An Investigation into the nocturnal moth community within the Central Platte River Valley with a focus on Erebidae and Sphingidae species

Central Platte River Valley nocturnal moth community

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AN INVESTIGATION INTO THE NOCTURNAL MOTH COMMUNITY WITHIN THE CENTRAL PLATTE RIVER VALLEY WITH A FOCUS ON EREBIDAE AND SPHINGIDAE SPECIES

CENTRAL PLATTE RIVER VALLEY NOCTURNAL MOTH COMMUNITY

David M. Baasch, Alexa C. Rojas, Andrew J. Caven, and Joshua D. Wiese

Abstract.—Numerous conservation and surveying efforts have been aimed toward assessing and documenting pollinators in decline, including bees and butterflies, across North America. However, less knowledge and study have been geared toward the often overlooked and seldom inventoried nocturnal moth species, which also provide important ecosystem services such as pollination. As a diverse group of pollinators, prey, and defoliators, moths are not represented adequately in ecological research. The purpose of our study was to identify the species of moths present on Platte River Whooping Crane Maintenance Trust Inc. (Crane Trust) properties, which are located within the Central Platte River Valley (CPRV) in Nebraska. We conducted an investigation that included 17 sites with various landcover types, land-use histories, and anthropogenic disturbance levels over a six-week period between June 8 and July 20, 2022 and on September 19 and 20, 2022. In an effort to attract a wide variety of species, we used a UV light trap and a fermented fruit lure to attract moths and surveyed 30 minutes to 5 hours after civil twilight. Our UV light trap was successful in helping us capture and identify 235 nocturnal moth species including 12 species newly recorded in the state of Nebraska. Our fermented fruit lure was not as effective and attracted only six moth species, all of which were detected at our light trap. Our findings contribute to the understanding of many species' ranges and are an indication of the great diversity of moths present within the CPRV. A full examination of the differences in species composition and richness between landcover types, land-use histories, and anthropogenic disturbance levels would be a worthwhile task. However, it would require further research that would involve multiple visits to each site and a survey period that extends from early June through late September to obtain species presence data that is more representative of the entire moth community.

Keywords.— Central Platte River Valley, Inventory, Erebidae, Lepidoptera, Light Trap, Macro Moth, Nebraska, Nocturnal, Pollinator, Sphingidae, Western Prairie Fringed Orchid

INTRODUCTION

Moths provide important ecological services such as pollinators, prey, and defoliators and yet they are greatly understudied (Slade et al. 2013, Fox 2013). They are the largest group of pollinators comprising of more than 1,300 species in the state of Nebraska and around 20,000 in North America north of Mexico (Dankert n.d.). Some large moths, such as species belonging to the Sphingidae family, carry the important task of providing genetic connectivity between populations of plant species by traveling long distances (Young et al. 2017, Skogen et al. 2019, Caven 2022). Various rare vascular plants, such as the western prairie fringed orchid (*Platanthera praeclara*), depend on these moths to support future generations (Westwood and Borkowsky 2004, Young et al. 2017). Moths also serve as an important food source to many birds, bats, herptiles, small mammals, and predatory arthropods (Hammond and Miller 1998, Slade et al. 2013, Fox 2013). Conversely, they are prominent defoliators and consume high proportions of foliage (Slade et al. 2013, Fox 2013, Hammond and Miller 1998). As significant pollinators, prey, and defoliators, they can affect plant population dynamics, predator-prey population dynamics, nutrient cycling, and microclimates (Brookes et al. 1987, Gange and Brown 1989, Elkinton and Liebhold 1990, Huntly 1991, Campbell 1993, Hammond and Miller 1998).

In addition to playing a significant role in ecosystem function, their sensitivity to changes in landcover could make them useful as indicator species. Panzer et al. (1995) proposed that moths were a group suitable for use as indicators because some moth species were found to be remnant-dependent. Additionally, moths belonging to Geometroidea have been noted for their sensitivity to habitat disturbance (Holloway 1984, Intachat et al. 1997). Remnant-dependence and disturbance sensitivity are most likely linked to host-plant specificity, making their presence in a landscape dependent on very specific plant assemblages (Panzer et al. 1995). Moths have been used for assessing the effects of habitat restorations, environmental impact assessments, and environmental change (Gimesi et al. 2012, Chaundy-Smart et al. 2012, Slade et al. 2013, Highland and Jones 2014). The identification of moth indicator species could prove useful in ecological monitoring and assessment of management and restoration actions in the Central Platte River Valley (CPRV) of Nebraska, a globally significant landscape for conservation that is generally associated with migratory waterbirds and also supports unique and remnant vegetative and invertebrate communities (Whiles et al. 1999, Caven et al. 2017, Caven and Wiese 2022).

Many scientists agree that Earth is undergoing a sixth mass extinction in geological time (Ceballos et al. 2015). Even though invertebrates make up 99% of species on earth, most of these species have not been included in conservation and extinction rate estimates (Régnier et al. 2015). The current estimate of extinct species in the world is 0.04%, but Régnier et al. (2015) estimated that number could increase to 7% if invertebrates were included. Invertebrate species that scientists choose to research are often the charismatic, such as butterflies and bumblebees (Fox 2013, Régnier et al. 2015). However, mass extinction threatens all taxa and the corresponding ecosystem services they provide. There remains a great need to learn about the geographic ranges, abundances, and population trends of a wider breadth of invertebrate species to better understand their population statuses and conservation needs.

