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Biogeography and Natural History of Tiger Moths and Spongillaflies of Intermountain North America with Experimental Studies of Host Preference in the Lichen-Feeder Cisthene angelus (Insecta: Lepdioptera: Erebidae: Arctiinae and Neuroptera: Sisyridae)

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Biogeography and Natural History of Tiger Moths and Spongillaflies of Intermountain North America with Experimental Studies of Host Preference in the Lichen-Feeder *Cisthene angelus* (Insecta: Lepdioptera: Erebidae: Arctiinae and Neuroptera: Sisyridae)

Makani Layne Fisher

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

Biogeography and Natural History of Tiger Moths and Spongillaflies of Intermountain North America with Experimental Studies of Host Preference in the Lichen-Feeder *Cisthene angelus* (Insecta: Lepdioptera: Erebidae: Arctiinae and Neuroptera: Sisyridae)

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The Intermountain West is comprised of impressive land formations, numerous ecoregions, and a unique biota. The area has many flora and fauna that have been investigated, but the region is generally considered undersampled when it comes to insects. However, I propose the matter to be a lack of shared experience in identifying key insect species and the underutilization of professional and personal collections. These impediments are highlighted by two insect groups in the Intermountain West: spongillaflies and tiger moths.

Spongillaflies can be difficult to recognize for the general entomologist and have rarely been recorded in the Intermountain West. My colleagues and I recently discovered a large population of spongillaflies in Utah that we present as a substantial additional record. I also followed the population throughout the 2016 field season to make natural history observations. I identified the spongillaflies to be *Climacia californica* and their associated host to be *Ephydatia fluviatilis*. During the season, a total of 1,731 specimens were collected, light traps were the most effective sampling technique and the population had one mass emergence event. I hope my work and figures will help investigators as they continue to search the area for spongillaflies.

Tiger moths on the other hand have largely been collected in the Intermountain West and are easily recognized, generally being brightly colored. Because of these bright colors, they attract collectors and have been sampled heavily throughout the Intermountain West. However, until now, these records have not been utilized and tucked away in collections. We took the vast amount of records and used them to create predicted models of biogeography for each tiger moth species in the area. We successfully created species level ecological niche models (ENM) analyzing environmental variables such as temperature, precipitation, elevation, and vegetation. Overall, I found tiger moths can be collected almost everywhere and during each month of the year with 93 different species scattered across the region. I anticipate our ENM models to help researchers locate tiger moths of interest to investigate within the Intermountain West.

During my studies, I investigated in detail the lichen feeding tiger moths (Lithosiini). Many tiger moths eat toxic plants, but only a few in the area consume lichen, an unusual host because of their secondary defensive chemicals. I investigated how these chemicals impacted *Cisthene angelus* caterpillars host selection by simultaneously offering them various lichens with differing chemistries. I expected these caterpillars to avoid usnic acid as it deterred other lichen feeding tiger moths. However, these caterpillars surprised me by consistently consuming the acid and being largely polyphagous. Our future work will be directed at how caterpillars balance nutritional needs and the chemicals they sequester.

Keywords: spongillafly, freshwater sponge, tiger moth, lichen feeding, polyphogous

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I want to thank all my committee members for their guidance and instruction in doing this thesis work. I would like to thank my committee chair, Dr. C. Riley Nelson, for fostering a continued sense of wonder and fascination of the natural world. I would also like to thank him for providing me the opportunity to study tiger moths by providing me transport to amazing sites within the Intermountain West, purchasing sampling and experimental gear, and lending his expertise. I want to thank Dr. Steve Leavitt for answering all my questions about lichen, being patient with me as I learned about the fascinating organisms, and spending time with me to work out experimental ideas. I want to thank Dr. Seth Bybee for pushing me to do things that in the moment may have seemed to be too difficult, but in the end have benefited my life and career.

I especially want to thank my wife who spent countless hours working on this project alongside me. I am eternally grateful for her long hours spent with me looking at specimens, running software, photographing specimens, and managing our move to start my PhD while still finishing my master’s at BYU.

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Chapter 1. Spongillaflies (Neuroptera: Sisyridae) in Utah with taxonomic and natural history observations

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Introduction

Sisyridae, or spongillaflies, and freshwater sponges (Porifera: Spongillidae) are tied together in a parasite-host association (Parfin & Gurney 1956; Steffan 1967; Resh 1976; Pupedis 1980). Sisyrids feed on freshwater sponge with stylets used to pierce and suck the contents from individual sponge cells (Cover & Resh 2008; Parfin & Gurney 1956; Pupedis 1980; Fig. 1). Freshwater sponges are found globally and have a wide radiation of shapes and sizes (Manconi & Pronzato 2008). Spongillaflies are also found worldwide having adapted to many of the same habitats (Cover & Resh 2008; Parfin & Gurney 1956). Within North America there are two genera and six species (Bowles 2006). Despite their occurrence in parts of western North America (Bowles 2006), sisyrids have only been recorded twice in the intermountain west. First, a host association was made for them with the sponge *Ephydatia mulleri* in Idaho (Clark 1985). Second, a Utah record was made from a single female specimen collected at a light trap in 1979 from the state's southern border (Bowles 2006).

After this initial Utah sighting, sisyrids have been sought extensively throughout the state by both professionals and students, largely from Brigham Young University (BYU) and Utah State University (USU). These efforts were directed towards habitats with potential freshwater sponge hosts. Sponges have rarely been noted in Utah, but exist in some regions providing potential habitats for the insect. C. Riley Nelson anecdotally has seen them at Wellsville Reservoir in extreme northern Utah as well as in several side channels of Lake Powell. Rader also identified *Ephydatia fluviatilis* in Utah Lake (Rader 1984; Rader & Winget 1985). Other researchers including Dennis Shiozawa, Russell Rader, Richard Baumann and various BYU aquatic entomology classes (personal communications) repeatedly searched many of these and other likely habitats throughout the state over the course of 35 years.

These intense efforts yielded no sisyrids, but sensitized Robert C. Mower to watch for them during his mosquito sampling for Utah County Mosquito Abatement (UCMA). After years of searching for sisyrids without success, Mower noticed sisyrid adults in mosquito light traps from Spring Creek, Springville, Utah in 2014 (Fig. 2). After repeatedly seeing sisryids in those traps, Mower alerted BYU entomologist C. Riley Nelson to survey the creek. In fall of 2014, BYU's aquatic entomology class collected larvae and adults from this creek in rather large numbers (Figs. 1-2). The creek appeared to have suitable conditions to maintain large populations of sisyrids.

After BYU students regularly collected specimens from this site in 2014 and 2015, we monitored the population for the 2016 field season. North American sisryid records and dates have been published by Bowles (2006), but no populations have been consistently followed through a season. In so doing, we present a substantial record of Sisyridae for Utah with their associated host sponge, and expand their known distribution in the Intermountain West (Bowles 2006). We also compare the two commonly used sampling techniques of sweeping and light trapping (Bowles 2008) and make natural history observations. In particular we investigated the effectiveness of the sampling techniques, length of the adult flight season, and the frequency and magnitude of emergence events. Compared to sweeping, we hypothesized light trapping to be superior as spongillaflies are strongly attracted to a variety of lights (Bowles 2008). In regard to their natural history, we expected the sisyrids to be active from May to November (Bowles 2006) and to be multivoltine (DeWalt et al. 2009).

Materials and Methods

We monitored sisyrids in Springville, Utah at the Utah Division of Wildlife Resources (UDWR) Fish Hatchery. The study site is located at N 40.182249° W 111.612038° at an elevation of 1395 meters. Spring Creek runs through the site and provides appropriate habitat for the sponges and sisyrids we examined.

We identified suitable freshwater sponge habitat within a 100 m stretch of the creek and sampled it intensively. We found many larvae present on the sponge (Fig. 1) and collected both larvae and sponge for taxonomic purposes. We collected sisyrid larvae from the sponge and stored them in 70% ethanol. We attempted to identify the larvae using keys in Pupedis (1980) and Bowles (2006).

In addition, we sampled four of these sponges for identification by scraping their surfaces using soft tip forceps and placing the scrapings in 50 ml vials filled with 70% ethanol. We extracted their spicules using several techniques to aid in identification of the species. We first used the technique described by Smith & Pennak (2001) for extracting spicules using heated HNO_3. We used a section of sponge tissue containing gemmules to ensure finding all types of spicules. This yielded both the megascleres and gemmoscleres (Fig. 3) needed for proper identification. We also left sponge tissue in 10% V potassium hydroxide overnight and found this to yield a good number of megascleres, but the gemmules did not reduce to gemmoscleres. We then explored treating the gemmules in cold HNO_3 for several days and many individual gemmoscleres were obtained using this approach. We mounted well-cleared megascleres, gemmoscleres, and sponge tissue onto glass slides for species identification (Ricciardi & Reiswig 1993).

We repeated this process for sponge we collected earlier the same year from the Provo River in Provo, Utah. This sponge did not have any sisyrid larvae, but its spicules were similar to those from Spring Creek. We compared both these sponge identifications to sponge previously identified from Utah Lake (Rader 1984; Rader & Winget 1985). This was done to identify other nearby local habitats with host sponge that may be suitable for the spongillaflies.

We monitored the adult sisyrid population along Spring Creek and identified them to species using Bowles guide (2006). We used wing veins and male genitalia for definitive identification (Figs. 4-5) as female characteristics tend to be more variable (David Bowles, personal communication). The population was monitored using quantitative sweep sampling and light trapping. For sweep samples we used a 45 cm (18") collapsible net to sweep the vegetation following the north side of the creek each week a light trap sample was taken. We started at the edge of unmown vegetation three meters east of the trap to 97 m beyond the trap for a total of a 100 m sweep. We collected all sisyrid adults (Fig. 2) from the net into 70% ethanol. This process was repeated back to the starting point resulting in vegetation being swept twice for a total sweep of 200 m. We checked our net for sisyrids every 15 sweeps. The number of sweeps we did fluctuated slightly due to available vegetation, but averaged 135 sweeps each way, 270 sweeps total.

For trapping we used a New Jersey Light Trap (Mulhern 1942) that was graciously provided by UCMA. They use this light trap to monitor mosquito populations. We deployed the trap continuously with a photoswitch to turn the light on each night and off each morning. We recovered the trap and sweep samples each Friday for the rest of the flight season and slightly beyond. We conducted a preliminary early season sweep around the trap site that indicated the adult flight season began near 20 May in 2016. We subsequently began our quantitative trapping and sweeping on 27 May 2016. We monitored the population intensively, recording the amount of sisyrids caught in each sweep and trap sample, until we consistently obtained low counts, essentially zero for both. We sampled the population 22 times as four light trap samples were also lost when they were not kept after mosquito counts were obtained, which produced a gap in our data. However, trends in numbers before and after those "lost" samples indicate that an assumption of uniform change during that period is reasonable because of the large number of weekly samples we collected throughout the season. This large number of samples also provided enough consecutive data to conduct statistical analysis of sampling technique effectiveness and the adult population over time.

As the sex ratio of sysirds has not been studied (Andersen & Greve 1975), to thoroughly investigate the sampling methods' effectiveness and the insect's natural history we also sorted samples by males and females in each sample (Table 1) for analysis. There were a few specimens whose genitalia were broken off and sex could not be determined. These were not recorded in counts or used in statistical analysis. For analysis, we used a generalized linear model with a log link function and assumed a normal distribution of the response variable (Proc GENMOD in SAS; SAS 9.3 SAS Institute, Cary, North Carolina, USA). We analyzed the main effects for gear (sweep and trap), time, and sex as well as their two-way and three-way interactions with an alpha level of 0.05. This was done using two levels for gear (sweep vs. trap) and sex (male vs. female) and the 22 sample times throughout the season (Table 2).

We vouchered all collected sponge, insects, and prepared slide mounts in the invertebrate collection (sponge) and insect collections at the Monte L. Bean Life Science Museum of Brigham Young University.

Results

We identified the host sponge from Spring Creek to be *Ephydatia fluviatilis* (Linnaeus, 1758) based on elongate megascleres and birotulate gemmoscleres (Fig. 3). We identified the sponge from the Provo River to be the same species. These identifications also match the identification for the sponge found in Utah Lake (Rader 1984; Rader & Winget 1985).

We identified the adult sisyrids as *Climacia californica* Chandler (1953). The identification was straight forward and we saw no change in forewing or genital characteristics (Figs. 4-5) over the course of the season, indicating only one species present at the site. Although we used male characteristics for identification, female genitalia and forewing patterns were also consistent throughout the season.

The larvae proved to be more difficult to identify. Using Bowles guide (2006) the larval characteristic of the number of setae, four large instead of three, on the meso- and metathoracic sclerite (Fig. 7) identify our larvae as *C. chapini*. This characteristic was taken from the previous work on sisyrid larvae by Pupedis (1980). However, in Pupedis (1980) this setae number identifies our larvae as *C. californica* bringing up some discrepancy between these two treatments and our specimens. Because of our confident adult identification and its consistency through the season we consider the one species, both adult and larvae, to be *C. californica.*

We had a total of 1,726 adult *C. californica*: 769 trap females, 725 trap males, 126 sweep females, 106 sweep males, in the 22 samples collected (Fig. 6; Table 1). From the generalized linear model (Table 2) we found that each of the main effects from the variables gear, sex, and time were significant, all having 2-sided p values <0.0001. All two and three-way interactions were also significant with the two-way interaction of gear and sex having a p value of 0.012 and all other interactions having p values <0.0001. The adult population was higher than 0 for sweeping and trapping from 27 May to 18 November 2016 (Fig. 6). With the exception of the beginning and end of the season, the trap caught more sisyrids than sweeping. Male and female numbers fluctuated throughout the season, but both techniques caught more females overall. The season was also characterized by a two-week peak of abundance at the end of July and beginning of August and the adult population diminished drastically and eventually disappeared in November (Fig. 6, Table 1).

Discussion

The general area where the spongillaflies were recently discovered was surveyed in the 1970s and 1980s by Dennis Shiozawa and Russell Rader (personal communications). The reason for this recent finding of spongillaflies in such large numbers now at the location is not clear. It could be due to introduced stowaways on fish or equipment into the fish raising facilities of the UDWR Fish Hatchery, improved sampling or specimen identifications, or the habitat becoming more suitable to maintaining larger populations. Whatever the reason, we have now found an established population that provides a large additional record for the rarely caught sisyrids in the state of Utah and Intermountain West (Bowles 2006).

The sponge *E. fluviatilis* is confirmed as a host as it is the only freshwater sponge currently identified in Utah (Rader 1984; Rader & Winget 1985) and we found larvae on it. Other members of the sponge genus *Ephydatia* have also been identified as hosts for *C. californica* (Clark 1985) within the Intermountain West.

The adult's forewing and male genital characters for *C. californica* shown in Bowles (2006) confidently provide evidence that our species identification is congruent with *C.*

californica. The confusion of whether the larvae support *C. chapini* or *C. californica* seems to come from a transcriptional error in Bowles (2006) which was based on Figure 1f from Pupedis (1980). With this apparent error and our confident adult identifications, we propose the larvae we collected to be *C. californica* and that larvae of this species have 4 major setae on the meso- and metathoracic sclerites, not three (Fig. 7).

The sample data (Fig. 6; Table 1) and significant three-way interaction between gear, time, and sex (Table 2) describe the male and female numbers collected by the two techniques throughout the season. The beginning and end of the season where few specimens were caught resulted in similar trap and sweep counts, but throughout the majority of the season the light trap caught more, at times hundreds more, than sweeping (Fig. 6; Table 1). With this attraction to light, we observed no unique male or female preference, similar to other neuropterans (Killington 1937). The numbers of females and males fluctuated similarly for both the sweep and trap and both techniques captured overall more females than males. We suggest that both techniques are accurate subsamples of the population with no preference biases, though light trapping is preferred if possible because of its ease and large capture rate.

The active adult season from May to November is consistent with records published by Bowles (2006). Furthermore, it gives the whole picture showing *C. climacia* adults being found consistently throughout the season. It also highlighted a striking two-week peak at the end of July (Fig. 6, Table 1). As both sexes increased equally, to peak at the same time, we interpret it to be a well-synchronized mass emergence before the onset of winter. This is likely for mating and laying eggs that hatch and develop into overwintering larvae (DeWalt et al. 2009). The single peak also suggests the population is likely univoltine, not multivoltine as predicted by others (DeWalt et al. 2009).

With this recently confirmed and thriving population of sisyrids, light trapping and sweep sampling around the state should be continued. Special attention should be given to areas containing the host sponge and sampling should be done during times likely to yield many specimens, such as the two-week peak. As these insects are studied by few and unfamiliar to most (David Bowles, personal communication), we also provide taxonomic aid clarifying and demonstrating key features in the identification of *C. californica* and its host sponge as they are looked for in the Great Basin of the Intermountain West. It is likely that more *C. californica* will be found as more informed sampling takes place around aquatic habitats where the sponge is located.

Acknowledgements

We give thanks to Utah County Mosquito Abatement for the use of their New Jersey light trap for sampling, for leading us to the Sisyridae population, and help in separating Sisyridae from each week's sample. We are particularly grateful to David E. Bowles from the U.S. National Park Service, Republic, Missouri and Department of Biology Missouri State University for confirming the identification of *C. californica* and discussions during the course of this study. We thank Mark Belk from the Department of Biology, Brigham Young University for help running the statistical models as well as with their interpretation.

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Chapter 1 Tables

Table 1. Male and female counts of *Climacia californica* from trap and sweep samples from 27 May 2016 through 18 November 2016 at Spring Creek, Utah.

Date	Trap Males	Trap Females	Trap Total	Sweep Males	Sweep Females	Sweep Total	Overall Total
27 May 2016	0	0	0	1	2	3	3
3 June 206	1	3	4	1	1	2	6
10 June 2016	12	9	21	7	8	15	36
17 June 2016	9	17	26	4	5	9	35
24 June 2016	19	31	50	1	7	8	58
1 July 2016	6	10	16	1	2	3	19
8 July 2016	11	32	43	3	4	7	50
15 July 2016	27	35	62	6	5	11	73
22 July 2016	60	93	153	6	6	12	165
29 July 2016	288	216	504	19	24	43	547
5 August 2016	180	208	388	17	15	32	420
12 August 2016	31	34	65	14	21	35	100
19 August 2016	26	23	49	8	9	27	66
26 August 2016	11	21	32	1	7	8	40
2 September 2016	-	-	-	-	-	-	-
9 September 2016	-	-	-	-	-	-	-
16 September 2016	-	-	-	-	-	-	-
23 September	-	-	-	-	-	-	-

2016							
30 September 2016	41	34	75	7	4	11	86
7 October 2016	2	3	5	2	1	3	8
14 October 2016	0	0	0	1	2	3	3
21 October 2016	1	0	1	1	1	2	3
28 October 2016	0	0	0	5	2	7	7
4 November 2016	0	0	0	0	0	0	0
11 November 2016	0	0	0	1	0	1	1
18 November 2016	0	0	0	0	0	0	0
Totals	725	769	1494	106	126	232	1726

Table 2. Results from running the Spring Creek, Utah, *C. californica* trap and sweep counts in a generalized linear model. Results from the main effects of Gear, Sex, Time, 2-way interactions, and 3-way interaction. We considered anything below a 0.05 alpha level as significant.

Parameters	DF	Chi Square	P value
Gear	1	18098.2	<0.0001
Sex	1	46.55	<0.0001
Time	21	101256	<0.0001
Gear * Sex	1	6.55	0.0105
Gear * Time	21	74893.3	<0.0001
Sex * Time	21	1877.96	<0.0001
Gear * Sex * Time	21	2141.96	<0.0001

Chapter 1 Figures

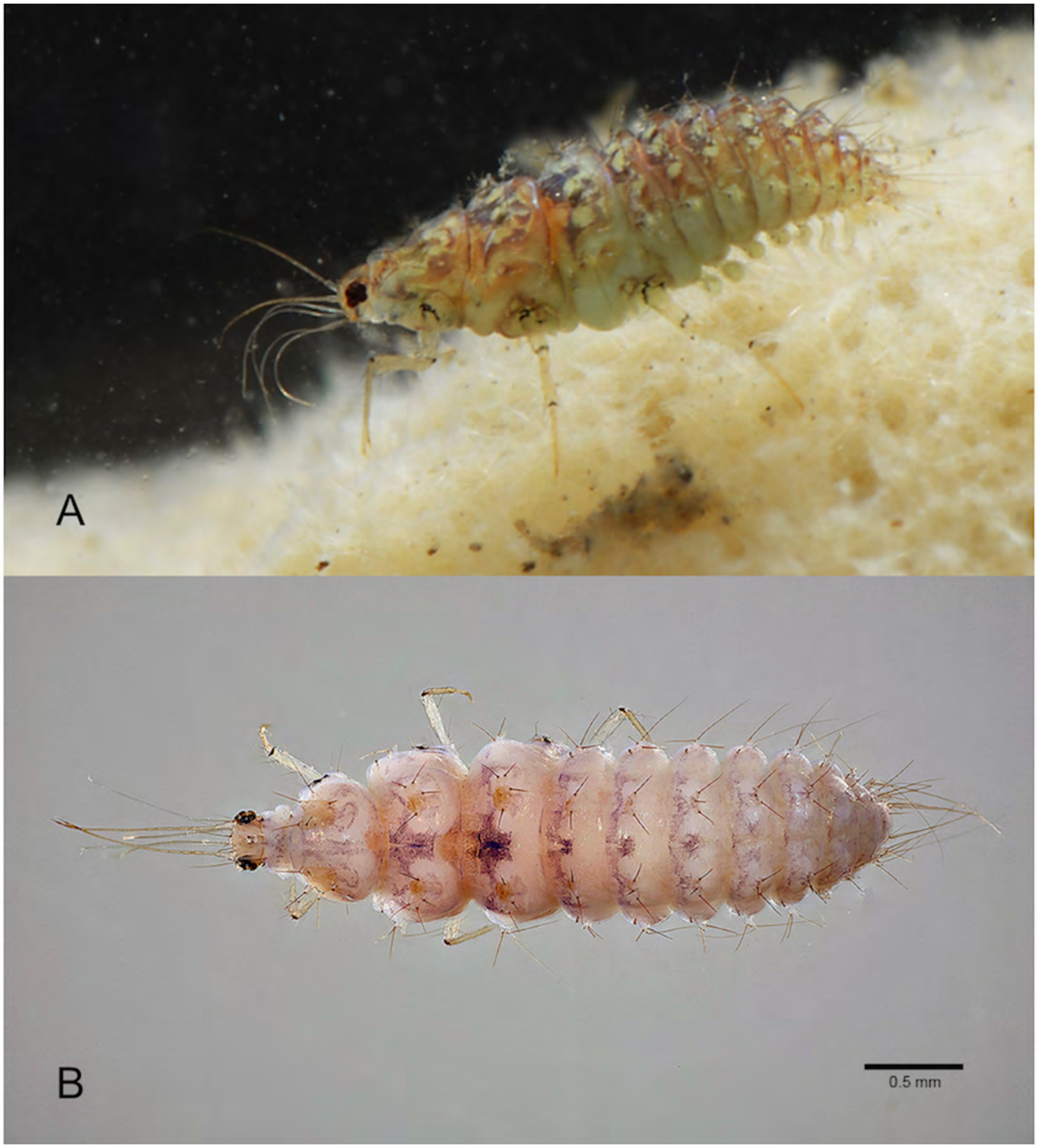

Figure 1. Larvae of *Climacia californica* from Spring Creek, Utah collected on 18 September 2014. A: Live larva on host sponge, B: Dorsal view of preserved larva.

