngii*.

4. No stripes in any stage, transversely banded. (**Fig. 6**)

5. White with no pronounced markings in any stage. (**Fig. 7**)

*Figure 3 No Stripe larva (*P. speciosissima)*.

*Figure 4 One Stripe larva (*P. astuta*).

*Figure 5 Three Stripe larva (*P. cataphracta*).

*Figures 2, 3 & 4 Photographs by Anthony E. McBride**.**

*Figure 6 Transversely Banded larva (*P. beeriana*).

*Figure 7 White, No Markings larva (*P. limpida*).

*Figures 5 & 6 Photographs by Anthony E. McBride**.**

Through the first three or four instars, larvae that have markings tend to retain them, but with each progressive molting these markings fade until towards the end of their time as larvae they have mostly turned a dirty white. *P. eryngii* is an exception to this, as it retains a fair amount of its coloration, albeit faded, right up to the time of pupation. No other species this author has encountered retains this much of its striped markings until pupation.

Species of *Papaipema* moth larvae mature at different rates. Some, once they start to feed, continue to do so right up to the time they pupate and in general are the earliest species to emerge as adults. Examples include *P. circumlucens* and *P. harrisii*. Both of these species go straight through this phase of their life without any pause and often pupate by late July, emerging as adults in late August. Other species, such as *P. silphii* and *P. eryngii*, are generally finished feeding by mid to late July; however, they will stay in their chambers and do nothing ("aestivate") for weeks before they are triggered to pupate, which happens in mid August to mid September. This is generally the case for species which are the last to take wing in the fall. There are also differences from species to species in where they pupate. Some leave the plant completely, arboreal species descend to the ground and burrow to pupate, while others in low plants leave the stem or bore out of the root into the ground. Still others stay within the stem or root chamber that has been home throughout their larval life and transform inside it, making some sort of escape hatch before pupation occurs.

Most species of *Papaipema* moths occur in eastern North America; 39 species are found primarily east of the Rocky Mountains, with seven species being found only in the western states. They are found in most habitat types, from forests (*P. furcata, P. marginidens, P. araliae*), bogs (*P. appassionata*), coastal marshes (*P. duovata*), canebrakes (two undescribed species), successionally transitioning areas (*P. cerussata, P. limpida*), and more than a dozen species, or roughly a fourth of the *Papaipema* moths, are either considered somewhat or entirely dependent on prairie habitats and utilize specific prairie plants as larval hosts. Some favor wet prairies, others drier prairies, but most will not be found outside of a true prairie or remnants of the same in its proper ecosystem sense. Some of these are *P. silphii, P. beeriana, P. sciata*, *P. nepheleptena* and *P. eryngii.*

History of the rattlesnake master borer moth, *Papaipema eryngii* Bird:
Papaipema eryngii was originally discovered in the prairies directly around Chicago, Illinois. On the morning of July 11, 1915, Chicago area lepidopterists Emil Beer and Alex K. Wyatt (aka Alexander Kwait, prior to about 1918), along with Henry Bird (noted expert on the genus *Papaipema*) who was visiting the region from New York, were in the area they called Healy Station. The three were having a discussion about possible host plants for *Papaipema* larvae. Rattlesnake master (*Eryngium yuccifolium*), which was growing in the area, had "seemed favorable for tenanting a *Papaipema*." Bird went on to say "Mr. Beer devoted himself to several plants in the foreground, and was successful in finding, in the crown of the taproot, a penultimate stage *Papaipema* larva, close to *P. cerussata.*" This was the moment of discovery of *Papaipema eryngii.* Henry Bird originally proposed it would be "fitting" to name the new species after its discoverer Emil

Beer; however, “our confreres consider it will be more helpful to call the species suggestively: *Papaipema eryngii*, n. sp.” (Bird 1917). Bird would later go on to name a species after Emil Beer in 1923, *Papaipema beeriana*, a *Liatris* (Asteraceae) feeder which is often found in association with *P. eryngii*. Henry Bird described 15 valid species and several forms of *Papaipema* moths as well as working out most of the known life history information for the entire genus. He published dozens of papers in various entomological journals over a period of about 50 years.

P. eryngii was found consistently in the Chicago area at least into the 1940’s, mainly by Beer, Wyatt, and others whom they knew and had shown how to locate it. After that point it seems that most of the old-time Chicago collectors were getting older or were looking for insects in other groups, and the interest in the *Papaipema* group waned. There is only one specimen known to this author historically from outside Illinois, and it wasn’t until 1990 that this specimen surfaced. Eric L. Quinter (retired AMNH, New York, unpublished notes), ran across a specimen in the collection of Iowa State University, Ames, Iowa. The specimen and its data label information are shown in (**Fig. 8)**; there are four labels, which are copied here and read exactly as follows:

*Figure 8 Historic 1928 Iowa specimen of *Papaipema eryngii*.

Label 1:	**Label 2:**	**Label 3:**	**Label 4:**
Ames, Iowa Sept. 19, 1928 G. C. Decker	E. yucca 9-19-28	Papaipema eryngii Bird	Papaipema eryngii Bird det. Eric L. Quinter, 1990

*Fig. 7 Photograph by Sara Jones, Iowa State University Lab Technician.

Although recent literature and reports continually refer to its historic range, the source of which is unknown to this author, the only historic specimen of *P. eryngii* that has ever been located from outside of Illinois is the Iowa specimen. All other records of the species from states other than Illinois are from the 1990's and later. There is one other literature reference, also from Iowa, that was recently brought to the attention of this author. In a conversation during July of 2016 with Aaron Brees, IDOC, Aaron mentioned "the Buffalo Center, Iowa records." Neither this author nor any colleague involved in the study of this group of moths had any knowledge of *P. eryngii* being found anywhere in Iowa outside of the 1928 Ames record. Aaron explained that the Buffalo Center record was from a 1929 Doctoral Thesis by George O. Hendrickson, titled "Studies on the Insect Fauna of Iowa Prairies" (Iowa State College). He kindly forwarded an email copy of the unpublished paper and on page 137 it states exactly the following:

> Papaipema eryngii Bird
>
> Five larvae were taken as stalk-borers of Eryngium yuccifolium, 5 mi. northwest of Buffalo Center, Aug 6, 1928. Several pupated about Sept. 5, and an adult appeared Sept. 22, 1928.

Concerning the Ames, Iowa *P. eryngii* specimen:

Over the last two years a survey has been conducted in Iowa for the Rattlesnake Master Borer Moth, *Papaipema eryngii* Bird in some of the best remaining parcels of prairie left in the state. Historically, Iowa was the only state outside of Illinois to have known occurrences of the moth prior to about 1990 and this information went relatively unknown until more recent times.