Declines in other pollinators, like bees and butterflies, have been well documented, but fewer studies have examined moth abundance and diversity (Pott's et al. 2010, Van Zandt et al. 2020, Fox 2013). The limited data available suggest that moths are also experiencing widespread declines. One study looked at hawk moths in northeast United States and found that 44% were in decline (Young et al. 2017). Conrad et al. (2004) used a database that spanned 35 years and reported the populations of the majority (66%) of moth species in their study had declined. Insect pollinators have close trophic relationships with host plants, which make them easily influenced by habitat loss and fragmentation (Holloway et al. 1992, Panzer et al. 1995, Schmidt and Roland 2006, Senapathi et al. 2016). In fact, over 98% of the tallgrass prairie has disappeared in Nebraska alone (Steinauer et al. 2011). The decline in available habitat and the development of a mass extinction event raises the reasonable concern that many moth species may also be in decline; thus, further research should be allocated to investigate them.

The primary objective of our study was to begin filling the knowledge gap in research on moth communities in Nebraska. We approached this by developing an investigation of nocturnal moths from sites across a variety of landcover types, land-use histories, and anthropogenic disturbance regimes within the CPRV. Landcover types included grassland, wet meadow, woodland, and agricultural; and land-use histories included remnant, restored, and farmed land. Concurrently, we examined moth species detection using UV lights and fermented fruit lure traps.

METHODS

Study Area

We surveyed Crane Trust properties located in southcentral Nebraska within the CPRV, which is comprised of about 2,575 ha of remnant and restored lowland tallgrass prairie, wet meadow, and shallow marsh habitat, as well as riparian woodlands and shrublands (Caven and Wiese 2022). The easternmost edge of our study area was US HWY 281 (Mormon Island, 40.808976°, -98.378534°; 576 m elev.) and the westernmost edge was between Alda and Wood River, Nebraska (40.776461°, -98.530898°; 591 m elev.). The study area followed the main channel of the Platte River and extended about 3 km north and south of the river at its widest points. We conducted the light trap and fermented fruit lure surveys at 17 sites with various habitat types, land use histories, and anthropogenic disturbance regimes. For the different habitats we had eight lowland tallgrass prairies, three wet meadows, three woodlands, and three agricultural fields. For land use histories we included four restored sites, 10 remnant sites, and three farmed sites. Finally, for anthropogenic disturbance regimes we had six low disturbance sites, 10 intermediate disturbance sites, and one high disturbance site. Cumulative disturbance level was estimated considering the relative abundance of anthropogenic landcovers within a 5-km buffer of sampling sites (low $<33\%$, moderate = 33-66%, and high $>66\%$). Classification of habitats based on vegetative communities was based on survey data and categorizations from Caven and Wiese (2022).

Target species

While we attempted to capture all species of moths observed, special consideration was given to larger species of moths (i.e., wingspan ≥ 2.0 cm), especially members of the family Sphingidae (e.g., sphynx moths) and members of the genus *Catocala*. Sphinx moths have been identified as pollinators of the endangered western prairie fringed orchid, so we were interested in determining how many potential pollinators of this rare plant persisted in the CPRV (Westwood and Borkowsky 2004). Species belonging to the Sphingidae family are able to disperse long distances, which could prove to be very beneficial for maintaining genetic variability in the future if western prairie fringed orchid populations were re-established within their historic range. We also focused our study on underwing species (*Catocala* sp.) because many of them are species of conservation concern in Nebraska. The Nebraska Game and Parks Commission stated that research on abundance, distribution, and population trends were necessary to advance our knowledge and conservation efforts (Schneider et al. 2018). By prioritizing underwings, we aimed to expand our understanding of their distribution in Nebraska. To ensure as many Sphingidae and *Catocala* species were captured and identified as possible, we focused our capture and processing efforts (i.e., photographed, identified, etc.) on them before other species regardless of abundance or order of capture time.

Field Methods

We used UV light traps and fermented fruit lures to attract nocturnal moths within a 4.5-hour survey period that started 30 minutes after civil twilight and tended to be between 2130 and 0200 hours. Fifteen surveys were conducted between June 8 and July 20, 2022 and two more surveys were conducted September 19 and 20, 2022. We did not survey between July 20th and September 19th due to funding and logistical limitations.

Light trapping is the most often used method for investigating moth communities and is often utilized to study the biodiversity in many types of habitats and climactic conditions (Beck and Linsenmair 2006, Infusino et al. 2017). We used a queen-sized white sheet (244 cm x 259 cm) stretched horizontally between two poles weighted with cement-filled buckets to create the background. We anchored the poles with ropes to prevent the setup from tipping over from wind and uneven terrain. We also placed a white canvas sheet on the ground underneath the white background to be able to identify moths that land on the ground. We used a 100w UV LED floodlight (110v) with a wavelength of 385– I400 nm (Van Langevelde et al. 2011, Jonason et al. 2014, Merckx and Slade 2014) and a 120° beam angle mounted on a tripod located 2-3 m from the sheet.

Each time we detected a new species for a given sampling period we captured it using an insect net or a contraption made up of the top half of a plastic one-liter pop bottle and a piece of cardboard to slide underneath. We photographed each individual and collected measurements of total and wingspan length for identification purposes. We photographed the dorsal side, the side profile, and/or the dorsal side of their wings spread to expose hindwings depending on the species and their shape. We also recorded the time of collection, the field identification or description, whether the individual was caught at the light trap or fruit lure, and the photo number or range of numbers associated with the individual. Very active moths were placed in a sealed jar in an ice box to be chilled and subdued for a few minutes to allow for easier photographing. Photographs were used at a later time to confirm the identification of species.