Figure 2. Adult female *Climacia californica* from Spring Creek, Utah collected on 18 September 2014.

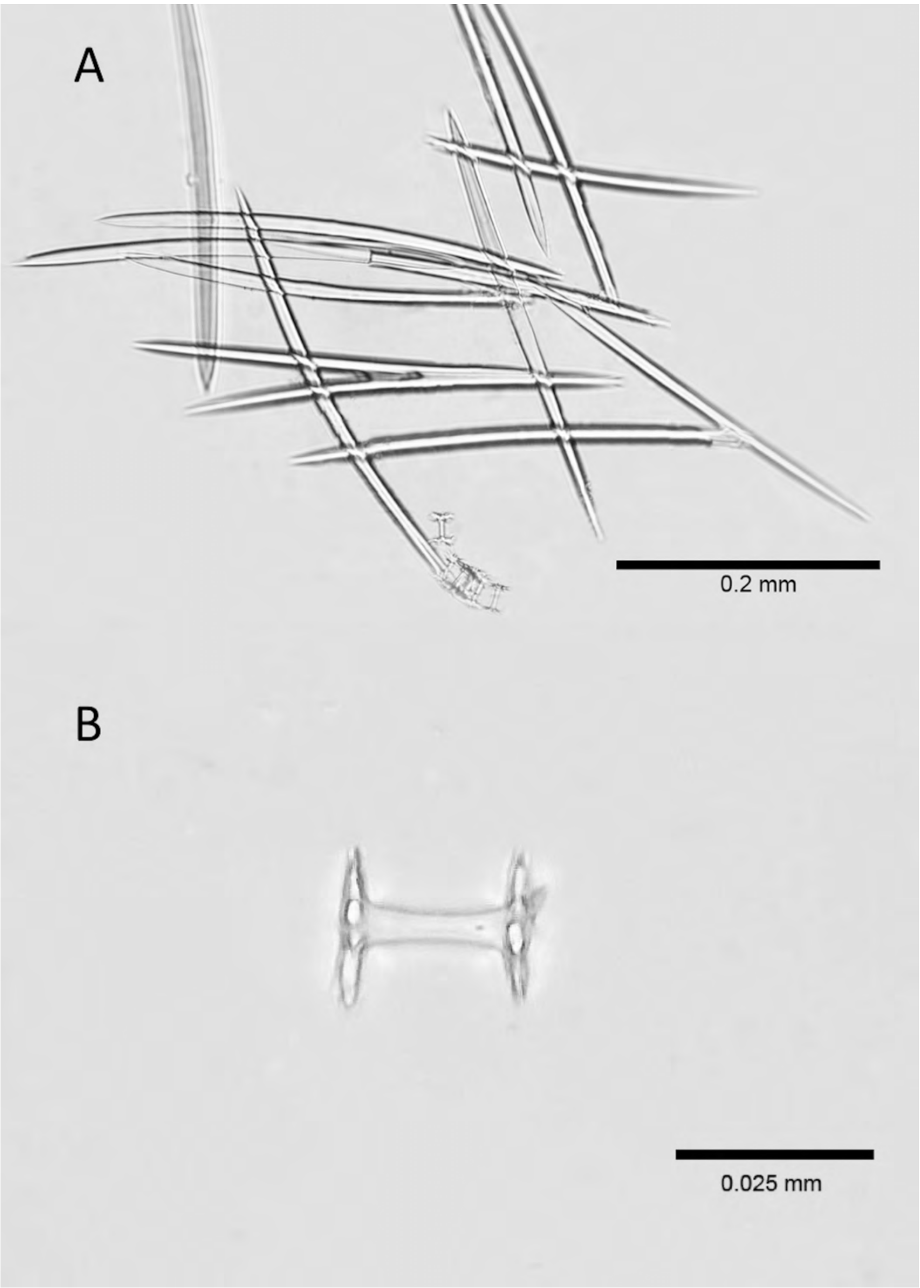

Figure 3. *Ephydatia fluviatilis* spicules extracted from host sponge collected at Spring Creek, Springville, Utah 25 September 2017. A: Cleared spicules including megascleres and gemmoscleres, B: Isolated gemmosclere.

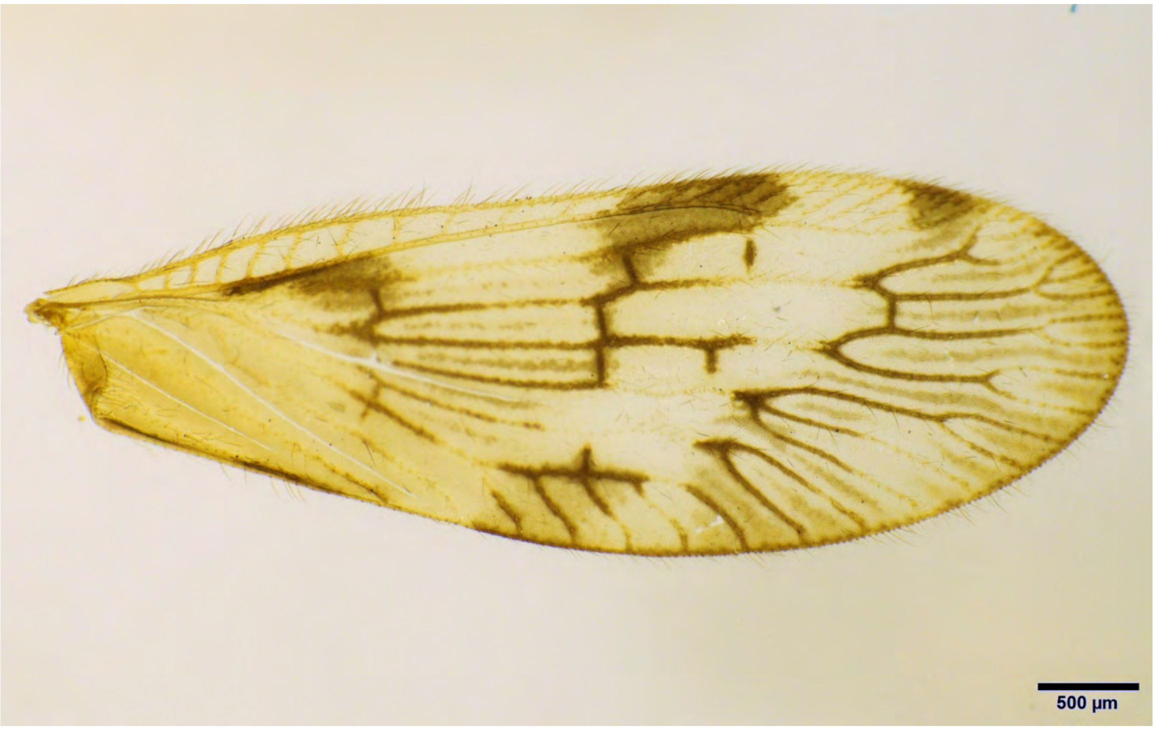

Figure 4. Forewing of *C. californica* from male collected at Spring Creek, Springville, Utah 5 August 2018.

Figure 5. Lateral view of male *C. californica* genitalia collected at Spring Creek, Utah on 18 September 2014.

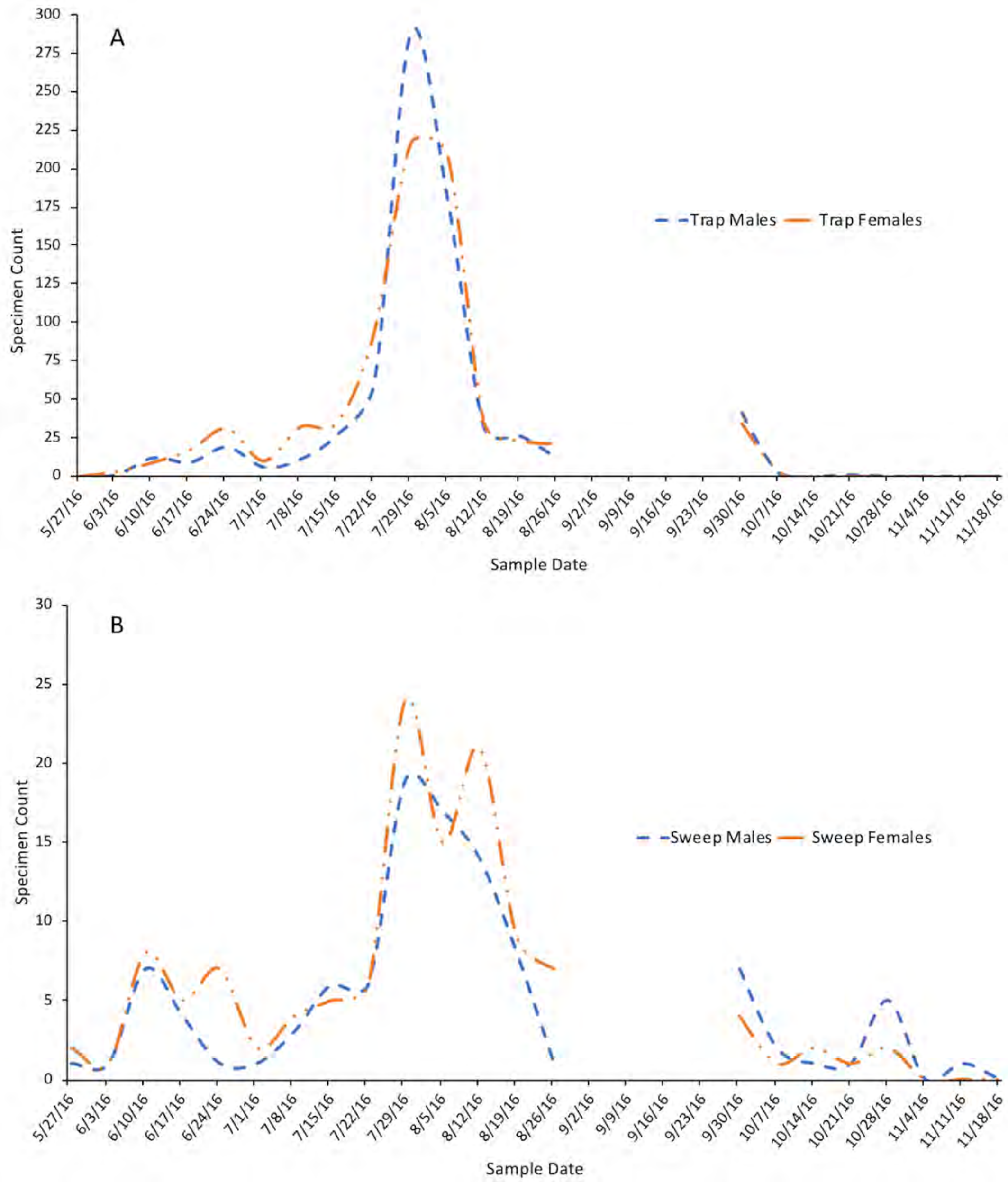

Figure 6. Male and female counts of *Climacia californica* from samples taken from 5 May 2016 to 18 November 2016 at Spring Creek, Utah. A: light trap male and female sample numbers, B: sweep male and female sample numbers.

Figure 7. Meso- and metathoracic sclerites of *Climacia californica* with 4 major and 1 minor seta from larvae collected from Spring Creek, Springville, Utah 18 September 2014.

Chapter 2. Biogeography of the Tiger Moths (Lepidoptera: Erebidae: Arctiinae) of the Intermountain West

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Introduction

Many moths are aposematic. They use flashy colors to warn predators of distastefulness as protection from being eaten. Tiger moths (Lepidoptera: Erebidae: Arctiinae) within the subfamily Arctiinae are especially known for this form of protection. These moths use yellows, reds, and other bright colors, punctuated with an array of lines and spots to advertise to daytime predators (Hristov and Conner 2005; Smilanich et al. 2011) and sound to alert nighttime predators (Dowdy and Conner 2016) that they are not a good meal. This unpalatability comes from the ability to sequester chemicals from toxic hosts (Boppré 1990; Bowers & Stamp 1997; Bowers 2009; Zaspel et al. 2014; Anderson et al. 2017) that range from plants, fungi, to even lichen (Zaspel et al. 2014). Some tiger moths also mimic wasps, beetles and unpalatable moths and butterflies (Zaspel et al 2014). These interesting behaviors and characteristics have attracted the attention of ecological and evolutionary biologists over the years.

Recently efforts have been made to more accurately deduce the moths' evolutionary history. In 2011-2012 tiger moths were moved from a family, Arctiidae, to a subfamily, Arctiinae, (Zahiri et al. 2011; Zahiri et al. 2012) within the expanded family, Erebidae. Other efforts focused on sorting out relationships between tribes (Jacobson & Weller 2002) with the most recent and in depth (Zaspel 2014), proposing four lineages including the more recently resurrected Amerilini (Dubalatov 2009). The most recent efforts by taxonomists have been on more specific levels grouping genera together such as the large *Grammia* genus being collapsed into *Apantesis* along with others (Rönkä et al. 2016).

This emphasis on their systematics and taxonomy present an opportune time to investigate the biogeography of these moths within the Intermountain West of the United States. For our purposes this includes: all of Nevada and Utah along with the most southern counties of Idaho, the most northern counties of Arizona, and the most western counties of Colorado and New Mexico (Fig. 1). The region is complex from geologic, vegetational, biogeographic, and climatic standpoint with at least 14 different Level III ecoregions (Fig. 2; Omernik 1987; U.S. Environmental Protection Agency 1999) with Utah containing half of these ecoregions.

In broad terms, the defined area covers the Great Basin, Colorado Plateau, and northern tip of the Mojave Desert. The Great Basin extends across most of Nevada and western Utah and includes the Central Basin and Range, Northern Basin Range, and Snake River Plain ecoregions (Fig. 2; Omernik 1987; U.S. Environmental Protection Agency 1999). The Great Basin is typified by lower elevation basins, peaked mountains, and flatter topped plateaus that range in elevation from 400 to 3000 m (Miller et al. 2013). The region has a semi-arid temperate climate with cold, somewhat wet winters, somewhat wet springs, and warm dry summers (Miller et al. 2013). Precipitation within the area is temporally and spatially variable with the region as a whole receiving 150 to 300 mm of precipitation annually (MacMahon 1980; Miller et al. 2013) so that an arid-adapted biota covers much of it. The region is dominated by an amazingly rich assortment of saltbushes (the genus *Atriplex* and relatives) at lower elevations. As you move upslope this community grades into a high diversity of sagebrushes (*Artemesia* spp.) that intermix at times with pinyon-juniper (West 1983). A more mesic sub-alpine forest has developed at the highest elevations (Miller et al. 2013).

The Colorado Plateau covers eastern Colorado and New Mexico; central, southern, and eastern Utah; and northern Arizona. The ecoregions of the Colorado Plateau are defined differently by researchers, but include Colorado Plateau, Southern Rockies, Arizona/ New Mexico Plateau, Arizona New Mexico Mountains, and a sizable portion of the Wasatch and Uinta Mountains ecoregions within our study region (Fig. 2; Omernik 1987; U.S. Environmental Protection Agency 1999). The land is characterized by strikingly beautiful plateaus, mesas, deep canyons, and barren badlands (Foos 1999) where bright colored red rocks catch the viewers attention. The whole area is characterized as a plateau (Holland et al. 2018) of broad geographic scope. The region contains three main vegetation zones according to (Holland et al. 2018): the woodland zone, mountain zone, and low zones. Within the woodland zone dominant plant species include several pinyon pine species, several juniper species, and various shrubs, including sagebrushes (Prim 2018; Foos 1999). Within the mountain zone, vegetation varies from ponderosa pine in the south to lodgepole pine and aspen in the north and on the highest mountains (Holland et al. 2018). The lowest zone has sparse vegetation, but includes arid grasslands, saltbush pans, sagebrush steppe, and several kinds of cacti and yucca in the south (Prim 2018). The plateau ranges from 900 m to 4300 m and has characteristic geography involving monoclines and volcanic accumulations that make it easy to separate from other regions (Foos 1999; Kelley 1955). Annual precipitation on the Colorado Plateau is low due to the rain shadow effect of mountains to the west and averages to about 250 mm a year (Foos 1999).

The Mojave Desert covers the Mojave Basin and Range ecoregion in the southern tip of Nevada and northeastern Arizona (Fig. 2; Omernik 1987; U.S. Environmental Protection Agency

1999) with a narrow neck in southwestern Utah. The region is dominated by grasslands/shrublands with creosote bush being the dominant plant (Oldemeyer 1994) on the bajadas and plains. The region receives very little annual precipitation, 5-25 cm (Vogelmann 2001; Hunter et al. 2003) and this combined with high summer temperatures makes it considered the most arid of the North American deserts (MacMahon 1988).

A few other ecoregions, the Wyoming Basin, Middle Rockies, Sierra Nevada, and Madrean Archipelago make minor appearances within our area of interest (Omernik 1987; U.S. Environmental Protection Agency 1999) and we include them in our analysis (Fig. 2).

The Intermountain West has long been considered undersampled for many insects like Lepidoptera (David Wagner personal communication). However, students, amateurs, and professionals readily collect tiger moths as their bright and colorful aposematic appearances are very attractive to collectors. Because of this, tiger moth records tend to be found throughout the region in both institutional and personal collections. Large numbers of well-curated specimens exist, particularly at Brigham Young University's Monte L. Bean Life Science Museum, Colorado State University's C.P. Gillette Museum of Arthropod Diversity, and the vast personal collections of Robert C. Mower. Despite the extensive records, little has been done in defining the ranges and biogeography of the various tiger moth species in the area. Some workers have done important work, but it has either been on specific genera like *Grammia* (now *Apantesis,* Schmidt 2009) or more general in species ranges (Powell & Opler 2009) not providing specific locations that can be used in biogeographic metanalysis. That these amazing records and specimens are available in collections yet haven't been used in detail is what moved us to look at this not-so-undersampled group's biogeography across the region. With these records our goal has been to provide a comprehensive list of the species collected in the region and give specific geographic and ecological details about where they have been found. As sampling has not been exhaustively done for the entire region, we also aim to use ecological niche modeling (ENM) to predict areas where species might occur, but haven't yet been sampled to help guide collecting efforts.

Materials and Methods

We obtained specimens and/or records of tiger moths from a large number of institutions and individuals to report in this single work. These same records were used to create predicted models of biogeographic distribution (Fig. 3).

The following institutions, museums, and personnel provided collection data or specimens examined by the authors:

BYUC: Brigham Young University Arthropod Museum: Provo, Utah

CSUC: C.P. Gillette Museum of Arthropod Diversity: Colorado State University Collection, Fort Collins, Colorado

UMNH-ENT: Entomology Collection at the Natural History Museum of Utah, Salt Lake City, Utah

NAUF-CPMAB: Colorado Plateau Museum of Arthropod Biodiversity, Flagstaff, Arizona

UVU-O: Utah Valley University and Heath Ogden's collection from Capitol Reef National Park, Provo, Utah

SUUC: Southern Utah University Collection, Cedar City, Utah

USUC: Utah State University Collection, Logan, Utah

NMSUC: New Mexico State Collection of Arthropods

CEHC: Chuck Harp Personal Collection, Fort Collins, Colorado

RCMC: Robert C. Mower Personal Collection, Brigham Young University, Provo, Utah

UI-WFBM: University of Idaho-William F. Barr Entomological Museum, Moscow, Idaho

NSMC: Nevada State Museum Collection, Las Vegas, Nevada

We also contacted the Idaho Museum of Natural History, University of New Mexico, and Las Vegas Spring Preserve and found they had no tiger moth records for our region of interest.

Records from USUC and NSMC were gathered and verified by author Robert C. Mower and the majority of BYUC, CSUC, UMNH-ENT, NAUF-CPMAB, UVU-O, SUUC, USUC, NMSUC, and RCMC were verified by the author Makani Fisher by looking at individual specimens. The moths at UIWFBM and CEHC were easily identifiable taxa. We confirmed the identifications of this small number of records without specimens by evaluating localities for these widespread taxa. We actively collected through the state of Utah during the field season of 2017-2018 and include any tiger moths that we collected as part of BYUC into which they were deposited.

We used external morphology to identify tiger moths and verify records. This was largely based on wing patterns and coloration, though other features such as foreleg color and abdominal spots were examined as needed. We used Powell & Opler's (2009) work on moths of the western North America and Schmidt's (2009) revision of *Grammia* (now grouped as part of *Apantesis*) heavily for specimen identifications. These proved especially helpful in taxonomically difficult taxa. We also used online resources: the Moth Photographers Group (2018) and BugGuide (2018) as aids in identifying specimens. We documented specimens using the most current nomenclature (Pohl et al. 2016; Rönkä et al 2016).

When possible, we photographed the species we verified by selecting a model specimen from each species that demonstrated the morphologically distinguishing features. Paul Frandsen at BYU graciously allowed us use of his BK PLUS Lab System by Dun, Inc.. With it, we took whole body photographs of the moths. Each specimen was photographed using a 100 mm lens, 5.2 focal length, and 1 to 1.3x zoom depending on the size of the specimen. The software allows the camera to take many photos with different planes of the specimens in focus. For each specimen we set a high point and a low point and the camera software calculated the optimal number of frames it should take along that continuum. Once the camera had taken the desired number of frames, we used Zerene Stacker 1.02 (2009-2010) to stack them into a focused composite specimen photograph. We edited photographs in Adobe Photoshop 2018 solely for contrast, color scale, and to input scale bars. Sometimes, especially in the case of species with few records, the best specimen was one that was damaged. Photographs of these were still only slightly edited and show some of the reality of trying to identify museum specimens.

All the verified specimens' locality and collection data were compiled into a Microsoft Excel spreadsheet and can be provided as a supplementary material if requested. All records were recorded using the World Geodetic System 1984 (WGS 84) reference system. For new records collected by the authors in 2017-2018, latitude and longitude were obtained using Google Earth (2009-2015). Records provided by others were sent to us directly or are available on the Symbiota Collections of Arthropods Network (SCAN 2018). A considerable number of records from NAUF-CPMAB were originally recorded in Grand Canyon Colorado River Miles. These localities were projected using WGS 84 as we converted them to decimal degrees of latitude and longitude using (Stevens 1985). For specimens with labels missing latitude and longitude, we found a best estimate using GEOLocate. If the original label included a description of the location, we used GEOLocate (Rios & Bart 2010) to pinpoint the location and provide geographic coordinates. For records with just a city as the locality, we found and used the center of the city using GEOLocate (Rios & Bart 2010). This was usually an intersection involving

State Street, Main Street and/or Center Street. Some city records had the approximation "environs", meaning "around" and we treated these similarly with city centers, but consider them less precise. For records that gave just a county as a location we used the county seat, finding and using the center of those cities in the same manner.