In 1990 as part of his decades long information acquisition of the genus Papaipema and it's close allies, Eric L. Quinter (retired American Museum of Natural History), discovered the lone known Iowa specimen of *P. eryngii* in the collection at Iowa State University while there gathering data. The label on this specimen reads as follows: Ames, IA Sept 19, 1928 G. C. Decker E. yucca Det Eric L. Quinter 1990. To the people most involved in studying the genus this remained the only non-Illinois historic record known until this past summer in July.

The author was in Iowa doing field work and accompanied by Aaron Brees of the Iowa Department of Natural Resources, who has taken quite an interest in moths and the genus Papaipema in particular. In a conversation, Aaron mentioned "the Buffalo Center eryngii" to which this author replied "I am completely unaware of this and to my knowledge none of the people studying this group, past or present,

have heard of it either". Later that evening Aaron was able to email a copy of the thesis by George O. Hendrickson titled *Studies on the Insect Fauna of Iowa Prairies,* 1929, Iowa State College. The paper is of major historic significance to the study of this moth because it very plainly states that 5 larvae were collected, several pupated and an adult appeared September 22, 1928. A copy of the relevant pages of the thesis will be included in this report.

Hendrickson states in the section titled Annotated List that "The following list furnishes the names of the species as given by the specialists whose names occur at the head of the order." The specialists listed for the Order Lepidoptera are: Dr. W.T.M. Forbes, of Cornell University and Carl Heinrich, August Busck, William Schaus, all of United States National Museum (the Smithsonian) all the biggest names of their day. The point being that there is little doubt as to the accuracy of the species determination of *Papaipema eryngii*. That said I would point out the following; of the six species of *Papaipema* moths listed in his report *P. marginidens, P. arctivorens, P. cataphracta, P. sciata, P. necopina, and P. eryngii*, there is one obvious error and here is the explanation to clear up any future confusion. *Papaipema marginidens*, described in 1852 by Guenee, is listed here and for many years was confused with several other *Papaipema* species, the most common being *Papaipema birdi* which was described by Dyar in 1908. The species was very shortly thereafter regarded as a synonym of *P. marginidens,* meaning they were considered the same species and the older name (*marginidens*) had priority in 1928. However,
P. birdi has since been resurrected back to species level after rearing, dissections and looking at many specimens, they are quite different. *P. birdi* as a larva is mainly a borer in *Cicuta maculata* and actually looks more like *P. eryngii* than P. *marginidens*. The larval host for P. marginidens is so far unknown but this author along with colleague Tony McBride of New Jersey have managed to rear it in the lab on artificial diet and the larvae are quite different from both *P. eryngii* and *P. birdi*.

Things get more complicated with P. birdi and P. eryngii as they are as adults very similar when freshly emerged and when flight worn can be almost indistinguishable. On occasion, *P. birdi* larvae have been found boring in *Eryngium yuccafolium* including one during this studying in northern Iowa. While the male genitalia of *P. birdi* are fairly typical of most *Papaipema* species, male *P. eryngii* valve are distinctive and arguably the most recognizable in the entire genus.

Another thing the author would like to discuss concerning the Iowa *P. eryngii* records is a question particularly about the Ames (Story County) record. Although there is no way to ever tell at this point in time what exactly happened, looking at the circumstances and data, the following questions arise. George C. Deckard and George O. Hendrickson were in college together and knew each other. Hendrickson specifically acknowledges Decker in his thesis as being "deeply indebted" to him "for reciprocal assistance in collecting and rearing a number of specimens". Decker was certainly familiar with the rearing and species of *Papaipema* moths by 1928 as he was already two years into his study of *Papaipema nebris* for his 1931 paper. It seems fairly remarkable that the only specimens recorded from the time of its formal description in 1917 until the 1990's outside of Illinois were two from Iowa, within 3 days of each other in the same year and 120 miles apart. Now, this certainly is not impossible and could very well be the case. However, when you consider they were helping each on projects, rearing moths from several areas around the state and no other *P. eryngii* were ever collected in the Ames area where research was on going, one must ask if there could have been an error here. The Ames specimen has "E. yucca" on the label which should indicate that it was collected as a larva and reared. Could Hendrickson have brought those five larvae back from Buffalo Center, either giving one or all of them to Decker to rear out and in the process the data was mixed up? Could the Ames specimen actually be one of the Buffalo Center specimens? There is certainly no reason that both areas could have had the species and I have no proof to support any of this other than the circumstantial evidence reported here. It just seems this should be brought to the attention of any future research interested in looking for this species in Iowa.

We will never know for sure; nevertheless, *P. eryngii* was at least at one time a breeding resident of Iowa.

Up to the time of these current projects in Missouri and Iowa, *P. eryngii* was known to occur in the following states:

1. Illinois - several counties, some with good populations, Wiker.
2. Iowa - Historic, only records are from 1928.
3. Oklahoma - discovery in the 1990's, Wiker has documented.
4. Kentucky – A couple of small populations.
5. Arkansas – Questionable, Wiker investigating in 2017.
6. North Carolina – possibly extirpated/overlooked, needs research.
7. Kansas – new, unpublished discovery by Wiker, 2016.
8. Missouri – new, discovered 2016, many populations, most secure area.

Larvae of *Papaipema eryngii*.

P. eryngii – young larva from summer burn unit
May 2016, Tucker Prairie, Callaway Co., MO

P. eryngii – half-grown larva
Grandfather Prairie, Pettis County, MO

P. eryngii – half-grown larva
Diamond Grove Prairie, Newton County, MO

P. eryngii – mature larva
Diamond Grove Prairie, Newton County, MO

P. eryngii – half-grown larva
Tucker Prairie, Callaway County, MO

P. eryngii – preserved larva
Tucker Prairie, Callaway County, MO

Typical male *Papaipema eryngii*, Little Osage Prairie, Vernon County, MO.

Typical female *Papaipema eryngii*, Mora Conservation Area, Benton County, MO.

Male and female *P. eryngii* are similar, although the female has forewings that are a bit more rounded than those of the male. Wing expanse for the species measures as small as 35 mm to nearly 50 mm, with the average right around 46 mm.