To minimize our impact on the moth community, species known to occur in the area per Lotts et al. (2017) were released after data were recorded. Exceptions to this case were individual species that were new to the state of Nebraska, which were collected and submitted to the University of Nebraska State Museum in Lincoln as evidence of a state record. However, regardless of distributional novelty, Tier-1 and Tier-2 species of concern were simply recorded, photographed, and released.

Moths were positively identified by a qualified lepidopterist using Peterson Field Guides (Beadle and Leckie 2012, Leckie and Beadle 2018). For all species captured, we submitted photographs to iNaturalist and Bugguide.net for storage and confirmation of identification. Collections were made under Nebraska Game and Parks Commission Scientific and Education Master Permit #1212.

To estimate relative abundance, a 1.0 m x 1.0 m grid was drawn at the center of the white background sheet and divided into 9, 33 cm x 33 cm cells. We counted the number of grid cells occupied by macro-moth (i.e., wingspan ≥2.0 cm) species at regular intervals (every 30 min) during the 4.5-hour survey period and took photographs for later processing. Additionally, we recorded temperature, wind, and humidity at each 30-minute interval. One minute prior to photographing, we ceased moth collections to allow time for moths to land on the grid. This represents a novel non-lethal method for assessing relative abundance that provided a preliminary evaluation of macro-moth abundance.

We chose to implement a fermented fruit lure as a secondary detection method to target underwing and other macro-moth species (Utrio and Eriksson 1977, Pettersson and Franzén 2008). We placed a 5 cm x10 cm wooden board with 1 cm-deep holes on top a 90-cm tall, free-standing 10 cm x 10 cm white post and coated the top with a fermented mixture. This mixture contained wine, yeast, banana, and strawberry because underwings and a number of other macro-moth species are known to be attracted to fermenting fruit (Utrio and Eriksson 1977, Pettersson and Franzén 2008). The post was placed behind the UV light in a location that would not receive too much foot traffic. The lure was checked every five minutes throughout the 4.5-hour survey period and the bait was replenished every hour with fresh fermented mixture. Similar to the light-trap method, all species observed on the bait post were captured and photographed for identification.

Data Analysis

We calculated basic community summary statistics for each site trapped including species richness. We compared moth communities across sites as well as habitat types, land use histories, and anthropogenic disturbance gradients. We performed a Dunn post-hoc test using the dunn.test package in R (Dunn 1964, Dinno and Dinno 2017) to examine differences in species richness between landcover types (grassland, wet meadow, woodland, and cropland). We also examined species richness between remnant grassland and restored grassland sites using a Kruskal-Wallis test. We did not perform additional statistical analysis of species richness due to unequal sampling and small sample sizes. We performed a Kruskal-Wallis test to compare relative abundance between nights of two moon phase types. We categorized nights that the moon phase was between last quarter and first quarter as "crescent" and nights between the first quarter and last quarter as "gibbous".

RESULTS

We were highly successful capturing moths with the UV light trap and captured 235 unique moth species encompassing 22 families and 189 genera (Appendices 1 & 2). Out of the 131 macro-moths that were captured and identified, five were Sphingidae species and 23 were from the Erebidae family, two of which were underwings (*Catocala sp*.; Appendix 1). We captured a Whitney's underwing (*Catocala whitneyi*) moth, which was listed by the State of Nebraska as a Tier-1 at-risk species of greatest conservation need. We captured 12 species that had never been documented previously in Nebraska, as well as an Ello sphinx (*Erinnyis ello*) being notable as it had previously only been recorded in four other counties in Nebraska (Appendices 1 & 2). Two of the state-record species we captured, the goldenrod gall moth (*Epiblema scudderiana*) and *Bactra maiorina*, were found to be relatively common and were captured at five sites. Of these new species, most had been identified to occur in states surrounding Nebraska including Iowa, Missouri, Kansas, Colorado, and Wyoming; however, three had not. These three species included *Haimbachia albescens*, which was previously found in Indiana; *Occidentalia comptulatalis*, previously identified in Minnesota; and *Eucosma influana*, previously captured in southern Oklahoma and northern Texas, which may indicate range extensions beyond filling a distributional gap.

We captured 59 species that were exclusively found in grasslands, 13 species that were only captured in wet meadows, 41 species that were only captured in woodlands, five species that were only captured in croplands, and 117 "generalist" species that were captured in multiple landcover types (Table 1). Looking at land-use history, we captured 57 unique species that were only caught at remnant grassland sites, 41 species that were only caught at woodland sites, 18 species that were only caught at restored grassland sites, and five species that were only caught in farmed sites. On average, we captured more species of moths in remnant grasslands and woodlands with low to moderate development than we did in restored grasslands, wet meadows, or croplands (Table 2). We observed a significant difference in species richness between landcover types with woodlands (n = 3) having the highest mean species richness of 52 ± 3.5 and croplands (n = 3) having the lowest of 31.7 ± 4.4 (p = 0.0407) with no difference observed between remnant and restored grassland sites (p = 0.157). We found nights where the moon phase was between last quarter and first quarter (crescent moon) had significantly higher macro-moth abundance than nights when the moon was between first quarter and last quarter (gibbous moon). The composition of moth species detected in September was markedly different from the composition of species detected in June and July. During two surveys conducted in September, we captured 61 total species, of which 39.3% (n = 24) were new to the study. On average, we counted 5.1 (SE=5.0) macro moths during hourly counts of macro moths present on the light trap screen. We found no correlation (R=0.16) between the number of moths captured at each site and the abundance of macro moths counted every hour of our survey. We had a much lower success rate in attracting moths with fermented fruit where only six species were captured, all of which were detected at our light trap.