Once the locality data were found for each specimen we confirmed, we imported their localities into ArcMap version 10.6 (program package of ArcGIS, ESRI, 2017). We used a shapefile made with the counties included in our region of interest (Fig. 1) to define our study area and made two dot maps for each species (Figs. 4-96). One put collection records in a layer over a topographic background (ESRI National Geographic Basemap 2012) and one is represented as an overlay of Level III ecoregions (Omernik, 1987; U.S. Environmental Protection Agency, 1999). For both dot maps, records with "environ" and county level records were marked with (◉) while the remaining, more specific records were indicated with (•). The political borders of each county were used in our analysis as they were most compatible with the moth's historical locality data. This allowed people at other institutions to easily find records for us and were the most accessible using ArcMap version 10.6 (program package of ArcGIS, ESRI, 2017) while staying true to natural topographical markers.

To further investigate the tiger moth species within the Intermountain West we created maps of each species known distribution with predicted areas of occurrence through ecological niche modeling (ENM). To do this, we used a combination of ArcMap version 10.6 and Maxent version 3.4.1 (Phillips et al. 2018). We used the records gathered for each species but excluded those with "environs" and only county level records as their actual locations included uncertainties of place that were too large and apparent as spanning multiple ecoregions (Fig. 2). These excluded records eliminated less than 5% of the total data, a small proportion of total records. Thus, the remaining locality data we used to build our models were more precise with limited geographic extent.

Some obvious sampling bias existed for sites which long-time collectors like Robert C. Mower visited repeatedly. These heavily visited sites were usually located in Utah and Colorado (Appendix 1: Fig. 1) To account for the sampling bias created by these frequently visited sites we created a sampling bias file. To downsample we used the "Gaussian kernel density of sampling localities" tool in the SDMtoolbox (Brown 2014). We chose this method as it takes all the localities for the entire subfamily at once to create a widespread spatial sampling bias file we could subsequently use on a species by species level model (Brown 2014). Within the tool, we used a distance of 0.10 degrees to create a file scaled 1-20, with 1 being no bias and 20 being the maximum amount of bias (Appendix 1: Fig. 1) similar to the methods of Chávez et al. (2018), Elith and Phillips (2010) and Fourcade et al. (2014). This scale also highlighted areas we knew to be frequently visited, like those in central and southeastern Utah, while keeping undersampled areas, like the single points in Nevada, relatively close to 1.

We then obtained 21 environmental rasters for ENM model construction. These included the Worldclim bioclimatic raster datasets and Landfire's 2010 elevation and 2014 existing vegetation type mosaic rasters. In ArcMap version 10.6 we clipped all the rasters to the extent and shape of the county shapefile and resampled the Landfire raster datasets to 0.008333 degrees (1.00 km resolution) to match those from Worldclim. Being a continuous variable, the 2010 elevation raster was resampled using a cubic convolution algorithm whereas the categorical 2014 existing vegetation type raster was resampled using a nearest neighbor algorithm. Because we were interested in the impact of each of the environmental variables on the species predicted distributions, we then evaluated correlation between the continuous variable layers (Merow et al.

2013; Phillips 2005) using ENMTools 1.4.4. (Warren et al. 2010). Correlation between each of the layers was done by measuring overlap for all possible pairwise comparisons. From groups with high Pearson Product-Moment correlations (> r = 0.80) we chose one as the representative variable (Judson & Nelson 2012). We thus used a simpler, non-redundant model with nine variables in our Maxent analysis. The variables used included some of Worldclim's temperature and precipitation variables along with the elevation and vegetation type datasets (Appendix 1: Table 1).

We then subjected the resulting environmental rasters, verified species locality records, and sampling bias file to analysis with Maxent. The latest Maxent version (3.4.1) has the ability to run multiple species simultaneously (Phillips et al. 2018) so we input a file with all the species and localities together. We obtained per species results running the analysis including the bias file we had created. We prompted the software to create response curves to see how well each species model fit and to do jackknifing to measure the importance of each of the 9 variables on the distribution of the species. Other than these minor changes to account for sampling bias, Maxent was run with its default settings including the cloglog transformation as the most appropriate for estimating the probability of presence (Phillips et al. 2017). We were able to use these models to effectively predict distributions for all species with more than a single record. The percent contribution from each of the nine variables in each case is listed in Appendix 1: Table 2.

For each species we included the following when possible photographs, maps from both ArcMap and Maxent, and the following information about each species:

Species Name: Genus and species epithet (Author, Year)

State and County records: States with their respective counties in which we found specimens in collections.

Year Collected: Range of years on labels for which we found specimens in collections.

Flight Season: Range of earliest day and month of the year to the latest day and month of the year for a collected species.

Elevation Range: Lowest elevation – highest elevation ever collected in meters.

Notes: Any brief, interesting, and relevant information available about the species including a survey through the literature and how we distinguished between similar species.

Results / Discussion

In verifying records, we agreed with most identifications, only correcting the identifications of 10 specimens. We evaluated and included 15, 562 records. Of these, 6, 366 were unique having some difference in locality, date, or collector and 161 were "environ" or county level records that were excluded for ENM (Table 1). In this we found a total of 36 different genera representing 93 different species (Table 1). Utah contained the most tiger moth records with 4, 779 unique records compared to 1, 426 unique records found collectively in Nevada, Idaho, Colorado, New Mexico, and Arizona (Fig. 3). The region as a whole, however, is still well sample as tiger moths were found in every county (Fig. 1) and every Level III ecoregion, except the extremely small portion of the Madrean Archipelago. This is in large part due to the efforts of Robert C. Mower collecting the vast majority of unique records with a total of 2, 412 unique tiger moth records of the 6, 366. The large number of specimens also yielded tiger moths collected in each of the 12 months of the year (Table 1).

The ENM analyses conducted with each species will be useful to future workers in Nevada. Although in our study few tiger moths are reported from Nevada (Fig. 3), the ENM maps point to areas that should clearly be sampled more instensively. Further information about each species including the results of the ENM analyses, is presented below in the individual species accounts.

Chapter 2 Figures

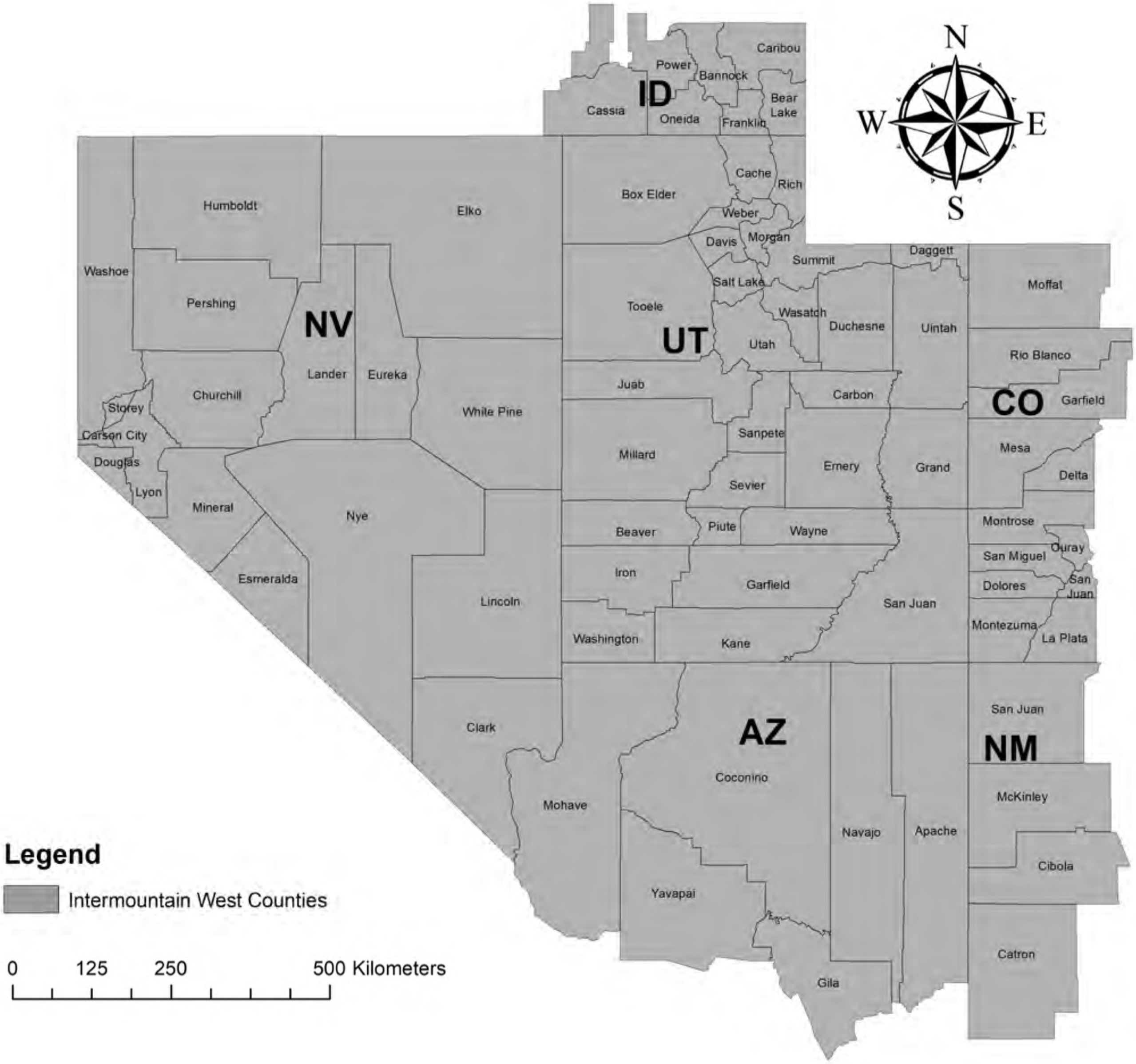


Figure 1. Our defined study area within the Intermountain West at the county level.

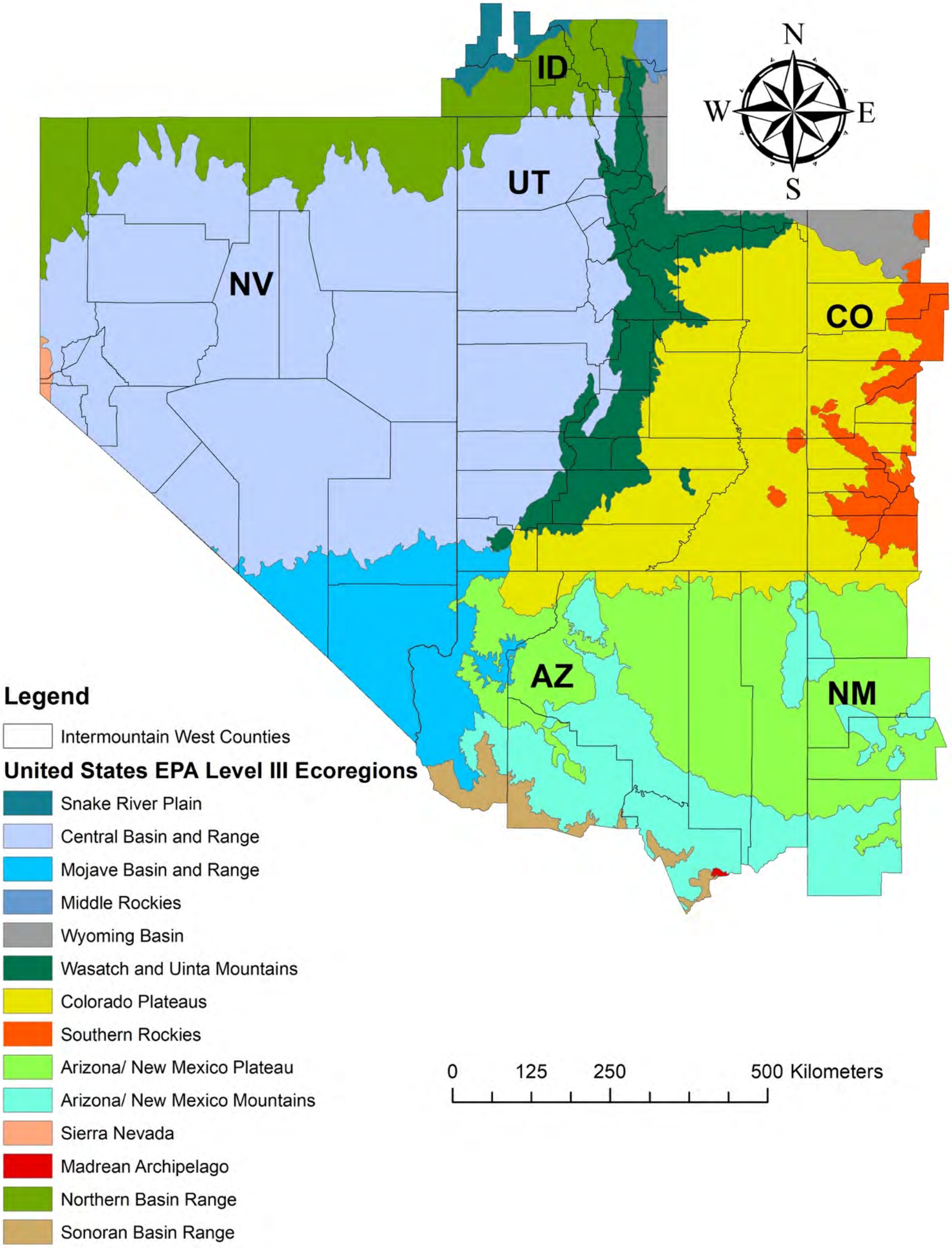


Figure 2. The Level III Ecoregions (U.S. Environmental Protection Agency, 1999) of our study area in the Intermountain West.

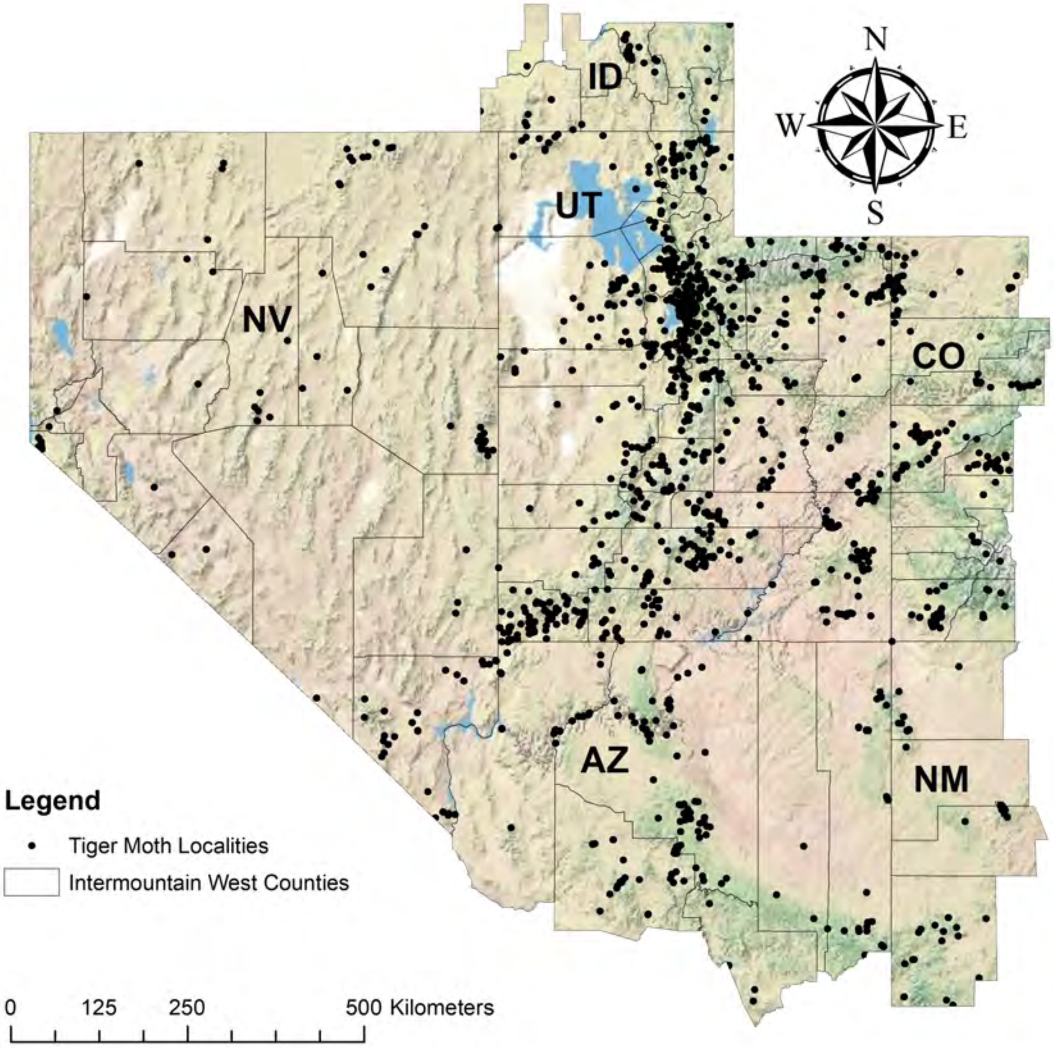


Figure 3. All the localities of tiger moth species that have been collected across the study site in the Intermountain West.

Species Accounts

Alexicles aspersa (Grote, 1883)

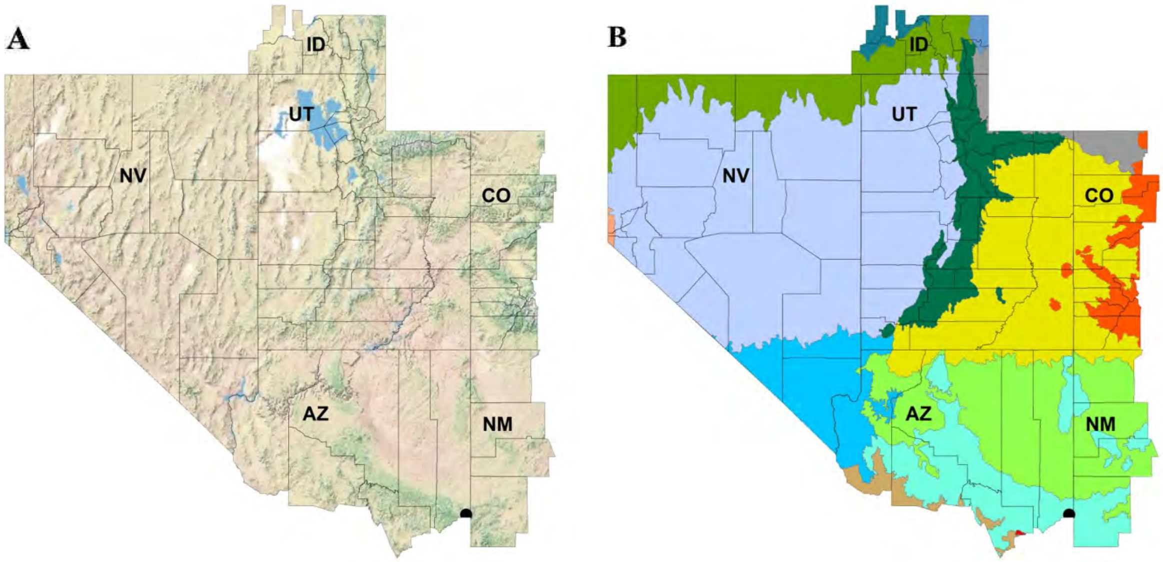


Figure 4. *Alexicles aspersa* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Apache

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1967

Flight Season: 16 June

Elevation Range: 2441 m

Notes: We found one record of the species in the lower tip of the Intermountain West in the Arizona/New Mexico Mountains Level III ecoregion. Limited with one record, we did not conduct an ENM analysis.

Antichloris viridis (Druce, 1884)

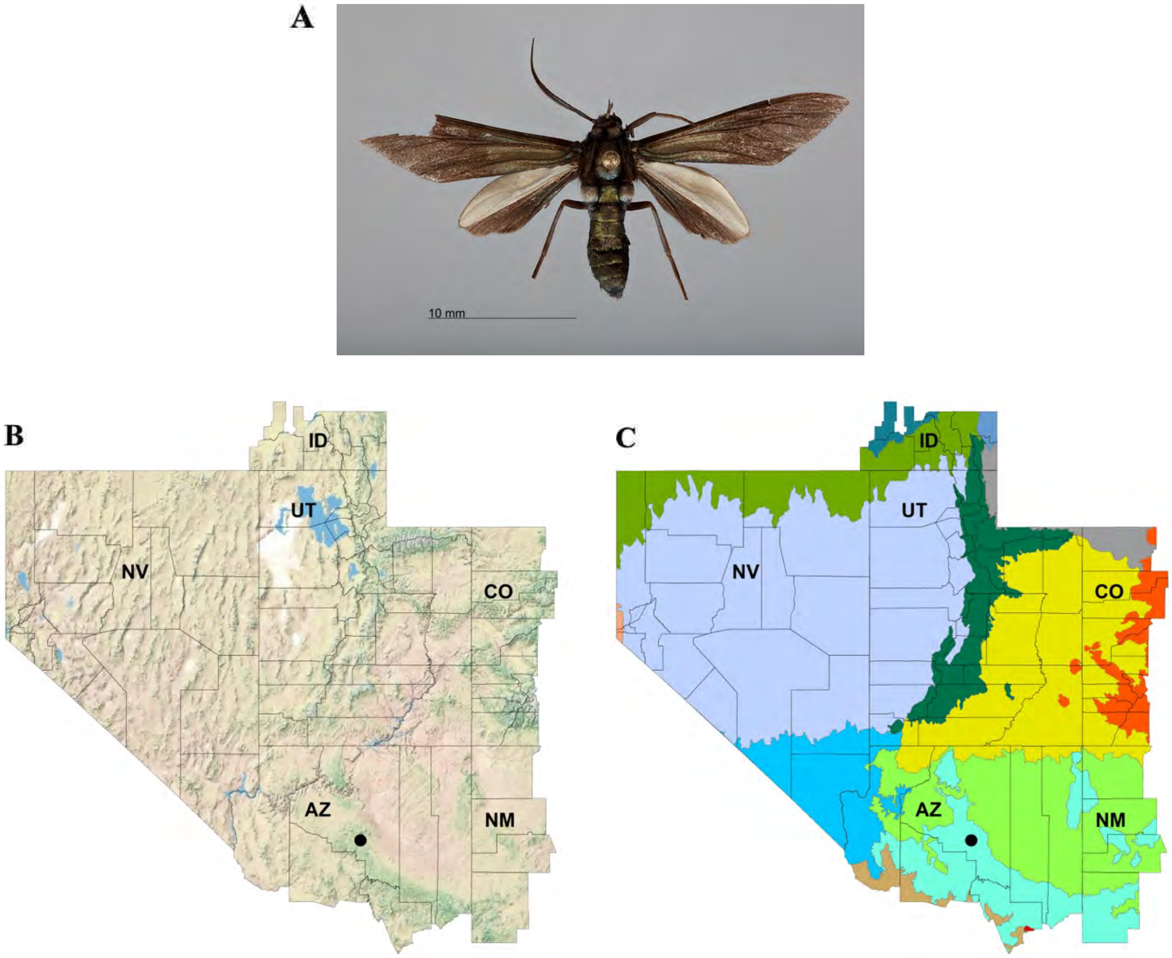


Figure 5. *Antichloris viridis* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 2007

Flight Season: 25 October

Elevation Range: 2461 m

Notes: The iridescent green species is not endemic to North America. Commonly called the banana moth, the larvae are pests in banana plantations (Robinson & Saúco 2010) and are occasionlly found in imported bananas. We found one such record from Arizona. Limited with one record of a stowaway, we did not conduct an ENM analysis.