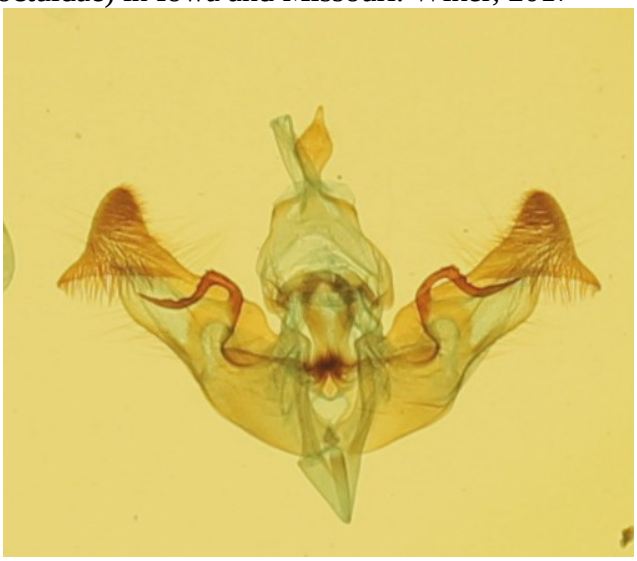
On the upper surface of the forewing, the basal area (next to the thorax) has a yellowish-white to white spot. The antemedial, postmedial and terminal areas are a purplish brown; the medial area is red brown, becoming lighter as it approaches the inner margin, where there are varying amounts of yellow powdering (some individuals having just a little, others quite a bit). Toward the apex there is another dash of yellow. The reniform, orbicular and claviform spots, which are characteristic of many *Papaipema* species, are all conspicuously large and white. The hindwing above is rather plain, being a fawn color often with a purplish tint, and with any lines or shading vague, if even discernible.

Underside: male *Papaipema eryngii*,
Grandfather Prairie, Pettis County, MO.

The underside of the forewing is a powdery purple, lightening as it grades into the hindwing. The hindwing usually has a prominent medial line crossing it; this line is sometimes visible on the forewing as well.

Lateral aspect, showing thoracic and abdominal tufts.
Papaipema eryngii, Wah-Kon-Tah, Foust Tract, St. Clair County, MO.

Genitalia: male *Papaipema eryngii*.
Phallus removed.
P. eryngii is unique in having a large, thick, singly curved (sickle-shaped) valval hook and a straight apex of the valva.



Genitalia: male *Papaipema eupatorii*.
Phallus removed.
This configuration, with doubly curved valval hook and sinuate apex of valva, is typical of most species of *Papaipema*.

PARATYPE: male *Papaipema eryngii*, Chicago, IL October 1, 1916, A.K.Wyatt.

PARATYPE: female *Papaipema eryngii*, Chicago, IL October 12, 1916, A.K.Wyatt.

Methods used in studying *Papaipema* moths:

Studying the occurrence of most any moth in the genus *Papaipema* is best done by surveying an area for larvae of the species you desire to find. All species are internal stem and/or root borers, meaning that they hatch from eggs and shortly after chew into the plant and live on the inside from that point until they become adult moths. With few exceptions, each species in this genus of moths, particularly in the prairie group, seems to be strongly associated with one genus of plant and sometimes one species within that genus. There are two species of *Papaipema* moths that have been documented feeding on several hundred plant species; they are *P. nebris* and *P. cataphracta*. These two and several other species, *P. birdi, P. maritima, P. silphii, P. cerussata* and *P. baptisiae,* have all been found as larvae and reared in *E. yuccifolium*; therefore, obvious *Papaipema* type larval damage on rattlesnake master is in no way confirmation of the presence of *P. eryngii.* It takes many years of field and lab work to begin to get a handle on the complexities of this group. Each species affects its particular larval host plant in a unique way, and learning the signs to watch for is the key to finding them. Evidence of occupation by a borer larva in a plant can be obvious or very subtle. Depending on the *Papaipema* species involved, some infested plants look very ill or dead, whereas others, even when internally bored from one end to the other, show little or no signs of stress.

There are still a couple species that have yet to divulge exactly what they use as a natural food plant host. In this region, the host of *P. marginidens*, a forest species with collection records scattered across the eastern U.S. is still a mystery. Ova secured in the lab from a gravid female in 2015 were reared to adult using carrots and potatoes as an artificial diet that produced good results. In spite of having no idea what plant to look at in the wild, this author along with Tony McBride of New Jersey, do at least have images of the larvae, which were previously unknown.

When searching for *P. eryngii*, the first task is to locate stands of the only known larval host, *E. yuccifolium* (**Fig. 9**). Once discovered, an assessment is made of its density and health. The larva puts a heavy stress on the plant, and though it seldom kills it completely, it takes enough out of it that the plant almost never produces a stalk or flower, or if it does, it appears as a very stunted individual. This becomes noticeable in May but is much more obvious by June. A stand of rattlesnake master that has many plants, most all of which look healthy and appear to be producing flower stalks, generally has no or few populations of the moth. If one walks into an area and there seem to be many mature plants with very few producing stalks, there is a high likelihood of a *P. eryngii* population. The plants will appear ill, sometimes with a yellowing leaf or two, and as time goes by, the center of the plant will look to be drying up and dying, and often a bore hole will be visible (**Figs. 10,11,12**).

Figure 9 Healthy *Eryngium yuccifolium*, Vernon County, Missouri.

Figure 10 *Eryngium yuccifolium* with dead central leaves, Vernon County, Missouri.

Figure 11 Same plant, closer photo.

Figure 12 Same plant, lower section showing bore hole and frass.

Figure 13 Same plant, with *Papaipema eryngii* larva exposed.

Figure 14 *Papaipema eryngii* larva in lower stem, Pettis County, Missouri.

By mid to late June, the larvae have usually reached the root crown (**Figs. 13,14**) and begin to bore into the bulb. This is important information if grazing or haying are part of the site's management plan. By late June the larvae should be far enough down in the plant to avoid being eaten by cattle or cut even by a low blade mower; neither should have much effect on the larvae. An exposed open stem resulting from these activities could possibly make larvae a bit more vulnerable to parasitism or predation by other insects. However, other species occasionally have stems that break off from the wind with no apparent harm. During years of searching for larvae and quite often checking such broken stems, most of the time the larva has been found to be alive and well.

Searching for larvae allows a two to three month widow of opportunity to conduct surveys. Surveys can start as soon as larvae are detectable, often by mid-May, and for *P. eryngii* you can generally assume that they have left the plant by August 10th to the 15th and are no longer obtainable. Adults on the other hand offer a window of opportunity of about two to three weeks, and only a week to ten days of prime flight that falls from about September 20th to around October 10th.