Discussion

The past direction of scientific research has led to gaps in our knowledge about moth species distributions and ranges despite the important roles they play in various ecosystems. Since moths represent a very diverse and declining group of invertebrate species, there is a great need to investigate their population trends, distributions, and abundances. Such research could help shed light on the conservation status of overlooked species or uncover species that may play valuable roles in advancing conservation efforts as indicator species. Our study has exemplified the diversity of moths by identifying more moth species (235) than known butterfly species in Nebraska (211) in a relatively short timeframe of 47.5 survey hours.

Among the species captured were sphinx moths, which included some species that were common at our sites. We caught at least one Sphingidae species at 12 out of the 17 sites and had white-lined sphinx (*Hyles lineata*) moths at 10 sites. The presence of sphinx moths may be an indication of the potential to reestablish the western prairie fringed orchid in the CPRV by providing pollination opportunities. Sphingidae moth species are capable of maintaining genetic connectivity of separated populations through pollination across long distances (Young et al. 2017, Skogen et al. 2019, Caven 2022*)*. The persistence of plant species in fragmented environments is thought to be dependent upon long-distance gene flow provided by pollinators and other species (Finger et al. 2014, Skogen et al. 2019). The important roles sphinx moths play in the population dynamics of rare vascular plants highlights cause to investigate them further. For instance, investigating their abundance and diversity could help us determine if sphinx moths are well represented enough regionally to support a western prairie fringed orchid population, which was last detected on Mormon Island in the year 2000 (Caven 2022). If declines and/or low diversity among sphinx moths were discovered, we could identify conservation and management actions that could be implemented to restore populations.

Our study was successful in revealing species that had never been documented before in Nebraska. Out of the 12 new species captured and identified, eight were micro-moths and four were macro-moths. An interesting pattern found among these moths is that the majority of these state records were small, neutral-colored species, including the goldenrod gall moth (*Epiblema scudderiana*) and *Bactra maiorina*, which were quite common at five sites. Their prevalence begs the question, why were they not discovered before? The more apparent explanation is that their nocturnal behavior keeps moths concealed from human observations during the day. Similarly, their small and neutral-colored appearance makes these moths more cryptic and allows them to blend well with their surroundings, making them less noticeable. Another explanation is that when they are sighted, their appearance does not warrant enough interest to identify them (Culumber et al. 2019, Niemiller et al. 2021). Furthermore, moths are not ordinarily viewed as a charismatic group and do not evoke substantial interest for people to record them, causing many regions to have gaps in the number of known species present.

Having robust knowledge of species composition across moth taxa is important to our understanding of what services and functions are fulfilled in an ecosystem. For example, an abundant and diverse composition of moths would suggest that many bat and bird species have a dependable food source (Sánchez-Bayo and Wyckhuys 2019). Additionally, the presence of sphinx moths informs us that certain groups of plants, such as orchids that are pollinated by them, are likely receiving sufficient visitation and that lack of pollination may not be a primary driver of plant population declines (Westwood and Borkowsky 2004, Caven 2022). Our results offer encouragement to those interested in investigating moth communities in areas where they have been understudied.

Our methods could not only be used to inventory species, but they may also indicate broader habitat or landscape conditions. Having a greater number of unique species present at remnant sites reveals the potential to investigate species that could be remnant-dependent. If remnant-dependence is found among these species, they could be used as indicators of habitat condition and aid conservation efforts along the CPRV (Panzer et al.

1995). Panzer et al. (1995) identified *Schinia* sp. and *Papaipema* sp. as genera that were remnant-dependent with the potential to be used as indicators in conservation projects. We found *Schinia* sp. at two sites and *Papaipema* sp. at another two sites, and all four sites were on remnant land. Members of the superfamily Geometroidea have also been suggested to be useful as environmental indicators due to their sensitivity to habitat disturbance (Holloway 1984, Intachat et al. 1997). Slade et al. (2013) suggested that larger, more mobile moths with high habitat affinity are most vulnerable to habitat fragmentation and as they tend to be heavily dependent on habitat connectivity. Future studies should investigate these taxonomic and morphometric groups to determine if they are remnant-dependent, sensitive to anthropogenic disturbance, or sensitive to fragmentation making them suitable indicator species.

Species richness, diversity, and abundance measurements may also be useful in assessing habitat condition. Habitat disturbance and fragmentation have been shown to negatively affect species richness, diversity, and abundance in moths (Holloway et al. 1992, Beck et al. 2002, Slade et al. 2013). Slade et al. (2013) found that forest connectivity increased species richness and abundance of forest specialists. Forest disturbance has been found to decrease species richness and diversity (Holloway et al. 1992, Beck et al. 2002). These trends are often investigated in forested habitat, which demonstrates the need to examine species richness, diversity, and abundance in understudied habitats such as prairies. Our remnant sites had a relatively higher number of unique species (i.e., higher species richness) than restored and farmed sites, although the differences were not statistically different. This trend could indicate that remnant sites have habitats suitable for more species. These results are encouraging enough to continue the study and increase site visits so that we could build enough data to potentially detect significant differences. Since our remnant sites were generally less disturbed than restored and farmed sites, our results support previous studies that have found that moth diversity and species richness is higher in less disturbed habitats (Holloway et al. 1992, Beck et al. 2002).