Apantesis arizoniensis (Stretch, 1873)

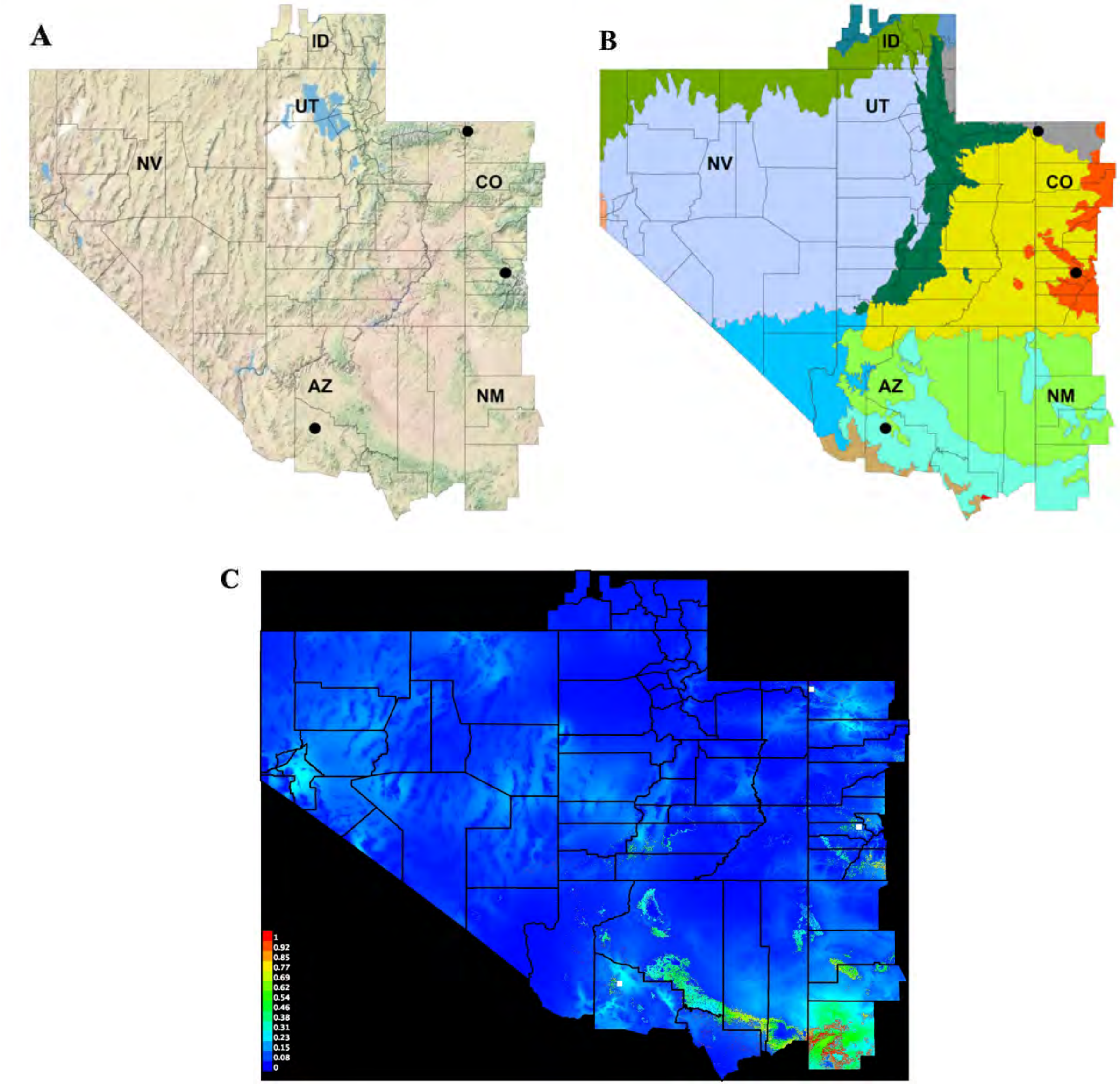


Figure 6 *Apantesis arizoniensis* A: Topographic map of documented distribution, B: Level III ecoregion map of documented distribution, and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Yavapai; COLORADO: Moffat

Ecoregion Records: Arizona/ New Mexico Mountains and Southern Rockies

Years Collected: 1978, 2009

Flight Season: 28 June - 8 August

Elevation Range: 1548 – 1828 m

Notes: The species resembles a pale and smaller *Apantesis proxima* (Powell & Opler 2009) as both species were formerly in the genus *Notarctia* (Rönkä et al 2016). Little more is published on the species.

Apantesis bowmani (Ferguson & Schmidt, 2007)

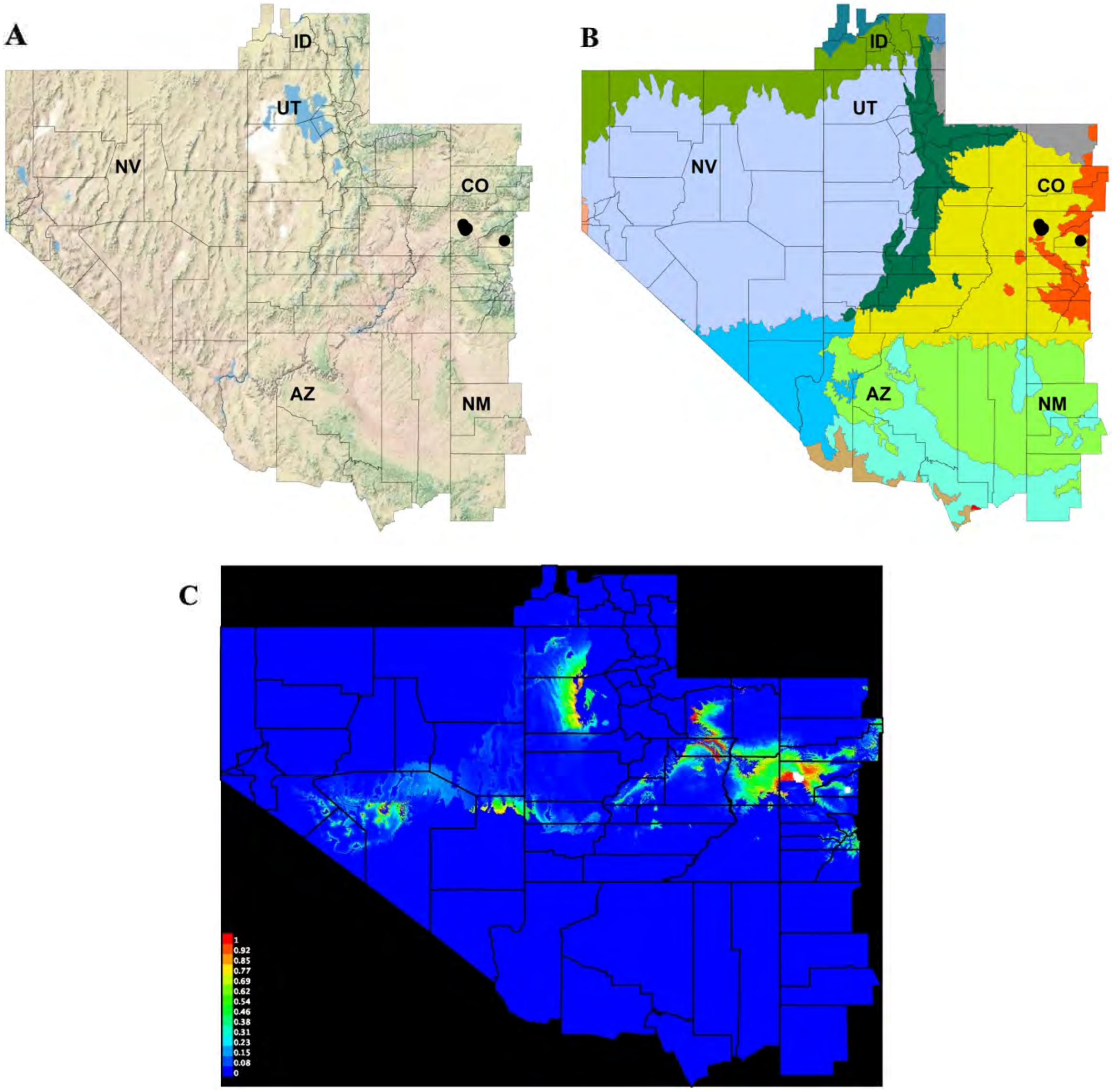


Figure 7. *Apantesis bowmani* A: Topographic map of documented occurrences, B: Level III ecoregion map of documented occurrences, and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta and Mesa

Ecoregion Records: Colorado Plateaus

Years Collected: 1997 - 2001

Flight Season: 14 May - 15 July

Elevation Range: 1400 – 2055 m

Notes: Ferguson & Schmidt (2007) present it as an intermediate between *Apantesis nevadensis superba* and *Apantesis williamsii*. It can be distinguished from *A. nevadensis superba* by having shorter antennal branches, forewing median and postmedian bands that tend to be straight, and black wing fringes (Ferguson & Schmidt 2007). It can be distinguished from *A. williamsii* by having longer antennal branches and median and/or postmedian lines that extend beyond the postcubital band (Ferguson & Schmidt 2007).

Apantesis brillians (Schmidt, 2009)

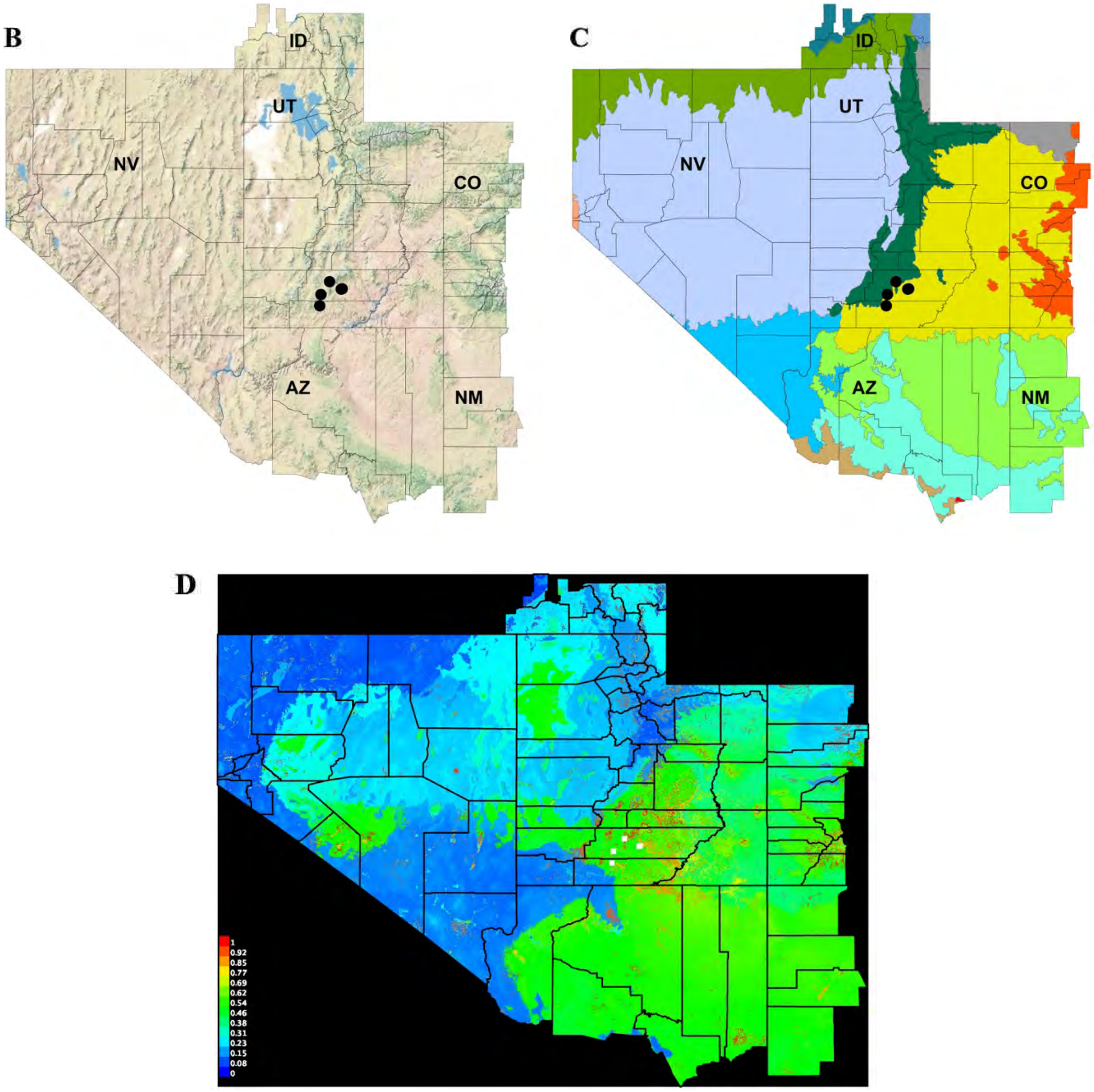


Figure 8. *Apantesis brillians* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Garfield and Kane

Ecoregion Records: Colorado Plateaus and Wasatch and Uinta Mountains

Years Collected: 2013

Flight Season: 14 May - 15 July

Elevation Range: 1621 – 2625 m

Notes: Schmidt (2009) described the species and aptly named it for the hindwing's bright, saturated colors. The species is most similar to *Apantesis bowmani,* though it lacks antemedial and medial markings on the hindwings (Schmidt 2009). We found a cluster of records in southern Utah, though a quite large population is moderately predicted through the eastern portion of the region. Bryce Canyon National Park is the species only previously known locality and Schmidt (2009) postulated the species to be endemic to southern Utah. Though the ENM model had a large training data AUC score (Appendix 1: Table 3), further investigation with more records is needed to truly define the species range within the Intermountain West.

Apantesis carlotta (Ferguson, 1985)

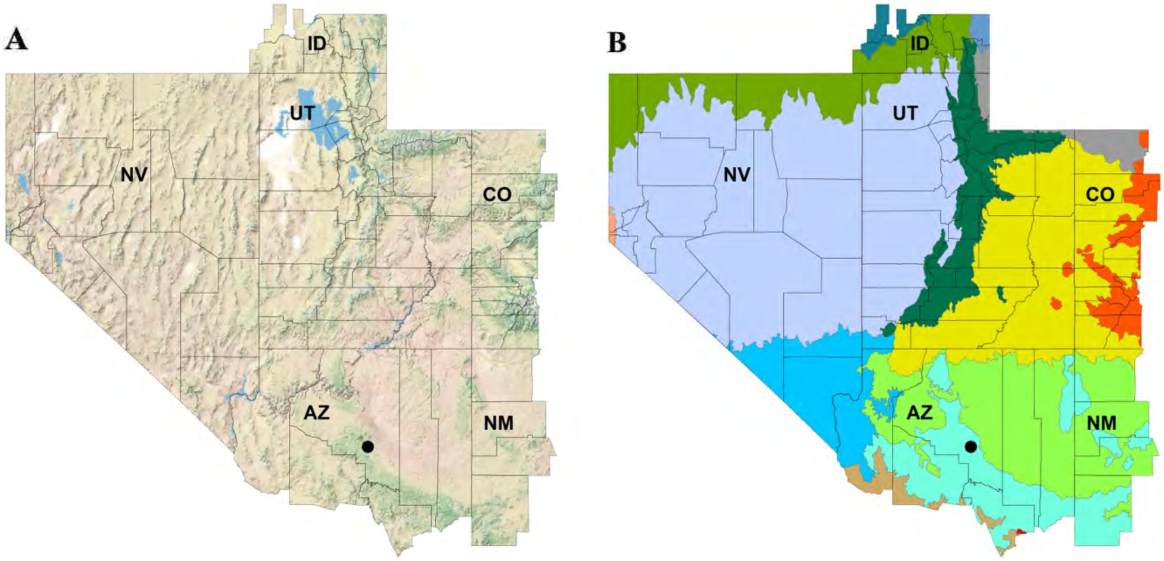


Figure 9. *Apantesis carlotta* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 2008

Flight Season: 7 August

Elevation Range: 1466 m

Notes: As an eastern North American species, it is not commonly collected in the Intermountain West. Limited with one record, we did not conduct an ENM analysis.

Apantesis eureka (Ferguson & Schmidt, 2007)

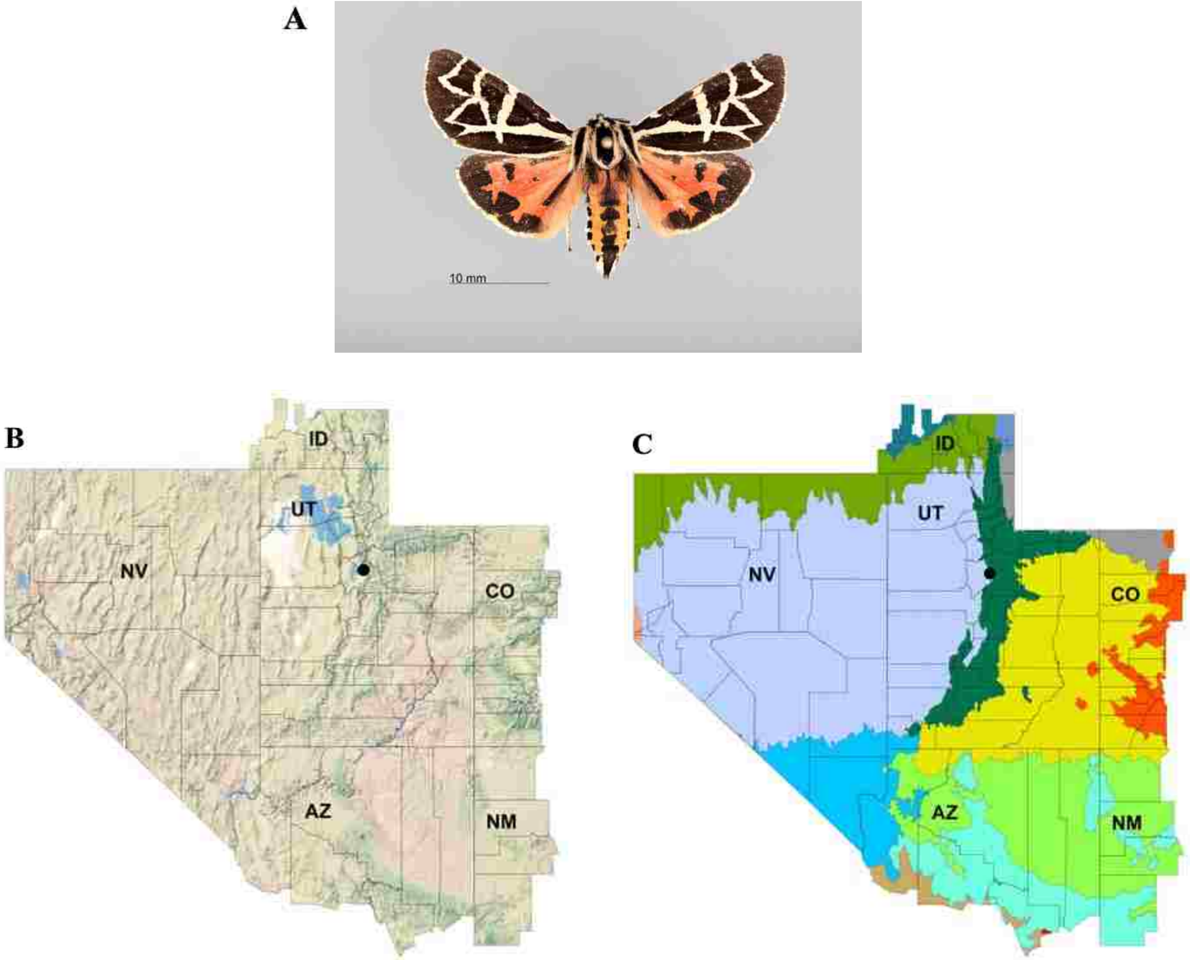


Figure 10. *Apantesis eureka* A: Specimen image, B: Topographic map, C: Level III ecoregion map of documented occurrencess.

State and County Records: UTAH: Utah

Ecoregion Records: Central Basin and Range

Years Collected: 2018

Flight Season: 5 June

Elevation Range: 1840 m

Notes: Ferguson &Schmidt (2007) described the species from a handful of older specimens. These specimens were collected over 100 years ago, 1909-1910. The species was described as having reduced eyes and was hypothesized to be diurnal as an explanation of why these have not been collected more commonly. However, we collected three specimens that came into a UV light trap suggesting some light attraction. We collected them at a somewhat rocky canyon mouth dominated by oak trees (*Querces gambelii*), sagebrush, and grasses. Further investigation into this species habitat and behavior is needed. Limited with one record with GPS coordinates, we did not conduct an ENM analysis.