Lighting:
Lighting can have great success in attracting some species, whereas others seem to ignore light almost completely. Mercury vapor, blacklight, and Blacklight Blue all will attract *Papaipema* moths; Blacklight Blue may have a bit more drawing power than the others, but all will work. Some *Papaipema* species will even on occasion come to incandescent light. Standard methods using lights include the following:

Mercury vapor lights require an external ballast, which is heavy and therefore somewhat limiting as to where and how far it can be taken. Any wattage can be deployed, but the most common is 175 watts, the wattage of a standard street light. It will either need to be run off of household current and set up close enough to reach a 110-volt outlet, or for more portability, it can also be connected to a small gasoline generator, so long as the induction, or start up, wattage does not exceed the generator's rating. The bulb is usually mounted to some sort of pole and placed in front of a white bed sheet hung from a rope stretched between two trees or whatever is available to hang it from. Some insects are strongly attracted to the spectrum of light produced by mercury vapor and land on the sheet or nearby vegetation, where they can be observed or collected (**Fig. 15**). Using this type of setup is more labor intensive and requires more equipment than do other lighting methods, but the results are usually worth the effort. None of the other high-intensity discharge lights such as sodium vapor, the standard yellowish looking street lighting that replaced mercury vapor a decade or so ago, or high-output LED lighting, has nearly the drawing power of mercury vapor. Metal halide has marginal attraction to insects.

Figure 15 Mercury vapor light setup.

Figure 16 Blacklight sheet setup.

Blacklight – can be used like a mercury vapor light with a bed sheet hung on a rope (**Fig. 16**), the main difference being that the blacklight setup is much more portable. In recent years, technology has created highly efficient 12-volt sealed gel cell batteries in various sizes and weights, which have made using these lights not only much less laborious to haul around but longer running per battery charge. Blacklight bulbs also come in different types; one is the usual "bug zapper" type light blue bulb, and the other is the old Blacklight Blue (BLB) type bulb. Both work great; however, it seems as though the BLB bulbs are a bit more attractive to *Papaipema* moths. Also, they are much less noticeable in the field when set on and therefore tend to be less prone to vandalism. They can either be built to run on 12-volt DC or 120AC current, depending on how portable you need them to be.

Another way to use blacklight is with bucket type traps (**Figs. 17,18,19**). These are very portable and an efficient tool for doing surveys and assessments of an area. They are made using a bucket, funnel, light, and battery, and they often have some type of rain drain. They can be used with or without a killing agent, although during mid-summer when the greatest numbers of insects are flying, beetles will destroy most anything in the bucket if no killing agent is used. This is normally not much of an issue late in the season when adult *Papaipema* moths are on the wing, because by then most beetles have ceased to flying for the year.

Figure 17 Blacklight bucket trap.

Figure 18 Bucket trap with BLB laid into the funnel, no vanes used.

Figure 19 Same trap opened up with previous night's catch.

Baiting:

Baiting with mixtures of ripened fruit and sugar will on occasion attract moths in this genus, but is not an overly effective way to assess the presence of any given species. Often if one does come to the bait it is a female, which is useful for obtaining ova and

trying to rear them out the following season. Baiting can be done several ways. For example, a paintbrush can be used to apply the mixture onto trees and fence posts. Another way to use bait is in traps to which the moths come to feed and end up in a cylinder made of netting, so that the catch can be assessed the next day (**Fig. 20**). Wine roping is another very useful baiting method, in which lengths of natural fiber ropes are soaked in a red wine, fruit juice, and sugar mixture. The ropes can by deployed quickly along a trail, by hanging them on tree limbs. They need to be checked as night comes, and one can selectively collect wanted specimens (**Fig. 21).** Both of these methods tend to be more productive early in the spring and in the fall, as sources of food for the adults become harder to find.

Figure 20 Bait Trap.

Figure 21 Wine Rope.

Iowa results:

In the two seasons covered in this report, almost 25 areas in 16 counties were directly surveyed. Unfortunately none of the areas searched produced any populations of *P. eryngii.* Since Iowa is the only state that has a historic record besides Illinois, it is certainly possible that it occurs somewhere in the state and has eluded discovery. *Papaipema* adults are not known to travel very far at all from the place of their birth; however, females will disperse towards the end of their lives and can end up far from where they started. Severe weather events and unnatural transportation can also move insects around. With a large population less than 100 miles away in Missouri there is always a chance of a population being established somewhere, especially in southern Iowa. Particularly in any areas with prairie-chickens as the two often favor the same type of habitat.

Lighting:

A 400-watt mercury vapor light sheet, a blacklight sheet and blacklight bucket traps were all randomly used during this study, with varying results.

Mercury vapor was used at five sites, at two of which adult *P. eryngii* were attracted. One flew in to the light at the Grandfather Prairie in Pettis County on September 30, 2016, but the most was learned at the Tucker Prairie in Callaway County. A 400-watt mercury vapor light was set up in back of the Clair L. Lucera Research Station on the night October 1, 2016. At least six *P. eryngii* were drawn in by the light, all after 1 AM, and most flight activity had ceased by the time the light was shut down at about 3 AM. Many *Papaipema* moth species tend to be active late at night, often not being seen before midnight and then flying for only

an hour or two. Based on this very limited observation one can reasonably conclude that the main flight time of *P. eryngii* likely is from 12:30 AM until around 2 AM. This should be the female "calling time" which refers to the time when she releases male-attracting pheromones into the air. Many species of moths release sex pheromones, and this is usually done within a very precise time frame. Fall moths, including all *Papaipema* species, need to find each other promptly to breed. They live on the edge every day of their lives, with the chance of freezing weather always looming. These strongly attractive and well-timed pheromone releases help males to locate females and initiate the mating process with minimal delay.

A blacklight sheet was used at a couple of sites; no *P. eryngii* were attracted. All of these blacklighting efforts took place prior to October 1; the absence of *P. eryngii* on these nights can likely be attributed either to cool weather, or to the lights being set out too early in the season to encompass the annual flight period of the moth.

Bucket traps, mostly using a 7-watt dark blue blacklight (BLB), worked well at both Mora Conservation Area and the Tucker Prairie. A trap was set on several occasions at the northeast corner of Mora in both 2015 and 2016. Multiple catches of *P. eryngii* were made every night the trap was set. On the night of October 1, 2016 at the Tucker Prairie, four traps were placed in various areas north to south. The next morning all four traps contained three or four *P. eryngii*. Two of the traps were placed intentionally in the northeastern quarter of the prairie, which had a summer burn in August, 2015. This August burn did not appear to have nearly as much of a negative impact on numbers of *P. eryngii* individuals" as a spring burn seems to have (this will be discussed further under Management Thoughts and Recommendations). Three of these traps were set up like the one in Fig. 18, with the 7-watt bulb down in the funnel below eye level. In numerous observations over the last several years, this author sees no appreciable difference in numbers of

insects drawn into the traps, whether the bulb is visible or is down in the funnel.