Although light traps are the most commonly used method for attracting many species, moths can be lured using bait traps (Butler et al. 1999, Süssenbach and Fiedler 1999, Pettersson and Franzén 2008). Bait traps have been a useful method in the past, but our bait traps were not very effective at attracting moths. While *Catocala* (i.e., underwings) were a target genus of this study, we only captured two species of underwing moths. Given that underwing moths, one of our target genera, are mostly active in August and September, one likely cause for their absence is that the majority of underwing species were inactive in June, July, and late September when we surveyed. Summerville and Crist (2003) found a significant compositional difference in moth communities when sampling occurred early and late in the season.

Similarly, the moth composition from late September in our study varied greatly from the composition observed in June and

July. This outcome could be explained by the seasonality of moths that are normally attracted to fermented fruit. We implemented a fermented fruit lure in our surveys because underwings are reportedly attracted to this type of mixture and we had intended to survey through the end of September. In the future, surveys should be conducted throughout the entire season when moths are active (June - September) to ensure a representative number of target species, like underwings, are captured.

Surveying June through September would also allow one to document phenology and emergence times for many species of moths. Surveying from June to September would achieve a more accurate representation of the moth composition in this region and would be a better representation of whether underwings are common or rare. If underwing species are still not detected, this would be an indication they could be in severe decline, making them rarely detectable or even undetectable. This type of information would be valuable in the efforts to restore populations of species of conservation concern such as western prairie fringed orchid.

Several studies have found the number of individual moths caught in light traps decrease with the fullness of the moon (McGeachie 1987, Nag and Nath 1991, Yela and Holyoak 1997, Beck et al. 2011). Furthermore, McGeachie (1987) found light-traps were equally effective during nights that were more or less illuminated by moonlight and suggested some moths changed their behavior as moonlight illuminance changed. We found higher relative macro-moth abundances during nights with crescent, last quarter, or first quarter moon phase, which corroborates findings of these previous studies that reported some moths are less active on nights illuminated with a fuller moonlight. This is likely because when a high proportion of moonlight is polarized (i.e., crescent moon phase), flight activity increases; but when there is a low level of polarization, as at a full moon, flight activity decreases (Svensson and Rydell 1998). Therefore, insects such as moths may be more reluctant to fly at full moon because the non-polarized light may make them more conspicuous to predators.

Our study was designed to capture a sizable pool of moth species representative of the different habitats within the CPRV. However, we were limited in the number of surveys we could conduct due to budget and logistical constraints, so we did not visit each site more than once. Since we did not have replications for each site, we did not have a sample size sufficient to analyze differences between landcover types, land-use histories, and anthropogenic disturbance levels. Future investigations should aim to survey sites two to three times throughout the summer months when moths are active to examine whether significant differences between treatments can be detected.

Other future additions to our survey methodology could be to measure species' abundance and diversity. Diversity measurements would be useful to compare across habitat types and land use histories, which would be helpful in making inferences about ecosystem stability and habitat quality. Obtaining abundance measurements could help us determine if any communities are suffering from declines or are stable. Additionally, studies like ours should be implemented for multiple years to monitor population trends and examine species abundance and diversity over time. Long-term data is necessary to observe significant trends and notable changes to the community. Gathering data on distribution and population trends could help inform conservation statuses of a number of species, which would help to prioritize threatened species for conservation planning. However, one would need to weigh the consequences of lethal trapping when obtaining abundance and diversity measurements for conservation purposes.

CONCLUSION

For the relatively short amount of time and space sampled, we discovered many species that were not previously known to occur within the CPRV or the state at large. Obtaining data on the composition of moth communities is important in determining what roles and services are fulfilled in an ecosystem. Additionally, it is important to obtain this data to help inform the conservation status of species of conservation concern and the consequent management strategies used to recover them. Nocturnal moth surveys would also be valuable in conservation research through the identification of environmental indicators that could be used to assess habitat condition and the effects of conservation, restoration, and land management strategies.

Our study demonstrates the need for further investigation of abundance, diversity, and distributions of moth communities in Nebraska, and likely many more regions in North America. Furthermore, our results show promise for others to follow the same direction and launch projects aimed at inventorying and monitoring moth communities in areas that have been overlooked, as well as for citizen scientists and naturalists to pursue similar undertakings.

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Table 1. Numbers of moth species captured in the Central Platte River Valley in Nebraska during June 8-July 20 and September 19-20, 2022 within each of the various landcover types sampled, including croplands (3), grasslands (8), wet meadows (3), and woodlands (3).

Landcover Type	Species Captured
Cropland	5
Grassland	59
Wet Meadow	13
Woodland	41
Cropland & Grassland	11
Cropland & Wet Meadow	3
Cropland & Woodland	3
Grassland & Wet Meadow	14
Grassland & Woodland	26
Wet Meadow & Woodland	4
Cropland, Grassland, & Wet Meadow	8
Cropland, Grassland, & Woodland	12
Cropland, Wet Meadow, & Woodland	2
Grassland, Wet Meadow, & Woodland	7
Cropland, Grassland, Wet Meadow, & Woodland	27
Grand Total	**235**

Table 2. Numbers of macro- and micro-moth species captured in the Central Platte River Valley in Nebraska during June 8 - July 20 and September 19-20, 2022 within each of the various landcover types sampled.