Apantesis f-pallida (Strecker, 1878)

A

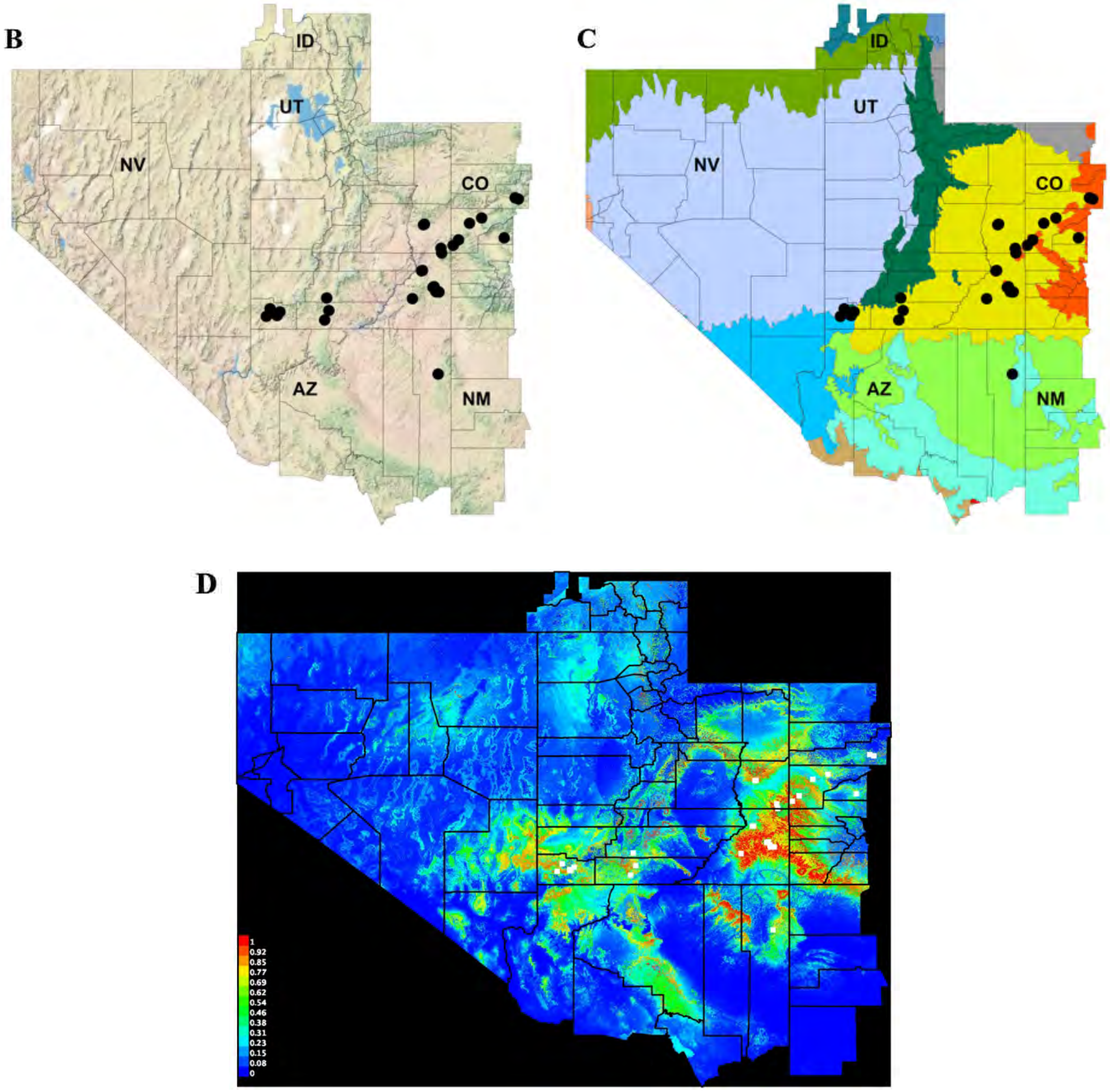


Figure 11. *Apantesis f-pallida* A: Specimen image, B: Topographic map, C: Level III ecoregion map of documented, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache; COLORADO: Delta, Garfield, and Mesa and UTAH: Garfield Grand, Kane, Mesa, and San Juan

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies Wasatch, and Uinta Mountain

Years Collected: 1964 - 2017

Flight Season: 6 June - 30 July

Elevation Range: 1282 – 2708 m

Notes: The species is easily recognized with white markings that make an F in the forewing. It has been collected through southern and eastern Utah and western Colorado. It very closely resembles *Apantesis figurata*, that occurs in the east, but has smaller forewings and eyes (Schmidt 2009).

Apantesis incorrupta (Edwards, 1881)

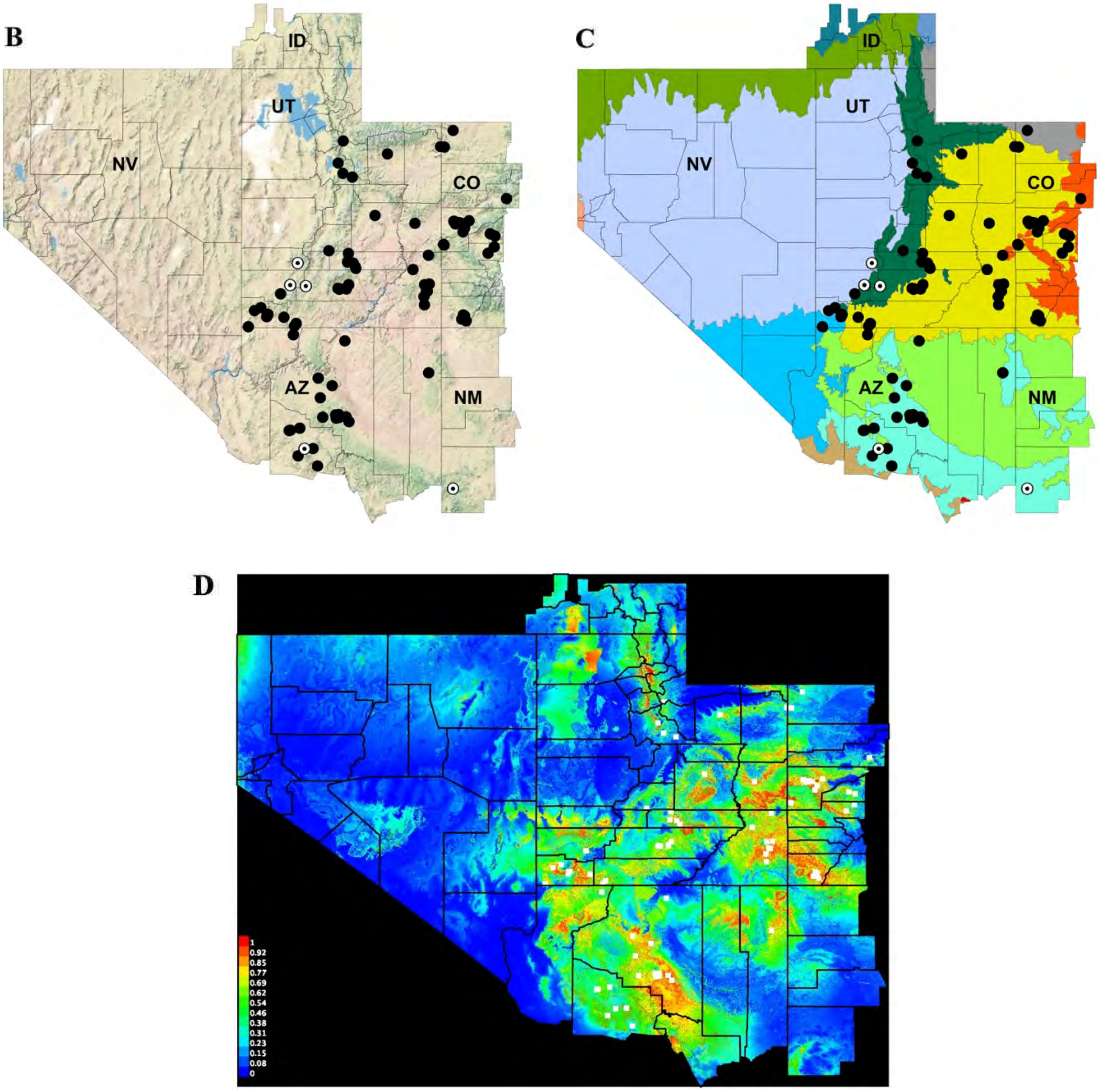


Figure 12. *Apantesis incorrupta* A: Specimen image (various forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Mohave, and Yavapai; COLORADO: Delta, Garfield, Mesa, Moffat, Montezuma, and Montrose; NEW MEXICO: Catron; UTAH: Beaver, Duchesne, Emery, Garfield, Iron, Grand, Iron, Kane, San Juan, Sevier, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, and Sonoran Basin Range, Wasatch and Uinta Mountains, Wyoming Basin,

Years Collected: 1920 - 2017

Flight Season: 9 March - 30 October

Elevation Range: 961 – 2870 m

Notes: The species is common everywhere except Nevada, consistent with Schmidt's (2009) reported distribution. It has morphological variation that makes it at times difficult to distinguish from *Apantensis nevadensis*, but Schmidt's (2009) revision of the genus was helpful. The species occurs in the southeastern half of the region and is largely allopatric with *A. nevadensis*, but an intermixed region does occur in southwestern Utah. In this case we relied more heavily on morphology. *A. incorrupta's* thorax may be striped, its hindwing margin is rounded, and the forewing is broader (Schmidt 2009). *A. nevadensis* thorax is solely black, its hindwing margin is straighter, and its forewing is more pointed to the apex (Schmidt 2009).

Apantesis margo (Schmidt, 2009)

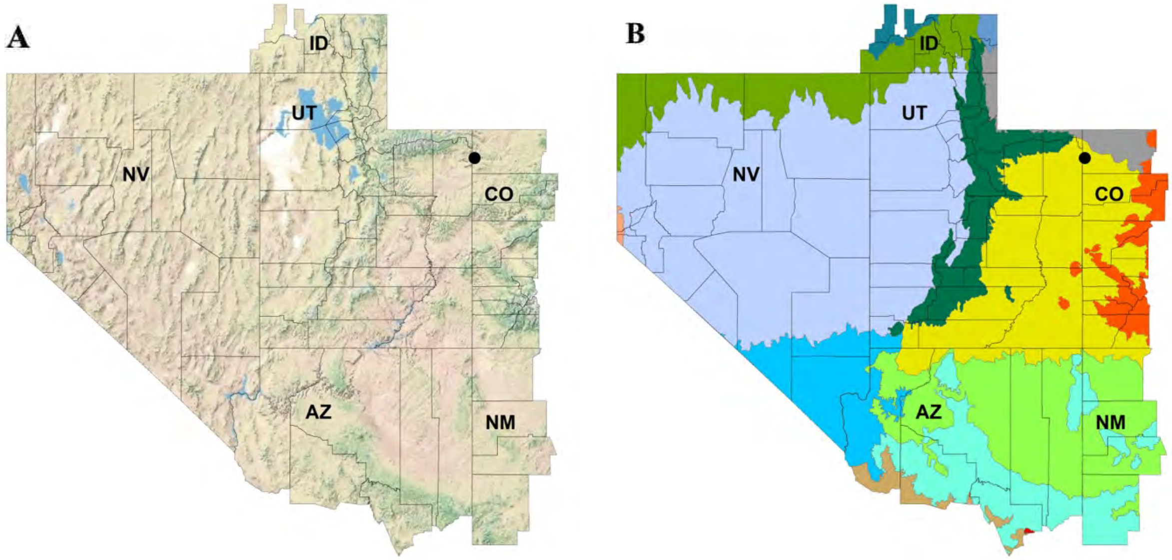


Figure 13. *Apantesis margo* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Records: COLORADO: Moffat

Ecoregion Records: Colorado Plateaus

Years Collected: 1992

Flight Season: 15 July

Elevation Range: 1676 m

Notes: The species is most similar to *Apantesis williamsii* though the species occurs in eastern Colorado through east-central Arizona, and is not common in the region (Schmidt 2009). It can most easily be distinguished by never having pink wings, among other various morphological differences (Schmidt 2009). Limited with one record, we did not conduct and ENM analysis.

Apantesis nevadensis (Grote & Robbinson, 1866)

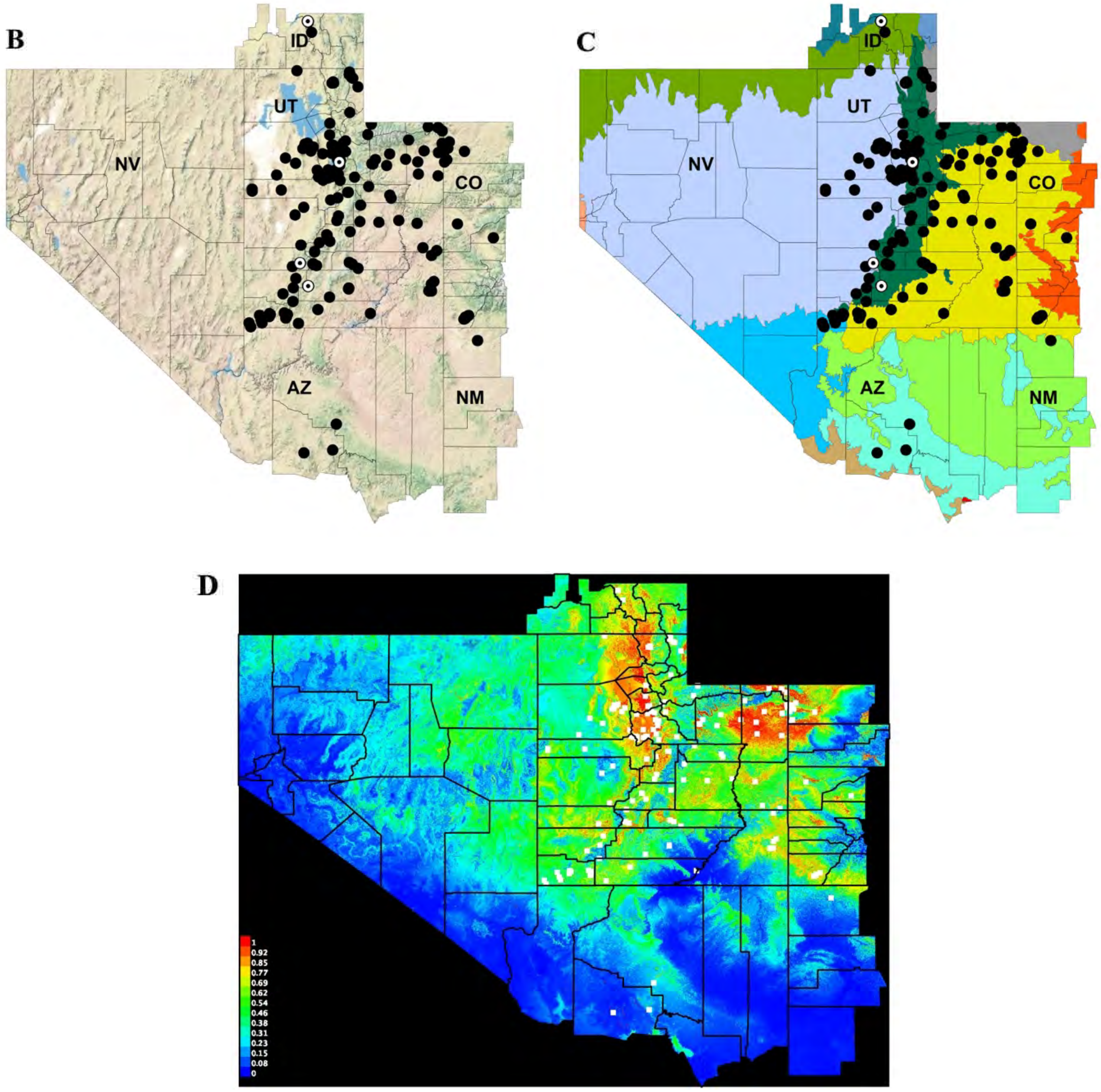


Figure 14. *Apantesis nevadensis* A: Specimen image (various forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino and Yavapai; COLORADO: Delta, Mesa, Moffat, Montezuma; IDAHO: Bannock; NEW MEXICO: San Juan; UTAH: Beaver, Box Elder, Cache, Carbon, Daggett, Duchesne, Emery, Garfield, Grand, Iron, Juab, Kane, Millard, Morgan, Piute, Rich, Salt Lake, San Juan, Sanpete, Sevier, Summit, Tooele, Uintah, Utah, Wasatch, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateaus, Northern Basin Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1921 - 2017

Flight Season: 24 March - 21 October

Elevation Range: 813 – 3121m

Notes: The species is very common north of *Apantesis incorrupta* with a mixed zone of the twon in southeastern Utah. With many forms, this species can be difficult to distinguish from *A. incorrupta* (Schmidt 2009). See 'Notes' under *A. incorrupta* for more information on distingusihing between the two.

Apantesis obliterata (Stretch, 1885)

A

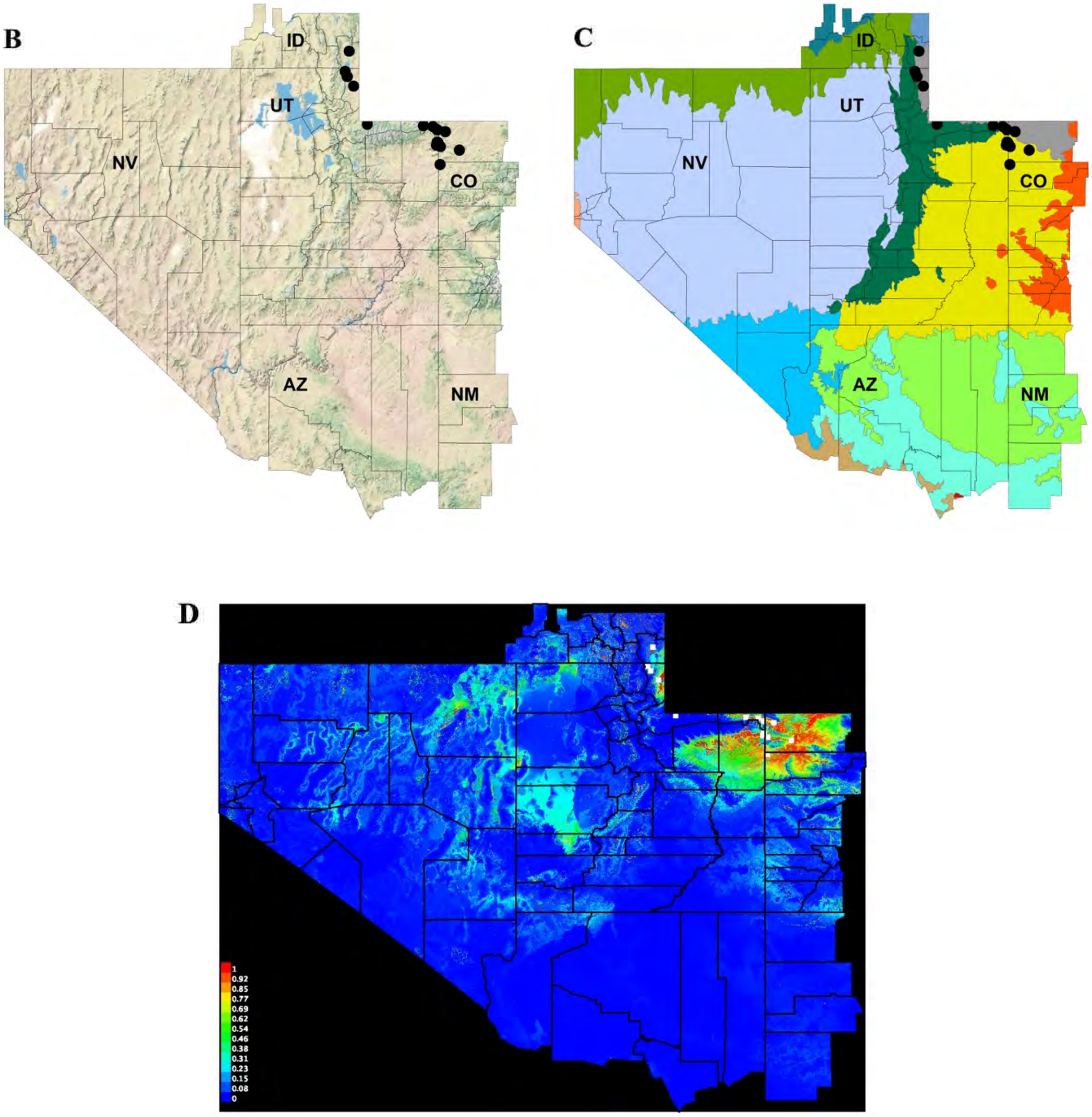


Figure 15. *Apantesis obliterata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Moffat and Rio Blanco; IDAHO: Bear Lake; UTAH: Daggett, Rich, Summit, and Uintah

Ecoregion Records: Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1929 - 2005

Flight Season: 1 July - 9 September

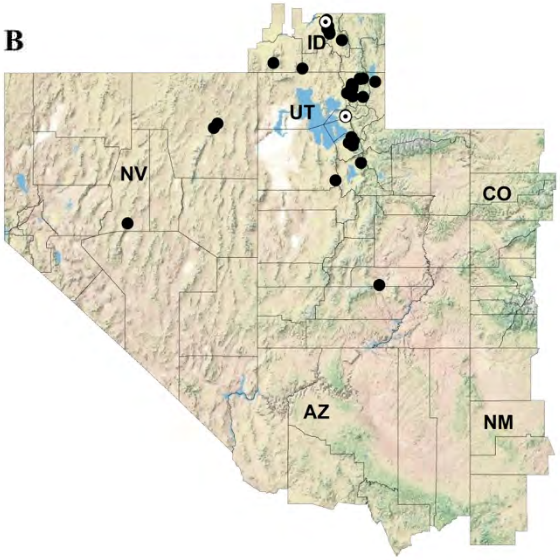
Elevation Range: 813 – 2528 m

Notes: Powell & Opler (2009) report the species to be nocturnal and attracted to lights and Holarctic with a Rocky Mountain distribution that includes northeastern Utah and northwestern Nevada as found here.

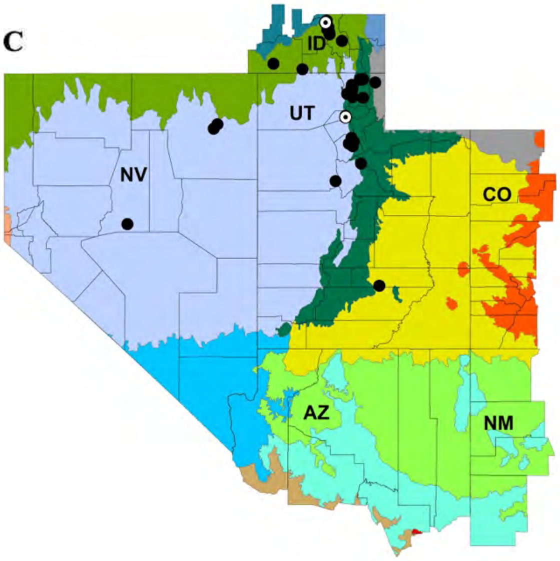
Apantesis ornata (Packard, 1864)

A

B



C



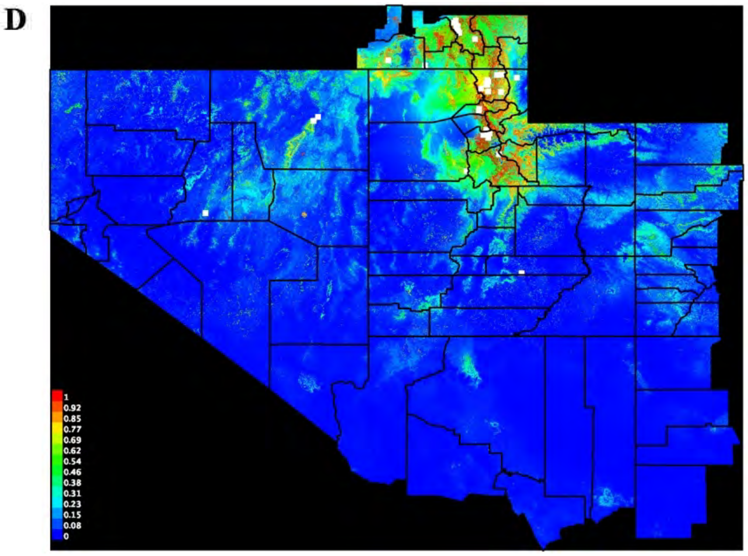


Figure 16. *Apantesis ornata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: IDAHO: Bannock and Cassia; NEVADA: Elko and Lander; UTAH: Cache, Utah, Rich, Salt Lake, Wayne, and Weber

Ecoregion Records: Central Basin and Range, Northern Basin Range, and Wasatch and Uinta Mountains

Years Collected: 1929 - 2016

Flight Season: 1 May - 12 November

Elevation Range: 985 – 2546 m

Notes: The males are nocturnal and attracted to lights while the females are can be found flying slowly during the day (Powell & Opler 2009). Schmidt (2009) also reports this species as the most variable *Grammia* (now *Apantesis*) in terms of forewing pattern and hindwing color. We found the species to be most abundant and predicted most heavily to occur in northern Utah and the included Idaho counties similar to Schmidt (2009).