Baiting:

One male *P. eryngii* was noted at a wine rope at the Tucker Prairie by Wiker and McKenzie on the night of October 1, 2016 (**Figs. 22, 23**). This represents the first record of the species being attracted to bait. During this period, two other species, *P. maritima* and *P. baptisiae*, were found at bait over the course of several days, in other site.

Figure 22 *P. eryngii* at wine rope

*Photo by Paul McKenzie and edited by Jon Rapp.

Figure 23 Close up of same.

*Photo by Paul McKenzie and edited by Jon Rapp.

As mentioned previously, baiting can be a useful option in the search for a female adult when trying to acquire ova for larval comparison, especially when the host plant is unknown. Even though the one *P. eryngii* that was recorded at the wine rope was male, it seems likely that female moths, due to their need to take nourishment to promote the health and development of their eggs at a time of year when food resources are not abundant, would be attracted to wine ropes. This is an old method but should be considered as an option to secure research stock. For example, this approach worked for *P. marginidens*, in which case, larvae from ova laid by a female adult *P. marginidens* captured at a wine rope were reared from hatching to pupation on red potatoes and carrots. This represents the first and, to date, the only instance in which unquestionably-confirmed *P. marginidens* larvae have been reared, photographed and preserved.

Site management issues and thoughts:

The first thing that should be said in regard to management of these prairie areas in Missouri is that whatever has been done in the past would appear to be working. The prairies that this author had the pleasure to explore in both Missouri and Iowa were beautiful and still had a nice assemblage of wildlife, including insects. The Iowa prairies are much smaller and more isolated than those in Missouri but still have an assortment of prairie-dependent insect life. Anything mentioned here would apply to either state, although the main focus will be Missouri since it has large areas that support the moth.

Burning:

In all probability, burning has been a part of prairie existence since these vast grasslands evolved. Without it, these open spaces eventually disappear as other ecosystems fight to gain a foothold and take over parcels of land that support their particular forms of life. Hard spring or late fall fires are meticulously cleansing of many species of insects that call the prairie home. After observing this over many years in Illinois prairies, it has become apparent to this author that this is a normal part of prairie life. After years of being attacked by whichever insects utilize them as a host, many times building up large numbers, nature has developed ways of giving these areas a break from the onslaught of arthropod attack. There is a noticeable lack of insect damage to plants during the summer after a late fall or spring burn. Although many species of insects can survive spring and fall fire, there are a good number that can not. This was not really an issue when the continent had millions of acres of prairie habitat. If an area the size of a state burned, there was so much adjacent prairie left that species over time moved back in, and if it took decades for that to happen, that was how it was. At the present time, however, we unfortunately no longer have the luxury of endless grasslands, and most areas are relegated to postage stamp size, these being isolated areas that

are spaced far from each other. Nowadays, one very complete burn in a smaller prairie could easily wipe out an entire population of a pollinator whose importance we have not yet even recognized, at which point the species would have no prospect of recolonization, because of the extreme isolation of the small fragments of habitat that remain.

George C. Decker (1931) in his paper on the stalk borer *Papaipema nebris* (Guenee), a pest of crops, especially corn, explicitly recommends the use of fire in fields to control this moth. He states: "Burning fence rows and infested grass lands between Nov. 1 and May 1, destroys the overwintering eggs and is one of the most practical means of control." He goes on to report "this method will reduce the borer population by 85 to 90 percent, and that burning in the spring is slightly more effective than burning in the fall. This is apparently due to the fact that dead leaves

of corn and weeds on which many eggs had been deposited were blown into the control plots during the winter". *Papaipema nebris* is a very widespread species that has several hundred reported larval hosts. A species such as *P. eryngii*, which has only a single host, on the other hand, would not have eggs on various weeds throughout a range of habitats as in *P. nebris*, but would be restricted to laying eggs only in the prairie, on dead and dying rattlesnake master. Henry Bird (1934) reports in a paper on the "Decline of *Papaipema*", a section titled "Exterminating Effects Of Fire". He starts this section off with the following: "Not only is it the experience of the writer, but from all correspondents who have followed *Papaipema* life histories comes the same complaint that fire is fast working extermination in areas covered by their respective information." He goes on to say "Invariably of artificial origin, such fires are set in late fall, winter, or early spring when the dead vegetation is more thoroughly consumed and the overwintering ova thereon are destroyed with a surprising completeness." These fires were not set for the purpose of managing natural areas in the sense of today but were meant to clear brush in what were considered waste places. Thus, even 80 years ago, the detrimental effects of indiscriminate burning on (at least) *Papaipema* moths was being documented.

Burning is an easy and very effective tool to use, and it certainly has its place in the management régime. Without it, we lose the prairie to non-native invasive plants or to natural succession, but too much of it at critical survival times can eliminate needed pollinators, as a result of which one or more plant species eventually can be lost due to lack of successful reproduction. One optional use of fire that, at least initially, appears to have minimally negative results for some insects, including species of *Papaipema* moths, is the strategy of conducting late summer burns. August to mid-September is a time period during which an insect that can survive fire is least vulnerable. Some species do not survive fire under any circumstances,

but if they can, this seems to be the most advantageous time. The plants have a chance to recover before winter sets in, and at least for *Papaipema* moths, this leaves an oviposition site for the females. This was observed by the author and Paul McKenzie in 2015/2016 at the Tucker Prairie. The northeastern unit of the prairie was burned in August, 2015. By October many of the plants had sprouted up ankle high and provided cover for a variety of life. The following spring, 2016, the northwest unit was burned in what looked to be a very hot fire. The site was visited on May 28, 2016 and without much effort, *P. eryngii* larvae were found in the northeast unit, whereas searches through the lush vegetation of the northwest unit yielded no *Papaipema* species.