Landcover	**# Sites**	**Relative Amount of Agriculture or Development within a 5-km Buffer***	**Status**	**Macro-moth Species**	**Micro-moth Species**	**Total Species**
Cropland	2	Moderate	Farmed	35	26	**61**
Cropland	1	High	Farmed	14	11	**25**
Grassland	2	Low	Remnant	41	26	**67**
Grassland	2	Low	Restored	25	27	**52**
Grassland	1	Moderate	Remnant	42	31	**72**
Grassland	3	Moderate	Restored	43	38	**81**
Wet Meadow	2	Low	Remnant	27	28	**55**
Wet Meadow	1	Moderate	Remnant	20	17	**37**
Woodland	1	Low	Remnant	21	25	**46**
Woodland	2	Moderate	Remnant	60	30	**90**

* Low (<33%), moderate (33-66%), and high (>66.6%) agriculture and development within a 5-km buffer.

Appendix 1. Macro-moth species captured and identified on Crane Trust properties during June 8 - July 20 and September 19-20, 2022 within four landcover types (Cropland, Grassland, Wet Meadow, and Woodland), with three management histories (Farmed, Remnant, and Restored), and three levels of agricultural and developed landcovers within a 5-km buffer including Low (<33%), Moderate (33-66%), and High (>66%). *denotes new Nebraska state records

		Cropland		**Grassland**				**Wet Meadow**		**Woodland**	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Acrolophus arcanella	*Acrolophidae*		X								
Acrolophus plumifrontella	*Acrolophidae*		X								
*Amydria effrentella**	*Acrolophidae*	X						X			X
Coleophora mayrella	*Coleophoridae*					X					
Prionoxystus robiniae	*Cossidae*										X
Achyra rantalis	*Crambidae*									X	
Aethiophysa invisalis	*Crambidae*							X			
Argyria nummulalis	*Crambidae*				X			X			
Chrysoteuchia topiarius	*Crambidae*			X							
Conchylodes octonalis	*Crambidae*							X			
Crambus agitatellus	*Crambidae*					X					
Crambus leachellus	*Crambidae*						X				
Desmia maculalis	*Crambidae*										X
Diatraea evanescens	*Crambidae*	X			X	X			X	X	
Donacaula melinellus	*Crambidae*									X	
Elophila obliteralis	*Crambidae*	X	X			X		X	X		
Euchromius ocellea	*Crambidae*				X						
Eustixia pupula	*Crambidae*							X			
Fissicrambus mutabilis	*Crambidae*					X					
Frechinia laetalis	*Crambidae*				X		X	X			X
Glaphyria sesquistrialis	*Crambidae*						X				X

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Hahncappsia pergilvalis	*Crambidae*				X						
*Haimbachia albescens**	*Crambidae*			X					X		
Loxostege cereralis	*Crambidae*									X	
Loxostege munroealis	*Crambidae*			X							
Loxostegopsis merrickalis	*Crambidae*	X		X			X				
Lygropia rivulalis	*Crambidae*	X						X			
Microcrambus elegans	*Crambidae*	X		X	X	X	X	X			X
Microtheoris ophionalis	*Crambidae*	X					X	X	X		
*Microtheoris vibicalis**	*Crambidae*		X								
Mimoschinia rufofascialis	*Crambidae*	X			X		X		X	X	X
Neodactria luteolellus	*Crambidae*						X	X			X
Nephrogramma reniculalis	*Crambidae*										X
Nomophila nearctica	*Crambidae*						X	X			
*Occidentalia comptulatalis**	*Crambidae*									X	X
Ostrinia penitalis	*Crambidae*					X					
Palpita magniferalis	*Crambidae*				X						
Parapediasia teterrellus	*Crambidae*			X	X	X		X			
Parapoynx badiusalis	*Crambidae*	X			X	X	X	X		X	X
Pediasia trisecta	*Crambidae*							X			
Perispasta caeculalis	*Crambidae*										X
Platytes vobisne	*Crambidae*			X							
Polygrammodes flavidalis	*Crambidae*			X			X			X	
Pyrausta signatalis	*Crambidae*	X						X			
Saucrobotys futilalis	*Crambidae*				X						X

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Sitochroa chortalis	*Crambidae*						X			X	
Stegea eripalis	*Crambidae*			X		X					
Thaumatopsis pexellus	*Crambidae*					X			X		
*Thopeutis forbesellus**	*Crambidae*	X		X	X		X		X		
Udea rubigalis	*Crambidae*										X
Urola nivalis	*Crambidae*				X		X			X	
Vaxi auratellus	*Crambidae*	X			X		X				X
Xanthophysa psychialis	*Crambidae*					X				X	
Agonopterix alstroemeriana	*Depressariidae*		X		X						
Aristotelia elegantella	*Gelechiidae*	X					X	X			
Chionodes discoocellella	*Gelechiidae*	X		X	X		X		X		
Mompha eloisella	*Momphidae*						X				
Callima argenticinctella	*Oecophoridae*						X				
Plutella xylostella	*Plutellidae*	X	X	X		X	X		X	X	
Thyridopteryx ephemeraeformis	*Psychidae*						X				X
Emmelina monodactyla	*Pterophoridae*		X			X	X			X	
Hellinsia inquinatus	*Pterophoridae*	X		X	X	X		X			
Adelphia petrella	*Pyralidae*						X				
Arta statalis	*Pyralidae*	X				X	X		X		
Canarsia ulmiarrosorella	*Pyralidae*						X			X	X
Homoeosoma electellum	*Pyralidae*	X		X		X	X		X		
Honora mellinella	*Pyralidae*						X			X	
Hypsopygia costalis	*Pyralidae*				X					X	
Hypsopygia intermedialis	*Pyralidae*			X		X	X	X	X	X	X