Apantesis parthenice (Kirby, 1837)

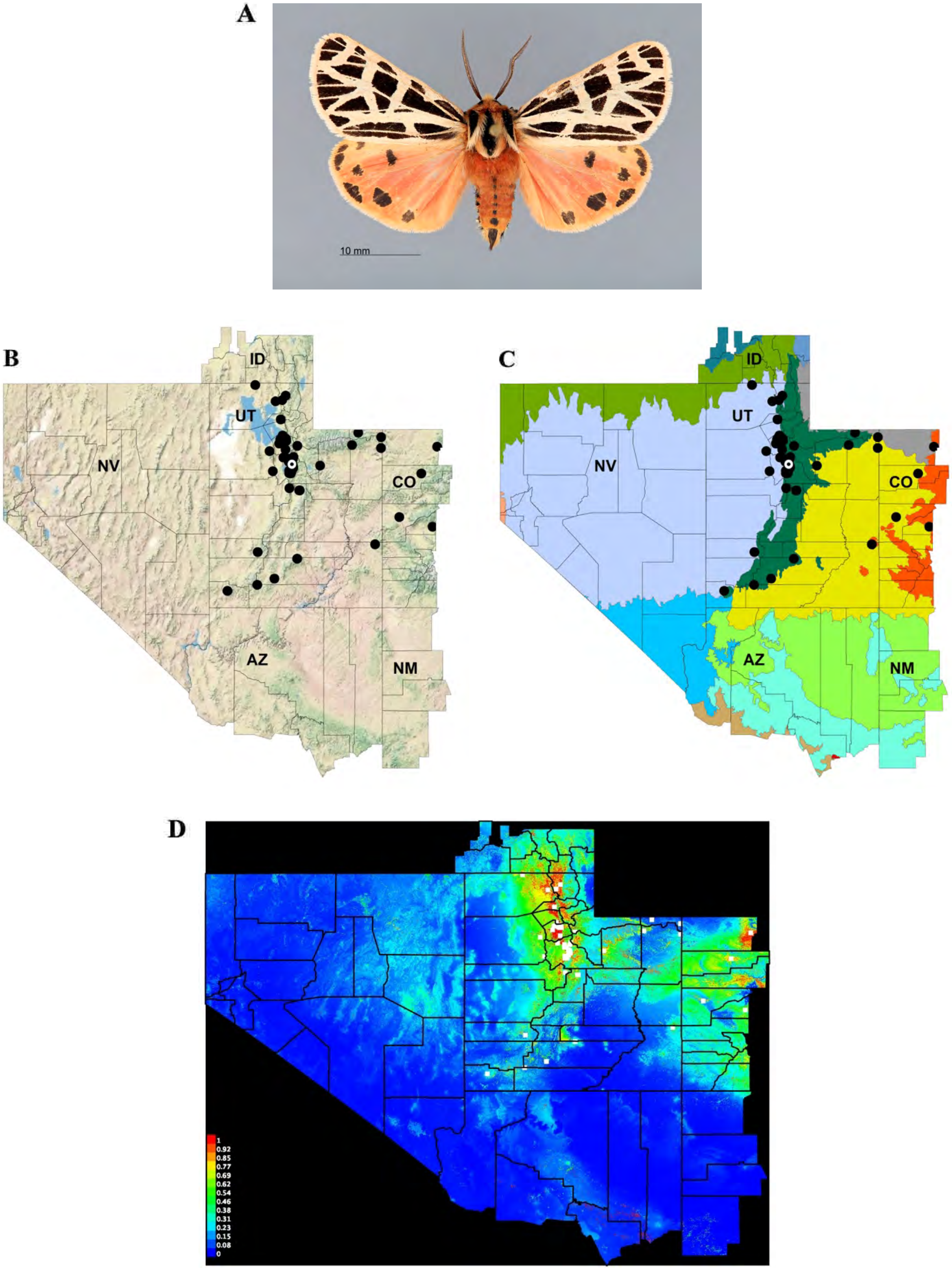


Figure 17. *Apantesis parthenice* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta, Mesa, Moffat, and Rio Blanco; UTAH: Beaver, Box Elder, Cache, Dagett, Davis, Duschesne, Garfield, Juanita Grand, Kane, Salt Lake, Sanpete, Tooele, Uintah, Utah, Washington, Wayne, and Weber

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin,

Years Collected: 1923 - 2012

Flight Season: 15 May - 17 October

Elevation Range: 689 – 3104 m

Notes: Powell & Opler (2009) describe the species as nocrturnal and to be prevelant in the Rocky Mountains and to occur south into Arizona and New Mexico. Schmidt (2009) mentions this as another variable species in terms of size, color that correlates with geography and populations. The species looks similar to *Apantesis virgo*, but lacks antemedial spots on the hindwing and has a thin cubital vein (Schmidt 2009).

Apantesis phyllira (Drury, 1773)

A

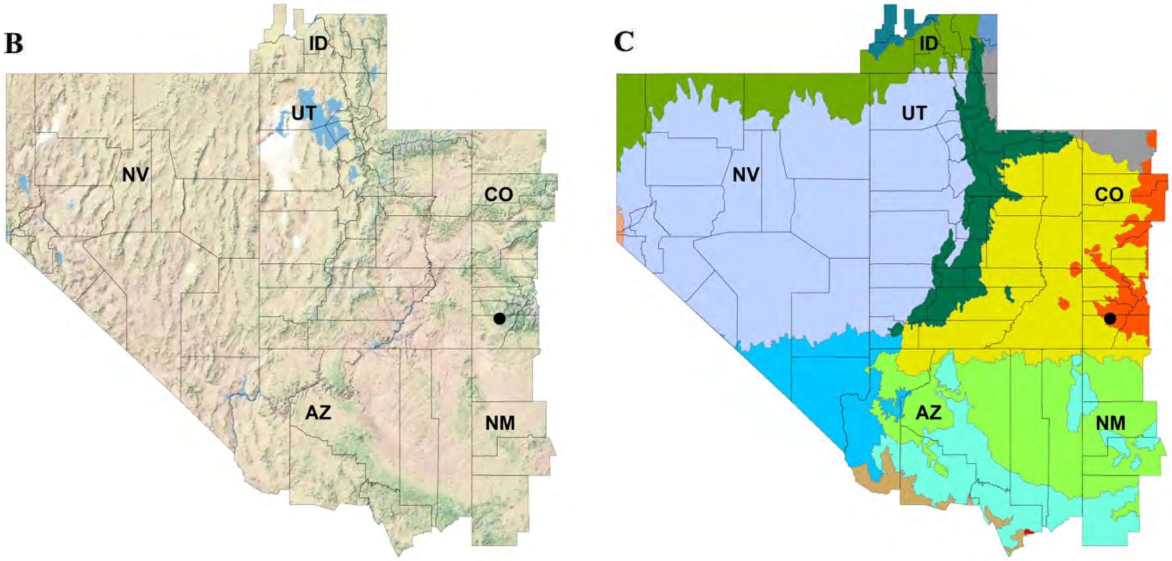


Figure 18. *Apantesis phyllira* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences

State and Coutny Records: COLORADO: Montezuma

Ecoregion Records: Southern Rockies

Years Collected: 1984

Flight Season: 4 August

Elevation Range: 2255 m

Notes: The species occurs in eastern Colorado (Schmidt 2009) and is rare in on the Intermountain West. Limited with one record, we did not conduct a ENM analysis.

Apantesis proxima (Guérin-Méneville, 1844)

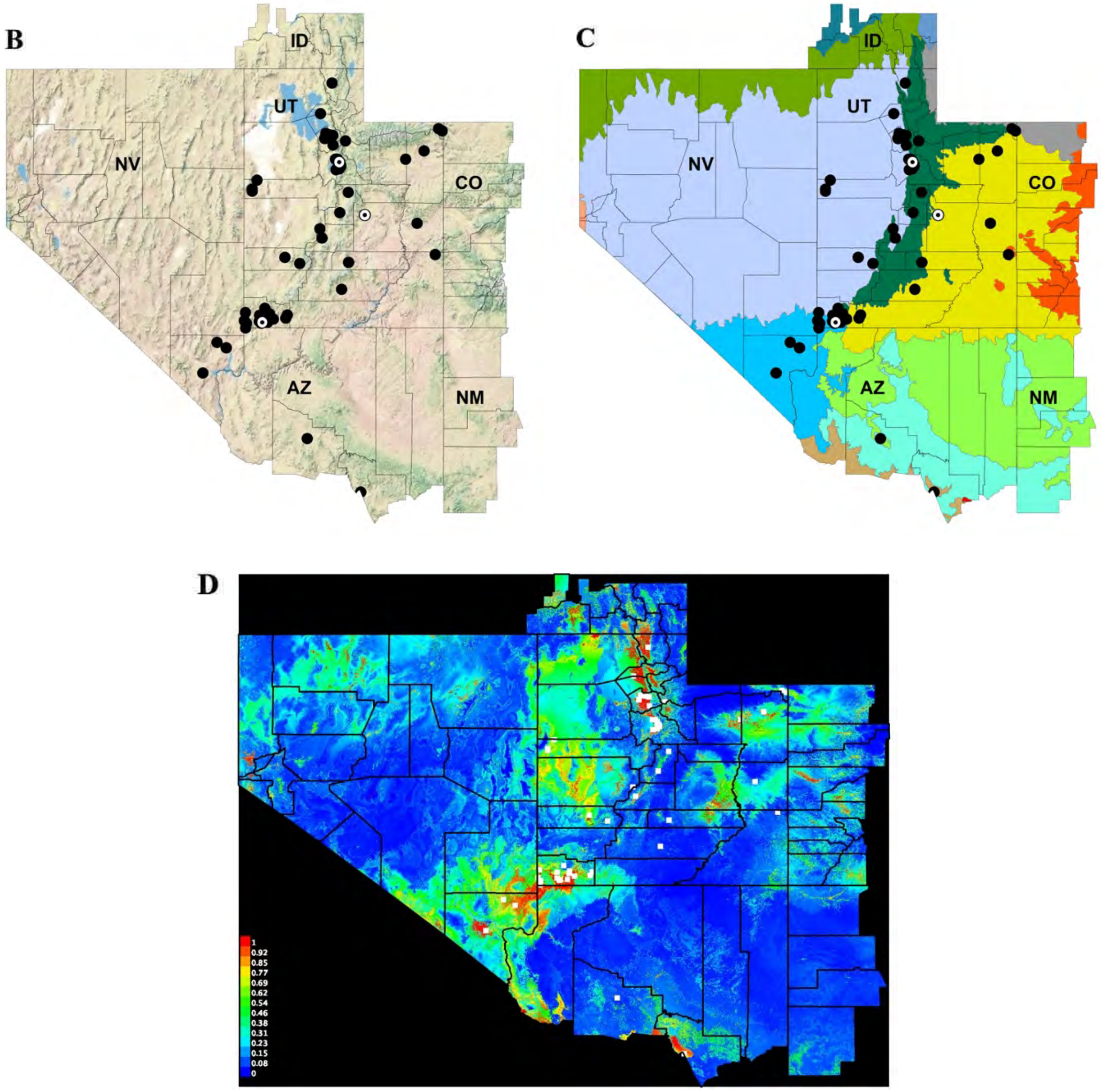


Figure 19. *Apantesis proxima* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Gila and Yavapai; NEVADA: Clark;

UTAH: Beaver, Cache, Daggett, Duchesne, Emery, Garfield, Grand, Juab, Millard, Salt Lake, Sanpete, Sevier, Summit, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, Wasatch and Uinta Mountains

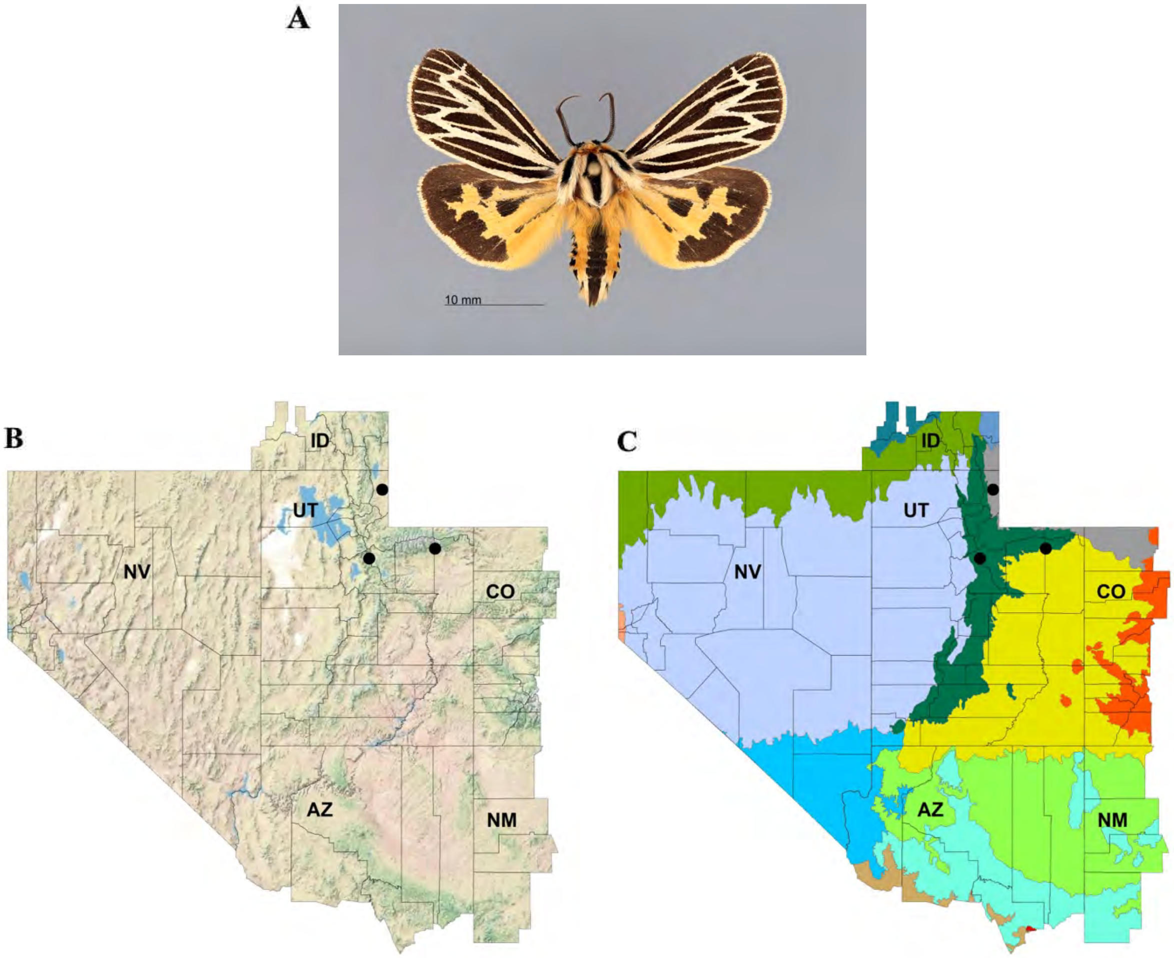
Years Collected: 1900 - 2017

Flight Season: 4 April - 20 October

Elevation Range: 416 – 3027 m

Notes: Similar to *Apantesis arizoniensis*, the species was formely in the genus *Notarctia* (Rönkä et al 2016). The species is dimorphic with males having red/pink hindwings and females having mostly white hindwings (Powell & Opler 2009).

Apantesis speciosa (Möschler, 1864)



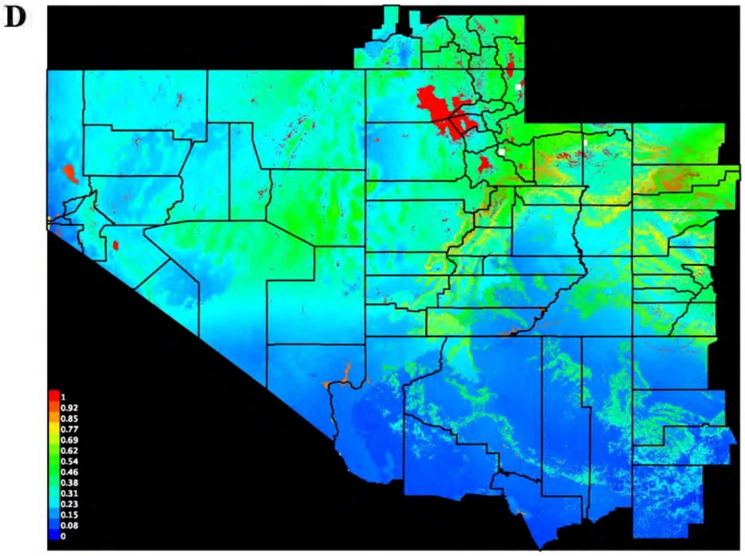


Figure 20. *Apantesis speciosa* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Rich, Wasatch, and Uintah

Ecoregion Records: Wasatch and Uinta Mountains and Wyoming Basin

Years Collected: 1993, 2002, and 2013

Flight Season: 28 June - 11 July and September

Elevation Range: 1652 – 2285 m

Notes: A small diurnal species commonly confused with *Apantesis virguncula* (Schmidt 2009). The species however is smaller and has a more elongate forewing, thinner-lined cubital vein, and usually more extensive hindwing black markings (Schmidt 2009).

Apantesis virgo (Linnaeus, 1758)

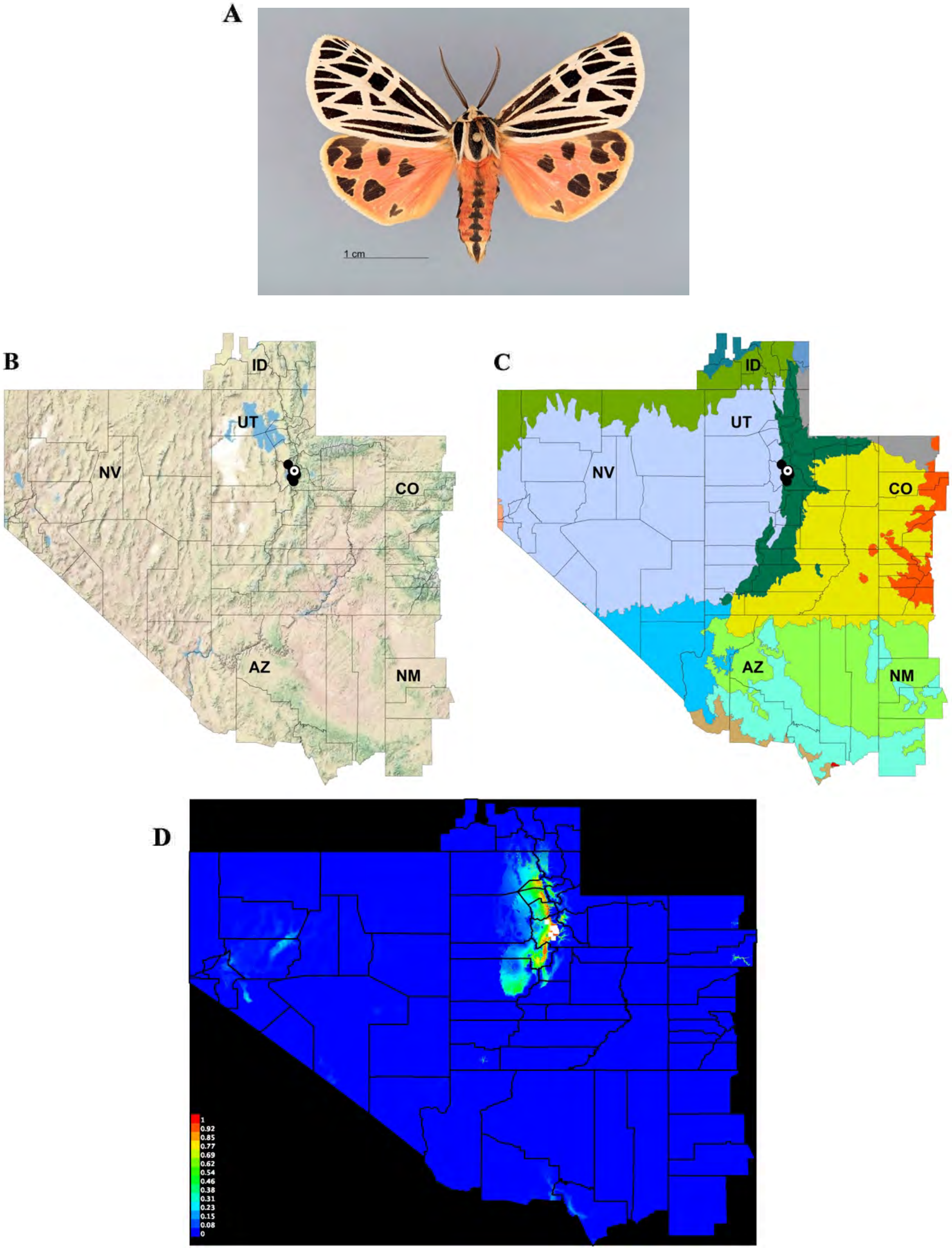


Figure 21. *Apantesis virgo* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Utah

Ecoregion Records: Central Basin and Range

Years Collected: 1969 - 2002

Flight Season: 5 July - 23 August

Elevation Range: 1371 – 2586 m

Notes: Schmidt (2009) mentions the species has isolated records in Provo, Utah, but did not examine them and were not included in his revision. The majority of these are stored at BYU and we verified the specimens and investigated their isolated distribution in the Rocky Mountains. Our ENM analysis also predicts the population to be isolated and to not extend far beyond central Utah. How this population got here is currently unknown.