With these results in mind, more experiments with late summer burns would greatly enhance our understanding of timing and survival rates in conjunction with

the use of fire. Heavy scorching of the prairie in the late fall to spring should probably be reserved for the worst cases of invasive-species invasion. Growing-season burns should be conducted and carefully studied, at least in some areas. This is of major importance when dealing with more isolated prairies that are many miles from the next suitable habitat. Fortunately, most Missouri prairies and the more northern Iowa prairies have several areas in fairly close proximity to each other and would sustain a bit more freedom with management. In Missouri, *P. eryngii* obviously repopulated areas in 2016 that were negative for larvae and had been burned in the spring of 2015. It appears that the adult moths are able to fly at least a few miles to seek out new breeding habitat. Care should be exercised that prairies be put on some type of burning rotation: never should all of any particular prairie be burned, and when dealing with a grouping of several sites in an area (such as the prairie complex south of Sedalia, MO), more of them should be left unburned than burned.

Grazing:

The large mammal component is something that disappeared from most prairies long ago; it could have a much more important role in maintaining the health of a grassland habitat than we suspect. This author had a conversation years ago with Vernon LaGesse, who tracked a population of *P. eryngii* at the Tallgrass Prairie Preserve in Oklahoma. According to LaGesse, at the time there were just a few, fairly dense populations of *E. yuccifolium* on the preserve, each a few miles from the other. *Papaipema eryngii* would move back and forth among them, infesting a patch heavily for a year or two then moving to the next. This was before bison were released in the preserve. Within a few years after their introduction, *E. yuccifolium* was being noticed in many new areas, and it was noted that the seed heads of *Eryngium* could be seen in the thick hair of the bison, which undoubtedly were passively spreading the seed around. Grazing done with some controls is

probably beneficial to the health of a prairie and can help keep the area from becoming unruly. It often keeps the vegetation around knee high or shorter, which is known to be favorable for many bird species, including prairie chickens and grassland sparrows.

The major issues with grazing, at least where *P. eryngii* is concerned, are timing and density of the grazing animals. Incidental eating of small larvae is a potential danger if the animals are brought in too early in the year. By mid-June, most larvae would be far enough down into the plant to be safe from being eaten. Additional research is also needed to determine the optimal density per acre of each grazing species (cattle, goats, bison) for keeping the vegetation low, but not down to the soil. Overall, grazing should be considered as a management tool in areas that can support it, provided that it can be carefully monitored.

Haying:

The use of haying in prairies appears to have benefits, the most obvious of which is keeping shrubby growth to a minimum and the overall height of the prairie at a level that is favorable to many bird species. Haying is being used as a management tool in at least one, maybe several, of the sites that have *P. eryngii* in Missouri. The author witnessed it in use at Diamond Grove Prairie in both 2015 and 2016. Admittedly, the vegetation looks rough for the first few days after the cutting, but it seems to rebound quickly, and within a week or two, new growth abounds. The only real concerns with baling, at least with what was seen at Diamond Grove, were the completeness of the area baled and how short it was cut. Several hundred acres were cut at a time, and it was mostly a clear cut; no areas were left uncut, and the vegetation was cut very low to the ground. It would surely be advantageous to wildlife in general if occasional linear strips were left as refugia for anything seeking shelter or escape from predation. It is probably of little consequence to *P. eryngii* as long as the first cutting is done after the middle of June, at which time the larvae would be at or in the root ball of rattlesnake master. Then the only issue might be the open plant stem inviting predation.

Some final thoughts:

Iowa:

It is unfortunate that *P. eryngii* did not turn up in the state. It certainly was part of the fauna in the past and should not yet be completely written off. This survey covered the most likely areas where the moth could be, but in no way was it a comprehensive study of all possible areas within the state. There is always a possibility that a relictual population still exists in some little prairie with a good stand of rattlesnake master. It is also just as likely that *P. eryngii* could eventually be found at least in southern Iowa, since there is a large population only 100 miles south at the Tucker Prairie in Missouri. One good southerly weather front could

blow one or two gravid females north across the state line into Iowa, and if they land in a suitable habitat, it is possible they could establish a population.

Missouri:

Missouri has the largest populations of *P. eryngii* in existence. The massive acreage of protected prairie, and the sheer size of the area it covers, put it far ahead of Illinois. In almost every case encountered during this survey, if a site had the moth, it was relatively easy to find. And, although this project documented merely presence or absence of *P. eryngii*, with no evaluation of population size or density, it was obvious that sites such as Tucker and Wah Kon-Tah Prairies comprise large numbers of *P. eryngii*. The large acreage of prairie that remains in Missouri, and the number of people who are involved in studying or caring for it, are remarkable. There is no reason that this shouldn't continue, as the management routines throughout the prairie region have been in place for years and the moth appears very secure at this time.

The entire prairie-restricted group of *Papaipema* species, of which most are no more widespread than P. *eryngii,* and several of which are now known from far fewer sites, will all benefit from any well thought-out management plan. It is imperative that all living things be taken into account when deciding how best to care for an area. There are many living things of which we don't understand the importance, either to us or in the overall scheme of things.

Documenting and rearing *Papaipema eryngii*.

As stated earlier, the best way to determine the presence of *P. eryngii* or most any species of *Papaipema* moth is to search for the larvae. In doing so, one must be prepared to spend time learning when to look, where to look and what to look for, as each species has its own way of affecting its host plant. It also documents proof of reproduction in a given area.

Several of the prairie species of *Papaipema* moths have roughly the same scenario when it comes to how the plants react to a larval infestation, and all are often found at the same location. Larvae of *P. eryngii* on *Eryingium*, *P. silphii* on *Silphium* and *P. beeriana* on *Liatris* stress their respective host plants to the point of preventing them from flowering, although the plants themselves may look rather normal. More often than not, walking into an area with any of these three plants and seeing that most of them are producing flower stalks indicates that the site probably does not have any larvae. However, finding stands of these plants where a lot of individuals are observed but many are not producing flower stalks, is generally an indication that they have borers living inside them. The plant is seldom killed by the larva, and it seems to recover in subsequent years, but it usually will not be

reproductive when hosting a larva. The larval evidence in **Figs. 24 and 25** is most easily found in June; after that time the larvae proceed to the roots, and the damage in the upper parts of the plant becomes less noticeable. It can be quite remarkable how such a large larva can stuff itself into the lower stem or root ball of a rattlesnake master plant (**Figs 26, 27**). After June, care must be taken when extracting a larva from the plant, as it can be easily crushed or cut, both of which are fatal. In the field, larvae need to be handled gently and it's best to place them in 2- to 3-ounce vials or jars. If the lid is plastic, make sure it is of good thickness or the larva may chew a hole through it and escape. Do not place larvae together; they can be cannibalistic, and three or four in a vial can quickly turn in to one. Place a very slightly damp crumpled piece of paper towel in the vial or jar, not too tightly, to give the larva something to hide in. Do not put pieces of the host plant in the vial/jar with the larva. If sealed tightly, this occasionally asphyxiates

Figure 24 *Silphium* with *P. silphii* larva, no flower stalk, dying leaf in center.