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Meroptera cviatella	*Pyralidae*						X				X
Peoria roseotinctella	*Pyralidae*				X						
Sciota celtidella	*Pyralidae*									X	
Sciota fernaldi	*Pyralidae*					X					
Tampa dimediatella	*Pyralidae*	X		X	X		X			X	
Scythris trivinctella	*Scythrididae*			X	X	X	X		X		
*Aethes Razowskii**	*Tortricidae*	X		X	X	X	X		X	X	X
*Bactra maiorina**	*Tortricidae*	X						X			
Celypha cespitana	*Tortricidae*	X	X	X			X	X	X		X
Choristoneura rosaceana	*Tortricidae*										X
Clepsis clemensiana	*Tortricidae*		X					X			X
Clepsis peritana	*Tortricidae*					X					
Ecdytolopha insiticiana	*Tortricidae*							X			
Endothenia nubilana	*Tortricidae*	X	X	X		X	X		X	X	
Epiblema abruptana	*Tortricidae*					X					
Epiblema minutana	*Tortricidae*	X	X	X				X			X
*Epiblema scudderiana**	*Tortricidae*					X		X			
Epiblema strenuana	*Tortricidae*					X				X	
Eucosma bilineana	*Tortricidae*							X			
Eucosma glomerana	*Tortricidae*			X	X	X				X	
Eucosma grindeliana	*Tortricidae*						X			X	
*Eucosma influana**	*Tortricidae*										X
Eucosma parmatana	*Tortricidae*										X
Eucosma radiatana	*Tortricidae*	X		X	X	X	X		X	X	

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Grapholita tristrigana	*Tortricidae*										X
Gynnidomorpha romonana	*Tortricidae*						X	X			
Pelochrista argentialbana	*Tortricidae*				X						X
Pelochrista galenapunctana	*Tortricidae*				X						
Pelochrista heathiana	*Tortricidae*					X					
Pelochrista matutina	*Tortricidae*	X									X
Pelochrista robinsonana	*Tortricidae*			X		X					
Pelochrista scintillana	*Tortricidae*			X							
Pelochrista vagana	*Tortricidae*							X			X
Sparganothis sulfureana	*Tortricidae*				X	X					
Xenotemna pallorana	*Tortricidae*			X			X				

Appendix 2. Micro-moth species captured and identified on Crane Trust properties during June 8 - July 20 and September 19-20, 2022 within four landcover types (Cropland, Grassland, Wet Meadow, and Woodland), with three land-use histories (Farmed, Remnant, and Restored), and three levels of agricultural and developed landcovers within a 5-km buffer including Low (<33%), Moderate (33-66%), and High (>66%). * denotes new Nebraska state records

		Cropland		**Grassland**				**Wet Meadow**		**Woodland**	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Elachista orestella	*Elachistidae*				X						
Apantesis carlotta	*Erebidae*										X
Apantesis parthenice	*Erebidae*										X
Caenurgina erechtea	*Erebidae*	X			X	X		X	X		X
Catocala illecta	*Erebidae*			X							
Catocala whitneyi	*Erebidae*			X			X				X
Cisseps fulvicollis	*Erebidae*				X						
Cycnia oregonensis	*Erebidae*	X				X	X	X	X	X	
Gabara subnivosella	*Erebidae*	X									X
Haploa reversa	*Erebidae*										X
Hypena manalis	*Erebidae*	X		X	X		X			X	X
Hypena scabra	*Erebidae*	X	X								X
Hypoprepia fucosa	*Erebidae*							X			X
Idia aemula	*Erebidae*										X
Idia lubricalis	*Erebidae*										X
Lesmone detrahens	*Erebidae*							X			X
Macrochilo orciferalis	*Erebidae*										X
Phalaenostola larentioides	*Erebidae*										X
Phalaenostola metonalis	*Erebidae*										X
Phragmatobia fuliginosa	*Erebidae*	X	X	X	X		X	X	X	X	X
Pyrrharctia isabella	*Erebidae*						X				

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Spilosoma virginica	*Erebidae*	X		X	X		X		X	X	
Tetanolita floridana	*Erebidae*	X			X	X	X	X	X	X	X
Virbia aurantiaca	*Erebidae*				X	X	X				
Anavitrinella pampinaria	*Geometridae*							X			
Cabera quadrifasciaria	*Geometridae*	X		X							
Chlorochlamys chloroleucaria	*Geometridae*									X	
Chlorochlamys phyllinaria	*Geometridae*	X				X					X
Costaconvexa centrostrigaria	*Geometridae*			X							
Digrammia continuata	*Geometridae*	X					X				
Digrammia gnophosaria	*Geometridae*	X				X	X				
Digrammia ordinata	*Geometridae*						X				X
Digrammia subminiata	*Geometridae*						X				
Ectropis crepuscularia	*Geometridae*	X	X	X	X	X	X	X			X
Euacidalia sericearia	*Geometridae*					X	X	X	X		X
Euchlaena johnsonaria	*Geometridae*										X
Euchlaena obtusaria	*Geometridae*										X
Eumacaria madopata	*Geometridae*							X			X
Eupithecia miserulata	*Geometridae*										X
Eusarca confusaria	*Geometridae*										X
Haematopis grataria	*Geometridae*						X				
Iridopsis defectaria	*Geometridae*					X			X		
Leptostales ferruminaria	*Geometridae*						X		X		
Macaria coortaria	*Geometridae*	X				X	X	X	X	X	X
Macaria pustularia	*Geometridae*	X		X	X	X	X		X	X	