Apantesis virguncula (Kirby, 1837)

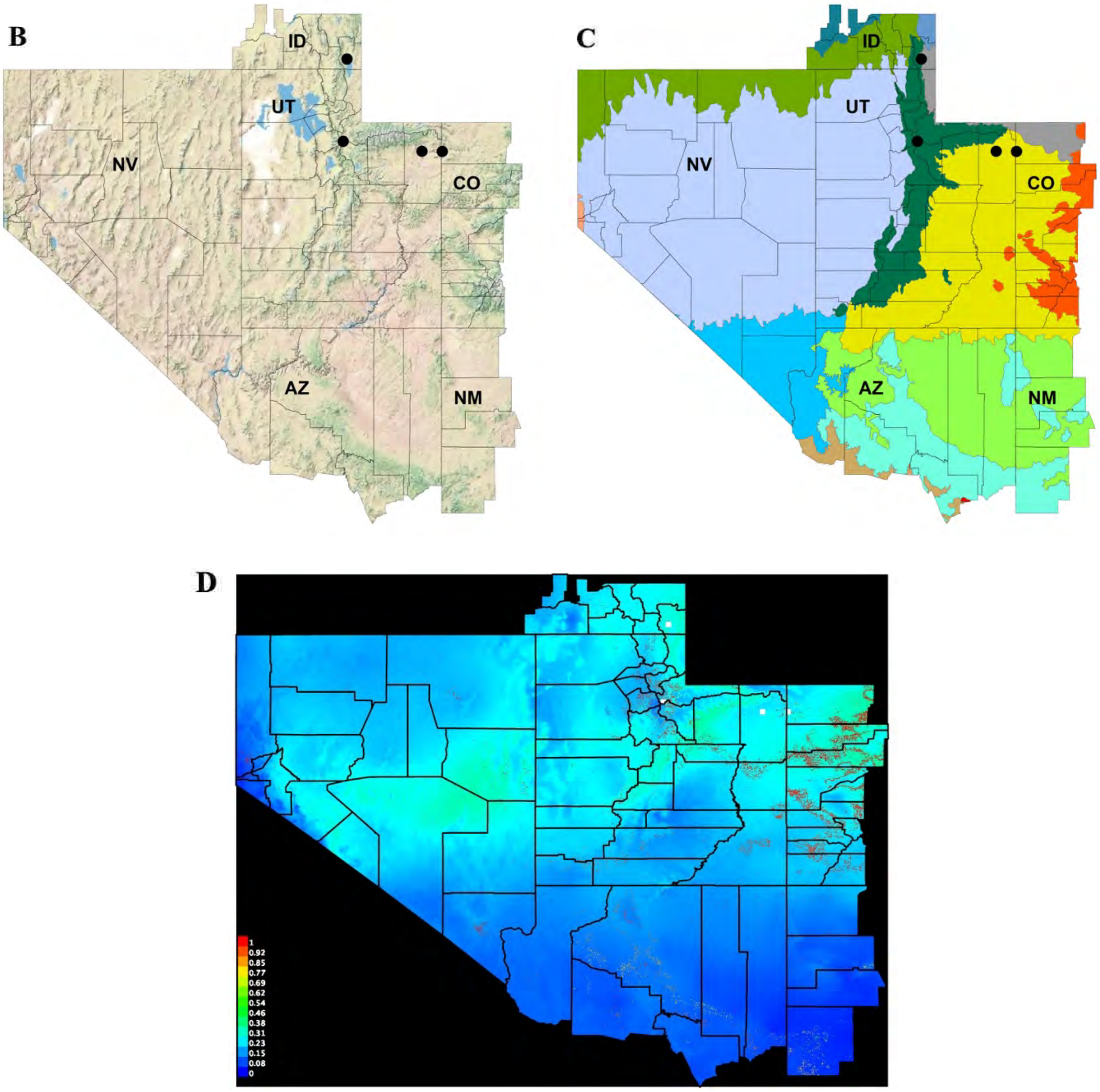


Figure 22. *Apantesis virguncula* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Moffat; IDAHO: Bear Lake; UTAH: Summit and Uintah

Ecoregion Records: Colorado Plateaus, Wasatch and Uinta Mountains, and Wyoming Basin

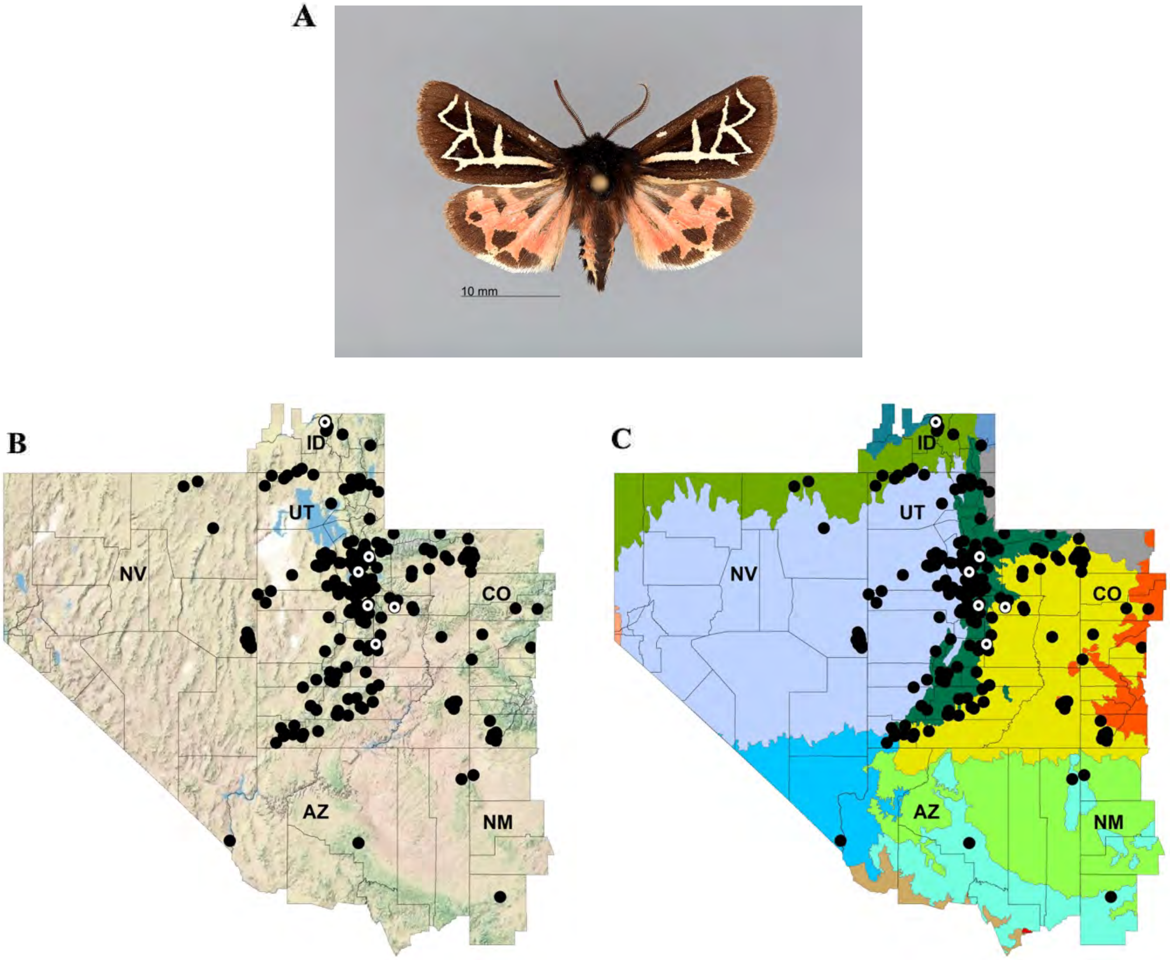
Years Collected: 1929 -1994

Flight Season: 6 July - 19 August

Elevation Range: 1379 – 2389 m

Notes: We found a few records of the species in northeastern Utah and southeastern Idaho. We present an ENM Maxent model here, but it is very broad and more data on this species is needed.

Apantesis williamsii (Dodge, 1871)



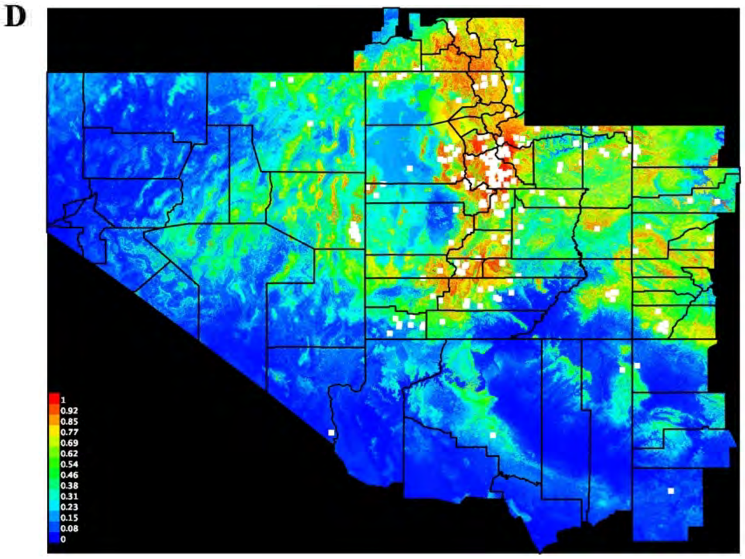


Figure 23. *Apantesis williamsii* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino; COLORADO: Delta, Mesa, Moffat, and Montezuma; IDAHO: Bannock, Bear Lake, and Cassia, NEVADA: Elko and White Pine; NEW MEXICO: Catron; UTAH: Beaver, Box Elder, Cache, Carbon, Daggett, Duchesne, Emery, Garfield, Juab, Iron, Kane, Millard, Morgan, Rich, Salt Lake, San Juan, Sanpete, Sevier, Summit, Tooele, Uinta, Utah, Wasatch, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Northern Basin Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1918 - 2017

Flight Season: 27 April - 16 October, 31 December

Elevation Range: 662 – 3135 m

Notes: The species is ubiquitous across the study site. It is a small, fairly recognizable species with reduced forewing lines and pink wings (Powell &Opler 2009). The species can be difficult to distinguish from *A. bowmani* (Schmidt 2009). See 'Notes' under *A. incorrupta* for more information on how to do so. It has been collected in good numbers by Makani Fisher and Robert C. Mower and can be found in very high numbers at light traps when active (personal observation).

Apantesis yavapai (Schmidt, 2009)

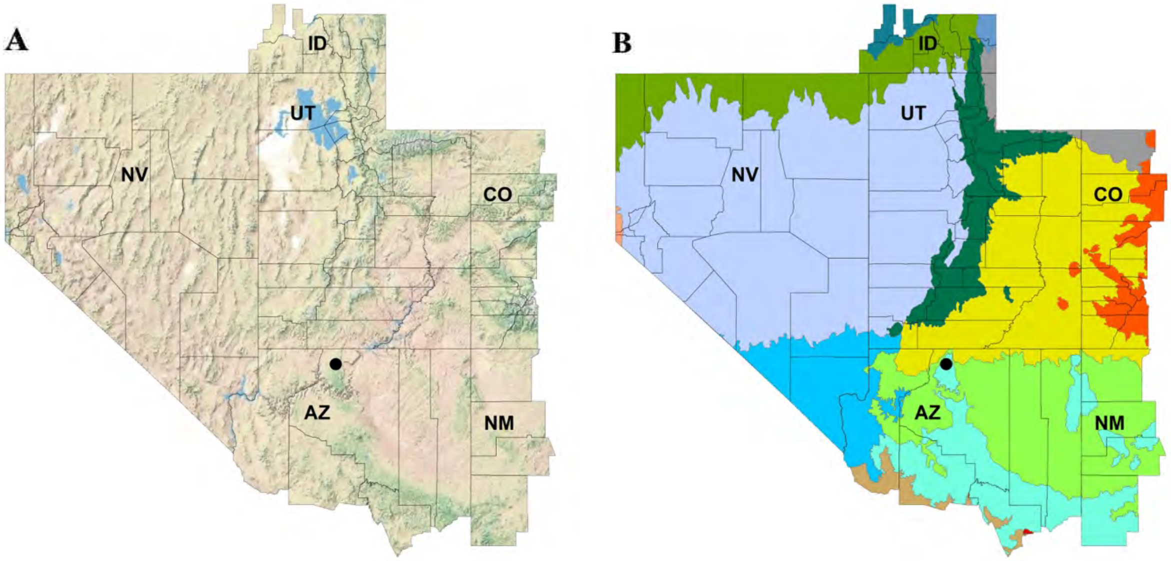


Figure 24. *Apantesis yavapai* A: Specimen image, and B: Topographic map of documented occurrences

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 2011

Flight Season: 15 June

Elevation Range: 1670 m

Notes: The species can look like a yellowish *Apantesis williamsii*, but does not occur in the same region, being further south (Schmidt 2009).

Arachnis citra (Neumogen & Dyar, 1893)

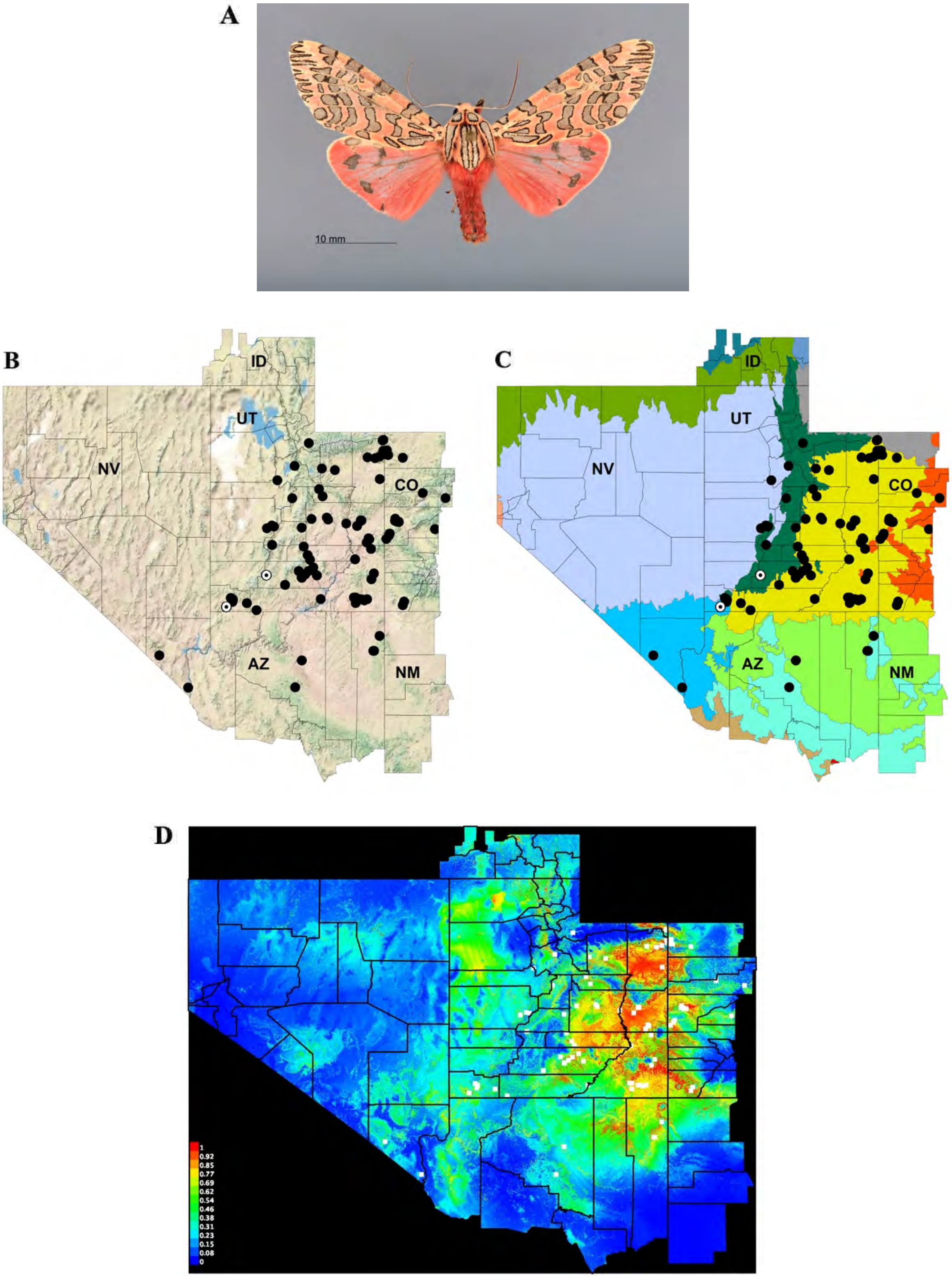


Figure 25. *Arachnis citra* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino; COLORADO: Delta, Garfield, Mesa, Moffat, Montezuma, and Rio Blanco; NEVADA: Clark; UTAH: Carbon, Daggett, Duchesne, Emery, Garfield, Grand, Juab, Kane, Millard, Sanpete, San Juan, Sevier, Piute, Uinta, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, Wasatch and Uinta Mountains

Years Collected: 1920 - 2017

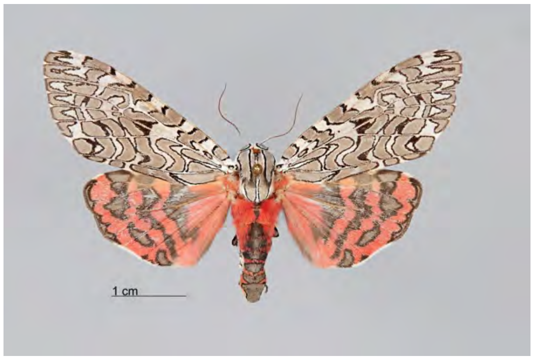
Flight Season: 5 February - 26 September

Elevation Range: 548 – 3573 m

Notes: The species is rather large and well-collected. We found records from the tip of the Mojave Desert across the Wasatch and Uinta Mountainss and into the Colorado Plateau. The moth can be distinguished from *A. picta* that has a white and gray forewing pattern by having orange/yellow forwings with a gray spot pattern. The underwings are red with various gray stripes.

Arachnis picta (Packard, 1864)

A



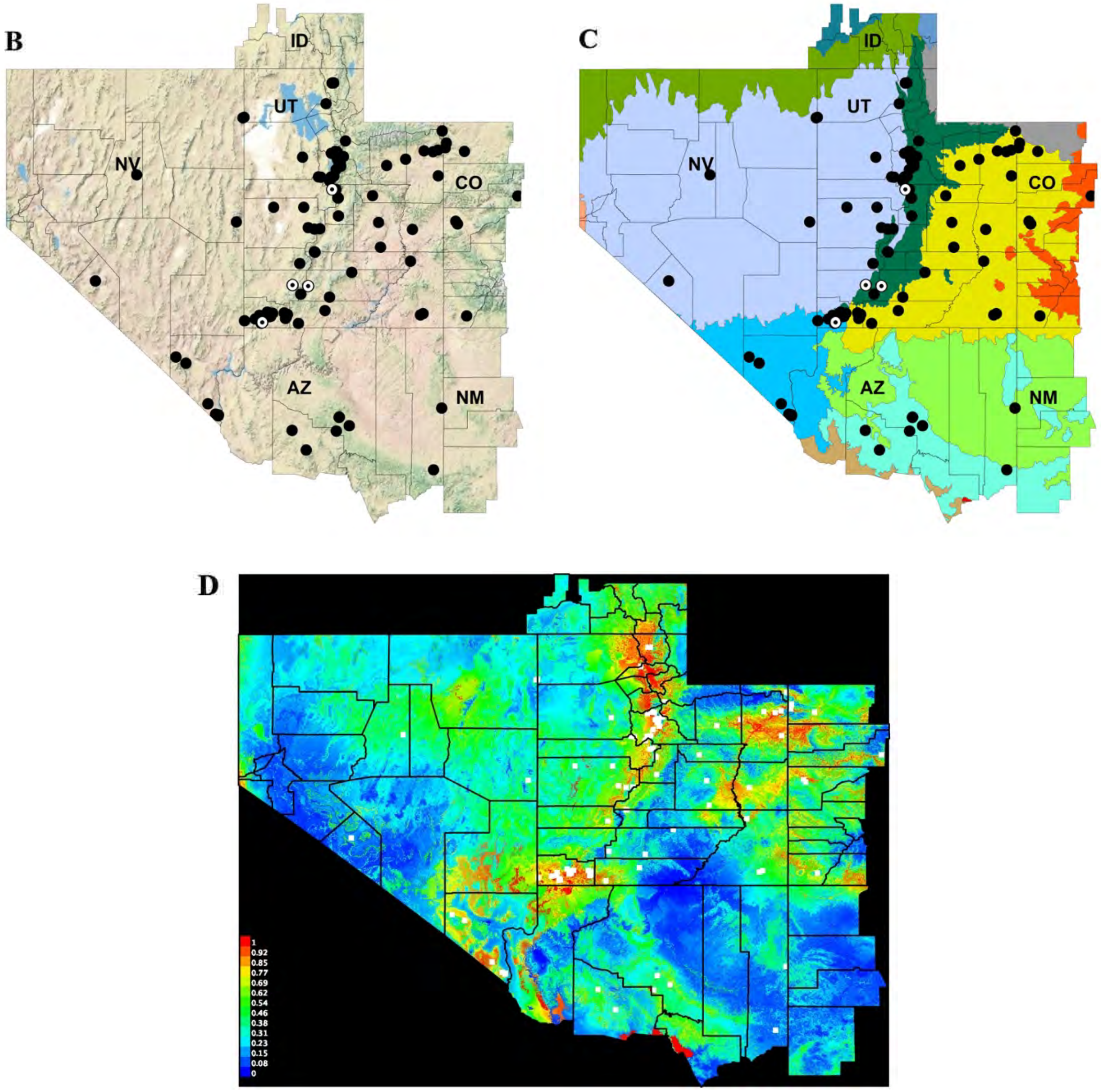


Figure 26. *Arachnis picta* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, and Yavapai; COLORADO: Mesa, Moffat, and Montezuma; NEVADA: Clark, Elko, Nye, and White Pine; UTAH: Beaver, Box Elder, Cache, Daggett, Duchesne, Emery, Garfield, Grand Iron, Juab, Kane, Sanpete, Millard, Uintah, Utah, Piute, and Washington

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, and Wasatch and Uinta Mountains

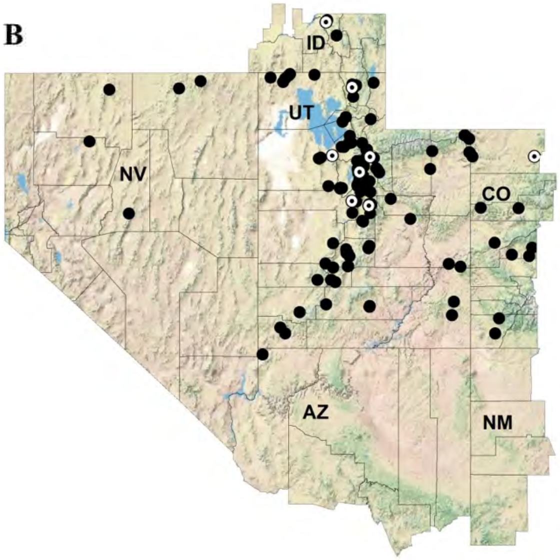
Years Collected: 1905 - 2017

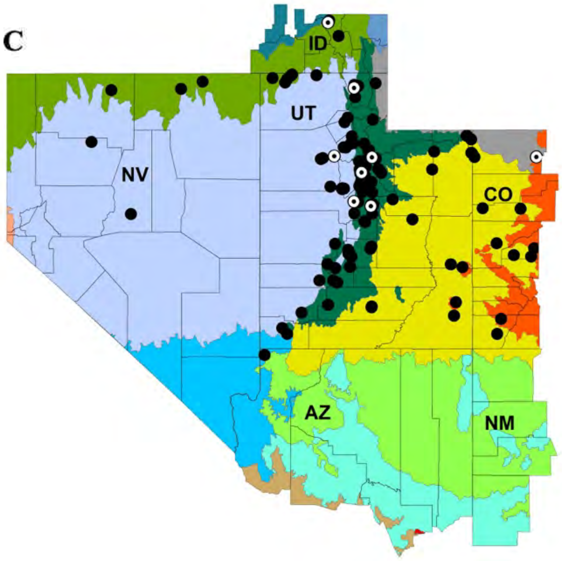
Flight Season: 4 April - 12 November

Elevation Range: 813 – 2762 m

Notes: The species comes together with *Arachnis citra* in Southern Utah, but extends into northern Utah, southern Nevada and northwestern Arizona where as *A. citra* spans more across eastern Utah. See the *A. citra* 'Notes' for how to distinguish between the two.