Figure 25 *Eryngium* with *P. eryngii*, no flower stalk, discolored center.

Figure 26 *P. eryngii* larva coming out of *Eryngium* root crown.

Figure 27 Same root ball cut open to reveal larval chamber.

the larva, possibly because of plant-released volatile compounds accumulating within the rearing container.

The larvae, if kept cool, will be fine for a day or two in the vials, and if they are found later on in July they are mostly finished feeding anyway. However, as soon as practical it is best to transfer them into more permanent living quarters. Any suitable container can be used, but this author has had productive results using a larval rearing system that is a variation of what was learned from Eric Quinter years ago. It involves the use of standard ½ pint glass canning jars along with a 60 by 60 mesh screen lid. This size of mesh seems to eliminate having to deal with any other insects, such as fruit flies (*Drosophila*). A wet, but thoroughly squeezed out paper towel is placed tightly around the edge of the jar. A carrot or slice of red potato shorter than the height of the jar, and with a hole drilled in it, is then wrapped in a piece of damp paper towel. The damp paper towel in this case is to

keep the carrot or potato contained if it begins to decay and prevent a slimy mess in the jar (although the larva does not seem to be affected by this situation if it occurs). The larva is enticed to enter the hole and the substitute host is placed in the jar. The jar is labeled and placed back in the box (of 12) that it was purchased in (**Figs. 28, 29, 30**).

Figure 28 Jar, lid, screen and carrot with larva.

Figure 29 Rearing jars for *Papaipema* larvae.

Figure 30 Carrot removed from jar and cut open to expose larva.

The jars can be cleaned as necessary and the paper toweling replaced. In late summer, when *Papaipema* larvae prepare to pupate, depending on the species, they do one of the following. They either pupate inside the chamber they have created, often sealing with silk the hole from which they entered; or else they leave the carrot or potato and pupate between the layers of paper toweling. With *P. eryngii*, the larva leaves the plant, as it does in the wild. In nature, it pupates in the soil after having constructed a bit of a silken tube to the surface, this to be used as an escape passage by the newly-emerged adult moth. In the lab, it usually bores out of the bottom of the carrot or potato and in between or under the paper towel, and pupates. To alleviate any potential problems with emerging, it is a good practice to remove carefully everything in the jar, which is then cleaned, and place a new, slightly damp paper towel back in the jar (**Fig. 31**). Carefully press the toweling around the jar, leaving no gaps that the freshly-emerged moth can crawl into. Make sure that at least some of the toweling extends upward to the top edge of the jar, so that the moth has no trouble reaching the screen lid, from which it needs to hang when expanding and drying its wings. When the larva first pupates, the pupal cuticle is very soft, which renders the pupa very vulnerable to both dehydration and physical trauma, and the cuticle-hardening (sclerotization) process may require several days to be completed. Cleaning the jar and changing the toweling, therefore, should not be done until at least a week after the larva appears to have pupated, by which time the pupa will be fully sclerotized; this will minimize the chance of its being damaged during handling.

Figure 31 *P. eryngii* pupa in clean jar.

At room temperature, *P. eryngii* will remain in the pupal stage for roughly 28 to 30

days. As the pupa begins its fourth week, the eyes begin to darken noticeably, and within two or three days before emerging, the wing pattern and characteristic white spots can be seen through the pupal cuticle. At this point it is a good practice to dampen the toweling slightly to replicate outside humidity and aid in emergence. *P. eryngii* usually emerge late at night (midnight or later) and often do not fly until the following night. They will spend a couple of hours expanding their wings as hemolymph is pushed into the wing veins, eventually enlarging them to their maximum size. For the only time in its adult life *P. eryngii* will sit with its wings fully over its back, a wing position that it cannot achieve again once the wings are hardened (**Figs. 31, 32, 33, 34**).

For several nights following emergence, the female moth will release powerful male-attracting pheromones roughly between midnight and two o'clock in the morning. It is during these hours that most adult activity is noted. These are late-season moths, flying as a group from about the 20th of September to the 10th of October, and during that period, an individual probably lives 10 to 14 days under the best of circumstances. They gamble annually with the possibility of early freezing weather, which could potentially cause very low reproductive numbers for a given time period. At the beginning of their flight/breeding season, should there be a hard freeze, this could temporarily but dramatically reduce a population size. Considering the loss of possible habitat over the last 150 years and the fragmentation of the areas that these moths inhabit now, this is a hazard that must be taken into account when managing areas in which they occur.

A fall flyer with a short adult flight season and very limited time period of activity on any given day, along with their unreliable attraction to sampling methods using lights, is why larval searches are by far the best method to survey for *P. eryngii* and most all *Papaipema* moths.

Another interesting observation has been made by Ted Herig (personal communication) of Michigan, who for years has done rearing experiments with many species of lepidoptera and with *Papaipema* moths in particular. It has been generally accepted that females of most moths put out "calling" pheromones, then breed, after which they proceed to go about the business of laying eggs. However, Herig has found that in several species of *Papaipema* moths, at least in captivity, females not only breed with multiple males, but also release "calling" pheromones after they have already produced viable ova. Though this is not a total surprise, there is little, if any, other documentation of this behavioral phenomenon; it is likely a natural adaptation for species that very seldom fly far from their birthplace and have populations that are subject to a number of factors that render them susceptible to crashing.

Figure 31 Newly emerged *P. eryngii*, wings not yet expanded.

Figure 32 *P. eryngii* expanding and uncurling its wings

Figure 33Wings expanded and hardening; only time it will hold wings over back.

Figure 34 Wings fully expanded and dry *P. eryngii*.

After emergence, the adult can be left in the jar and kept cool (in the refrigerator) until it is either vouchered as a specimen, released back at the site from which it came, or used as breeding stock in a captive rearing or other research program.

Papaipema adults spend very little time feeding, but if they are to be used as breeding stock, they should be fed daily with a cotton swab dipped either in sugar-laden fruit juice or in the bait used in traps or on wine ropes. Sometimes they will not readily take this and must be encouraged to eat. This can usually be accomplished by lightly holding the wings over the moth's back (the wing position in **Fig. 33**), using your fingers or a pair of spade-tip forceps. Then, place a pin into the curled-up proboscis and very gently unroll it onto the juice-soaked cotton swab. Generally you will be able to see that they are imbibing fluid by the pumping action of the proboscis, and often you can let go of the wings and the moth will continue to feed. Doing this will keep the adult alive for one or sometimes two weeks, giving ample time for a pairing or to wait for more individuals to emerge. Adults can be kept refrigerated for a couple of days at a time without needing to be fed.