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Mellilla xanthometata	*Geometridae*					X					
Metanema inatomaria	*Geometridae*										X
Nematocampa resistaria	*Geometridae*						X				
Orthonama obstipata	*Geometridae*		X			X					X
Psamatodes abydata	*Geometridae*		X								
Scopula inductata	*Geometridae*						X				
Synchlora aerata	*Geometridae*										X
Tolype velleda	*Lasiocampidae*						X				X
Abrostola urentis	*Noctuidae*	X					X			X	
Acronicta insularis	*Noctuidae*						X			X	
Acronicta lepusculina	*Noctuidae*	X				X					
Agnorisma badinodis	*Noctuidae*	X	X	X	X		X				X
Agrotis gladiaria	*Noctuidae*						X				
Agrotis ipsilon	*Noctuidae*	X	X	X	X	X	X	X	X	X	X
Agrotis venerabilis	*Noctuidae*			X							
Amphipyra glabella	*Noctuidae*			X							
Anagrapha falcifera	*Noctuidae*				X						X
Anarta trifolii	*Noctuidae*			X		X					
Anicla illapsa	*Noctuidae*									X	
Anterastria teratophora	*Noctuidae*			X		X		X		X	X
Apamea burgessi	*Noctuidae*			X							
Apamea devastator	*Noctuidae*			X							
Apamea inordinata	*Noctuidae*			X							
Autographa precationis	*Noctuidae*										X

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Catabena lineolata	*Noctuidae*	X					X				X
Chloridea subflexa	*Noctuidae*	X			X		X				X
Condica videns	*Noctuidae*										X
Crambodes talidiformis	*Noctuidae*						X				
Dargida diffusa	*Noctuidae*	X	X	X		X	X	X			X
Deltote bellicula	*Noctuidae*			X					X		
Elaphria grata	*Noctuidae*	X			X	X					
Eudryas unio	*Noctuidae*										X
Euxoa auxiliaris	*Noctuidae*			X							
Feltia Jaculifera	*Noctuidae*				X						X
Galgula partita	*Noctuidae*										X
Globia oblonga	*Noctuidae*	X		X							
Helicoverpa zea	*Noctuidae*										X
Heliothis phloxiphaga	*Noctuidae*								X		
Homophoberia apicosa	*Noctuidae*							X			
Lacinipolia renigera	*Noctuidae*			X		X					
Leucania adjuta	*Noctuidae*			X					X		
*Leucania amygdalina**	*Noctuidae*			X		X	X		X	X	
Leucania insueta	*Noctuidae*									X	
Leucania phragmitidicola	*Noctuidae*			X		X					
Leuconycta diphteroides	*Noctuidae*							X			
Magusa divaricata	*Noctuidae*			X		X					
Maliattha synochitis	*Noctuidae*	X									
Marimatha nigrofimbria	*Noctuidae*								X		

		Cropland		**Grassland**				**Wet Meadow**		**Woodland**	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Meropleon ambifusca	*Noctuidae*					X					
Mythimna unipuncta	*Noctuidae*							X			
Nephelodes minians	*Noctuidae*					X					
Ogdoconta cinereola	*Noctuidae*									X	
*Oligia obtusa**	*Noctuidae*	X			X	X	X	X	X	X	X
Papaipema baptisiae	*Noctuidae*	X		X	X						
Peridroma saucia	*Noctuidae*					X					
Perigea xanthioides	*Noctuidae*					X					X
Photedes defecta	*Noctuidae*			X	X	X					
*Photedes inops**	*Noctuidae*			X				X			X
Ponometia candefacta	*Noctuidae*										X
Ponometia semiflava	*Noctuidae*			X							X
Ponometia tortricina	*Noctuidae*	X			X	X	X	X	X		X
Proxenus miranda	*Noctuidae*										X
Pseudeustrotia carneola	*Noctuidae*										X
Rachiplusia ou	*Noctuidae*	X				X					
Raphia frater	*Noctuidae*		X	X	X		X	X			X
Resapamea stipata	*Noctuidae*	X	X	X		X	X	X	X	X	X
Schinia jaguarina	*Noctuidae*	X			X		X	X			X
Schinia meadi	*Noctuidae*					X				X	
Spodoptera frugiperda	*Noctuidae*			X			X	X			
Spodoptera ornithogalli	*Noctuidae*			X							
Striacosta albicosta	*Noctuidae*						X				X
Sympistis stabilis	*Noctuidae*			X		X					

		Cropland		Grassland				Wet Meadow		Woodland	
		Moderate	High	Low		Moderate		Low	Moderate	Low	Moderate
Species	**Family**	Farmed	Farmed	Remnant	Restored	Remnant	Restored	Remnant	Remnant	Remnant	Remnant
Tarache abdominalis	*Noctuidae*					X					
Tarache aprica	*Noctuidae*					X					
Trachea delicata	*Noctuidae*					X					X
Xylomia chagnoni	*Noctuidae*			X		X					
Garella nilotica	*Nolidae*					X		X			
Furcula cinerea	*Notodontidae*	X	X	X	X	X	X		X	X	
Gluphisia septentrionis	*Notodontidae*	X	X	X			X				X
Lochmaeus bilineata	*Notodontidae*	X	X				X	X		X	
Schizura unicornis	*Notodontidae*					X					
Ceratomia undulosa	*Sphingidae*		X	X	X	X	X				
Erinnyis ello	*Sphingidae*	X			X		X				X
Hyles lineata	*Sphingidae*							X			
Manduca quinquemaculatus	*Sphingidae*			X							
Smerinthus jamaicensis	*Sphingidae*										X