Whichever species of *Papaipema* moth one is dealing with, if a female has been bred in the lab or wild caught (which have almost certainly been bred as they seldom fly before breeding), a rather simple setup can be used to secure ova. For *P. eryngii*, place the female in a brown paper lunch bag, slightly dampen and put in some leaf material of the known larval host plant, in this case *E. yuccifolium*; use a few live leaves and a few more dried leaves. Do not use too many as each leaf will have to be examined for ova under a stereo-microscope or with a good hand lens. The ova usually will be arranged in rows that are located inside crevices, folds or in pieces of leaves that the female can pull together. The female may also deposit them in folds of the bag itself, so check there as well .They are very small and sometimes difficult to find; take your time looking. If any ova are found, they can

be overwintered in a refrigerator by being placed in some sort of closable container, such as a plastic food-storage box. Place a slightly damp paper towel in the container and place the leaf with the ova onto the towel, close the container, and label and refrigerate it. It's a good idea to check the container periodically over the winter, to see if mold has appeared, or if the towel has dried out; keep the towel slightly damp. In the spring, usually late April, take the container out of cold storage to room temperature and watch it closely for mold, or move the leaf to a more ventilated container. Within ten days to two weeks the ova should begin to darken, after which, within a day or two, the larvae will begin to hatch.

Once the larvae begin to hatch they can be introduced to their normal host plant or lab reared. The simplest lab rearing technique for hatchling *Papaipema* larvae, which is a combination of this author's experience and methods devised by Ted Hering, is to take a potato and slice it into several chunks or cubes. Poke a few holes with a toothpick into each cube, and with a very soft brush or the tip of a toothpick, introduce a larva into each hole. Gently plug the hole with a tiny roll of cotton or bit of the potato; this prevents the larva from wondering out of the hole, and forces it to start chewing. As in nature, many will survive and many will not, but at this point it is best to just leave them alone for a few weeks until they are large enough to be handled safely. Tiny piles of frass should become visible after a couple of weeks, ensuring that some larvae have accepted the substitute host. At the point when they reach about half an inch in length, each larva should be moved to its own individual container, to prevent any loss due to internecine combat and/or cannibalism. This entire process can also be done with carrots; however, potatoes, especially red potatoes because they tend to last longer before rotting, appear to be easier for these minute larvae to start out feeding on.

After they have been placed singly into their own containers, the larvae are relatively maintenance free, aside from occasionally cleaning the jar. Other than that, one must just wait for fall to see the adult moths (**Fig. 35**).

Figure 35 First adult *P. eryngii* from Missouri emerges, September 23, 2015.

The Iowa Survey Sites:

Species often associated with *P. eryngii* are the greater prairie-chicken,

Tympanuchus cupido (Phasianidae), regal fritillary butterfly, *Speyeria idalia* (Nymphalidae), leadplant, *Amorpha canescens* (Fabaceae), eastern gamagrass, *Tripsacum dactyloides* (Poaceae), blazing star, *Liatris spicata* and compass plant, *Silphium laciniatum* (both Asteraceae), and other moth species such as *Papaipema baptisiae, P. beeriana, P. silphii, P. maritima, Meropleon titan* and *Photedes inops* (all Noctuidae). Most of these species are considered habitat dependent and species of concern in many areas where they occur.

Iowa sites surveyed for Papaipema eryngii 2015-2016

	County	Site	Date
1	Adams	Hamilton Prairie	7-22-16
2	Calhoun	Munson Prairie	7-12-16
3	Clay	Kichner Prairie	7-13-16
4	Dickinson	Caylor (East)	7-13-16
5	Dickinson	Caylor (West)	7-13-16
6	Dickinson	Santa Fe Prairie	7-13-16
7	Emmet	Anderson Prairie	7-13-16
8	Howard	Hayden Prairie	7-16-16
9	Kossuth	Area of Buffalo Center	7-14-16 7-15-16
10	Lucas	Cinder Path Trail	7-28-15 7-21-16
11	Mitchell	Crossman Prairie	7-16-16
12	Montgomery	Erickson Prairie	7-22-16
13	Pocahontas	Kaslow Prairie	7-12-16
14	Story	Doolittle Prairie	7-28-15
15	Wayne	Cinder Path Trail	7-28-15 7-21-16
16	Wayne	Along Route 2	7-21-16 7-22-16
17	Webster	Liska-Stanik Prairie	7-12-16
18	Winnebago	Area of Buffalo Center	7-14-16 7-15-16
19	Winnebago	Along Route 9	7-14-16 7-15-16
20	Winnebago	Farland Access	7-15-16
21	Worth	Along Route 9	7-14-16 7-15-16
22	Worth	Rt 9 and Nettle Rd	7-15-16

Plates

Most of the following images are of *Papaipema* moths that are either very similar to *P. eryngii* or are often found in association with it; the remaining images are of interesting moths, butterflies and insects frequently occurring at sites that have *P. eryngii* (indicator species).

It must be taken into consideration when viewing these specimens that most of the *Papaipema* moths on the following plates were reared from larvae. This is important to consider when attempting to identify any *Papaipema* moth collected at light sheets or in traps because they likely will not look exactly like reared specimens. Most *Papaipema* moths emerge with a coating of darker, usually reddish scales that wear away after a few nights of flying, making them look quite different from one that has emerged and never flown. This difference has always plagued people trying to identify specimens from this group. Habitat, timing of emergence, local host plants, and nightly flight time are all factors that may come into play in order to figure out what you have. Fortunately, for male P. eryngii, the genitalia offer positive verification, whereas most other similar looking species have little variation and are difficult to tell apart. Below are examples of how species look just emerged and flight worn (designated as “flight worn”).

Once again, I want to thank Terry Harrison for his extensive time spent editing this paper. Thanks to Tony McBride, for editing and allowing me to use some of his wonderful larval images. Thanks to Paul McKenzie for everything connected to this project, his time and effort of countless hours spent pulling this project together. Thanks to John Pearson for his patience and help all along the way with this project and to Aaron Brees for his help and companionship in the field.

This completes the Iowa *Papaipema eryngii* survey report

Iowa Department of Natural Resources: Contract No. 16CRDLWSJPEAR-0001

Thanks to the following for making this possible:
Iowa Department of Natural Resources
U.S. Fish and Wildlife Service
Missouri Department of Conservation

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