Arctia caja (Linnaeus, 1758)





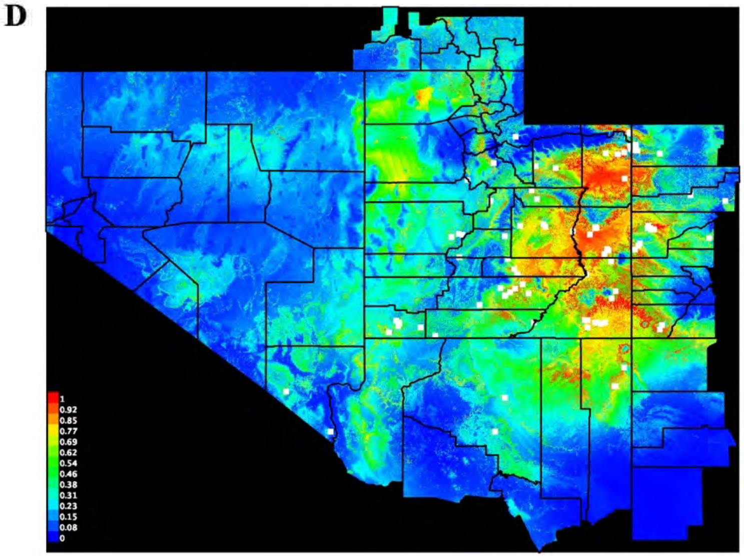


Figure 27. *Arctia caja* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Mohave; COLORADO: Delta, Garfield, Mesa, Moffat, and Montezuma; IDAHO: Bannock; NEVADA: Elko, Lander, Humboldt, and Pershing; UTAH: Beaver, Box Elder, Cache, Carbon, Daggett, Davis, Delta, Duchesne, Garfield, Iron, Juab, Millard, Morgan, Piute, Salt Lake, Sanpete, Sevier, Summit, Tooele, Uintah, Utah, Piute, Wasatch, Washington, and Weber

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Northern Basin Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1909 - 2018

Flight Season: 1 May - 24 October

Elevation Range: 1300 – 3308 m

Notes: The species is one of the larger and more ubiquitous species of tiger moths. Its caterpillars is highly polyphagous (Robert C. Mower personal communication) and is collected and reared by many professionals and amateurs alike (Gardiner 2002).

Arctia lapponica (Thunberg, 1791)

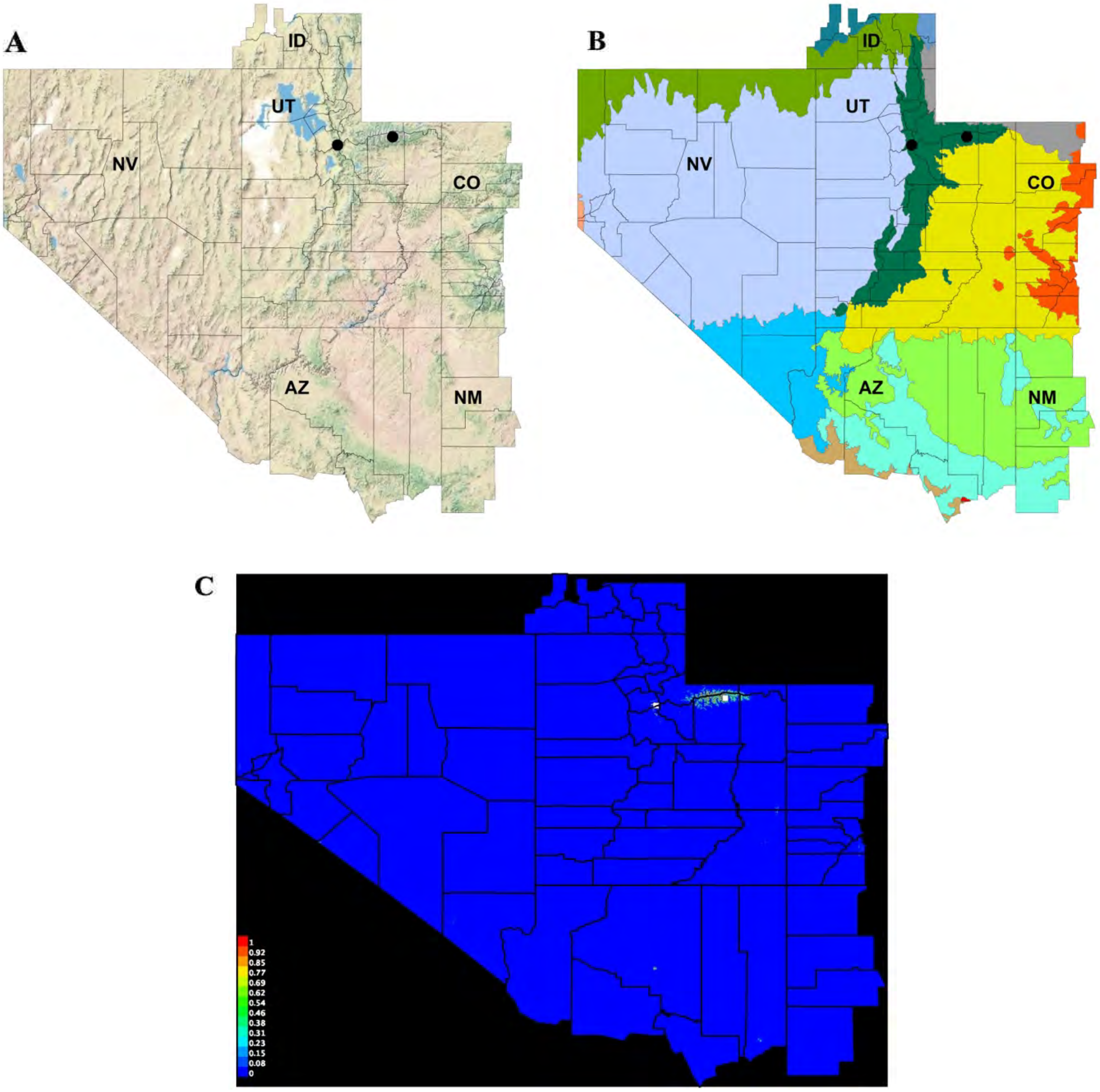


Figure 28. *Arctia lapponica* A: Topographic map of documented occurrences B: Level III ecoregion map of documented occurrences, and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Duchesne and Salt Lake

Ecoregion Records: Wasatch and Uinta Mountains

Years Collected: 1933

Flight Season: 9 July

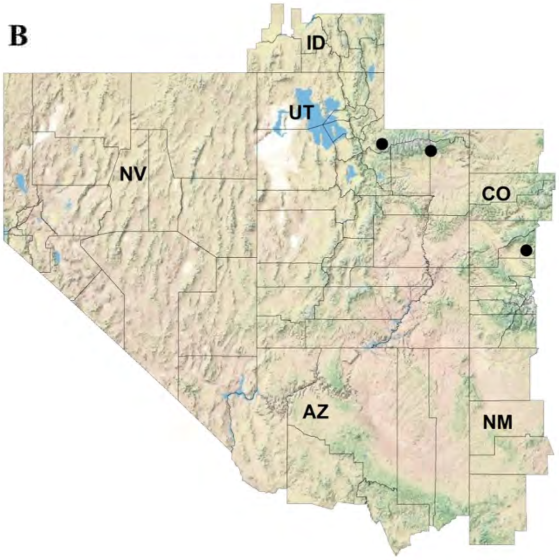
Elevation Range: 1582 – 1910 m

Notes: The species is similar to *Arctia yarrowi* and *Arctia caja.* It is easily told apart from *A. caja* as it has black markings and stripes on its hindwings instead of blue irridescent spots. Its hindwing pattern mostly resembels that of *A. yarrowi* and is difficult to tell apart. The two species are in need of some taxonomic work. Though an ENM Maxent model is presented here, the few available variables were not very informative on predicting its distribution.

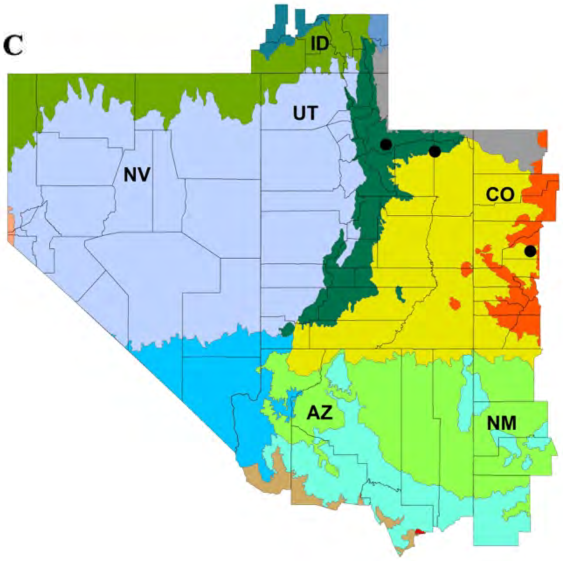
Arctia parthenos (Harris 1850)

A

B



C



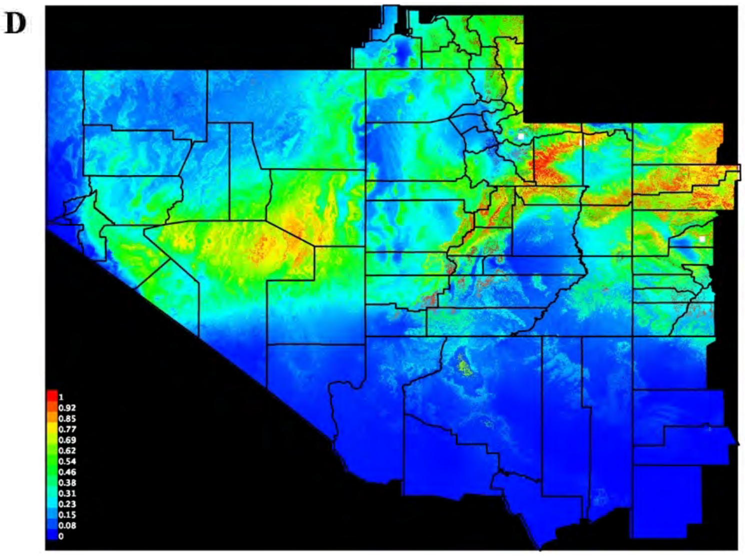


Figure 29. *Arctia parthenos* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta and Routt; UTAH: Summit and Uintah

Ecoregion Records: Colorado Plateaus and Wasatch and Uinta Mountains,

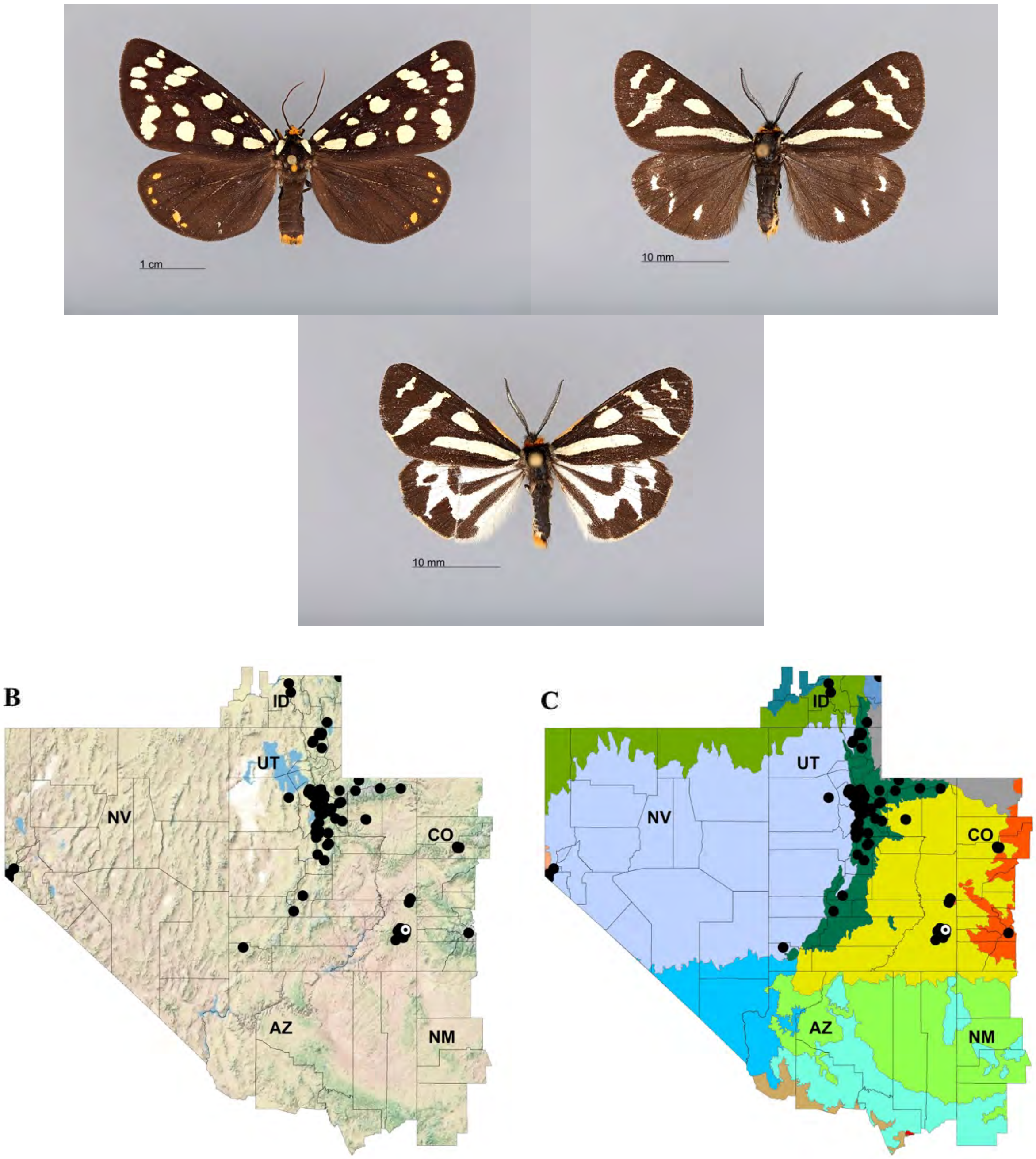
Years Collected: 1982 - 1998

Flight Season: 25 May - 12 July

Elevation Range: 1399 – 2499 m

Notes: The species looks most like *Arctia lapponica* and *Arctia yarrowi*, but can be easily distinguished from the two by having a reduced forwing pattern.

Arctia plantaginis (Linnaeus, 1758)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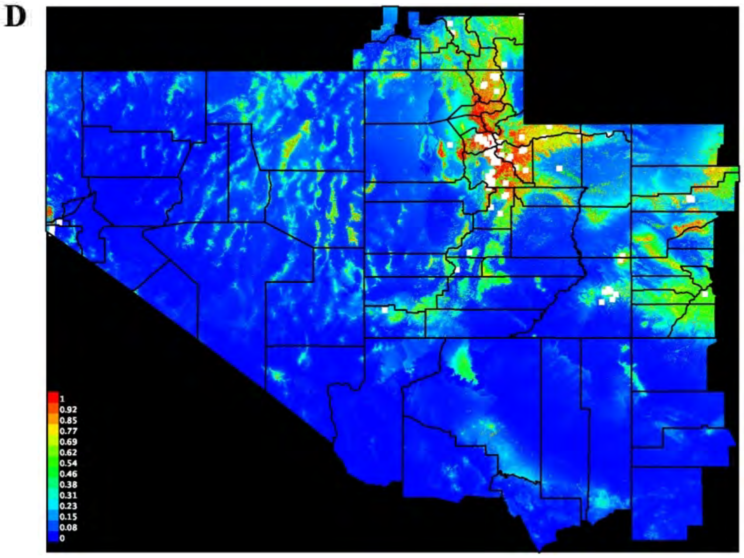


Figure 30. *Arctia plantagenis* A: Specimen images (various forms), B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Garfield and San Juan; IDAHO: Bannock, Bear Lakeand Caribou; NEVADA: Churchill and Douglas; UTAH: Cache, Daggett, Duchesne, Grand, Juab, Millard, Morgan, Piute, Salt Lake, Sanpete, Sevier, Summit, Tooele, Utah, and Wasatch

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Northern Basin Range, Southern Rockies, and Wasatch and Uinta Mountains

Years Collected: 1929 - 2017

Flight Season: 16 April - 30 October

Elevation Range: 416 – 3259 m

Notes: The species is diurnal with a good amount of variation. Forewing patterns are black with white lines and spot patterns with the hindwings varying in colors and patterns. The distribution is most heavily predicted to occur in central/northern Utah along the Wasatch and Uinta Mountainss Level III ecoregion.

Arctia virginalis (Boisduval, 1852)

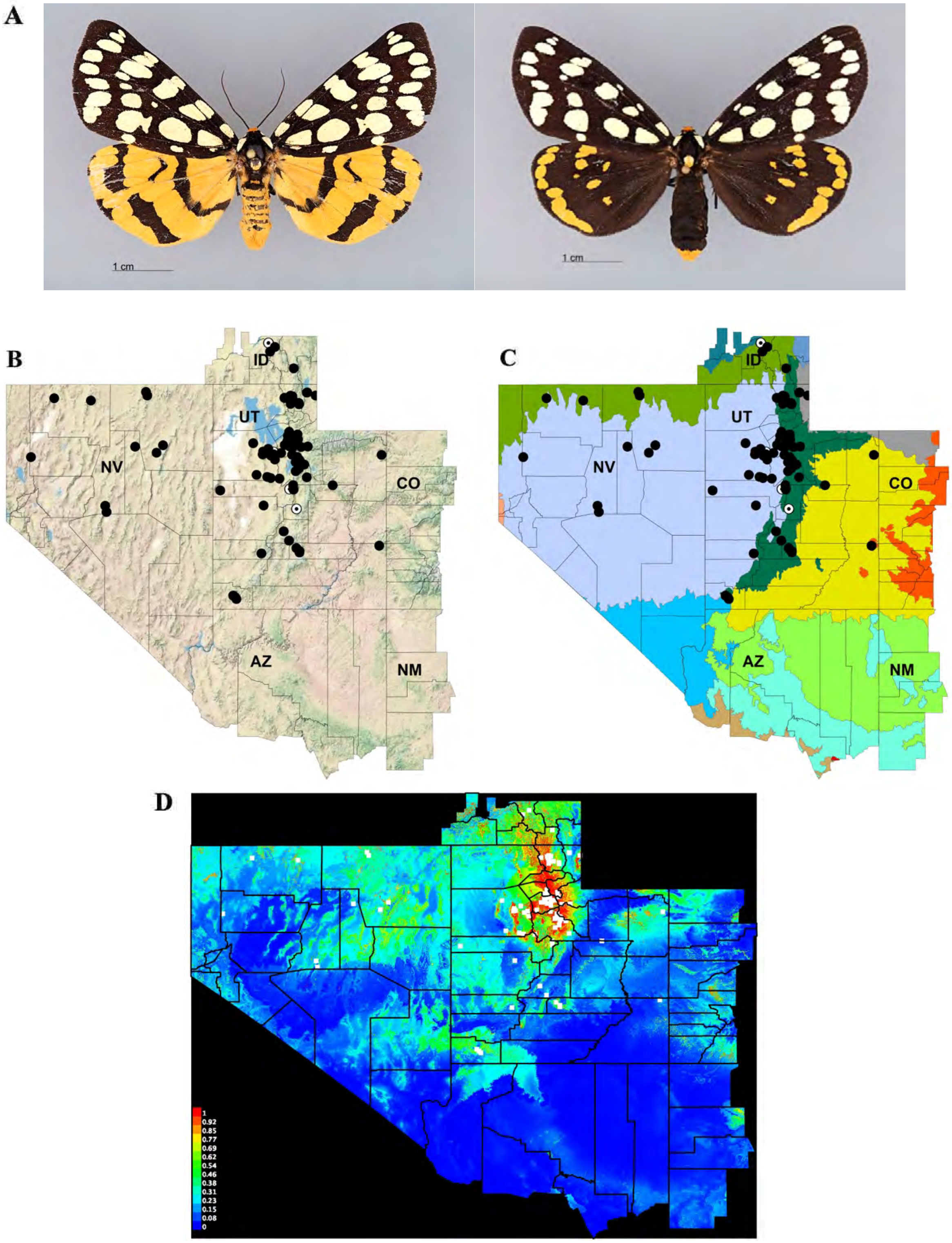


Figure 31. *Arctia virginalis* A: Specimen images (yellow and dark form), B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: IDAHO: Bannock and Franklin; NEVADA: Elko, Eureka, Humboldt, Lander, and Pershing; UTAH: Cache, Carbon, Davis Iron, Juab, Grand, Millard, Morgan, Rich, Salt Lake, Sanpete, Sevier, Summit, Tooele, Uinta, Utah, Uinta, and Utah

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Northern Basin Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1901 - 2015

Flight Season: 20 January, 9 February, 11 April - 4 October

Elevation Range: 976 – 3259 m

Notes: One of the larger species in the area. The moths are diurnal similar to *Arctia plantagenis,* but easily distinguishable. It is easily recognized by having a black forewing with white spots and yellow and black hindwings. The hindwings can be yellow/orange and striped or be majorily black with little color. This species is similar in distribution to *Arctia plantagenis*, but is more heavily predicted into Nevada.

Arctia yarrowi (Stretch, 1873)

A

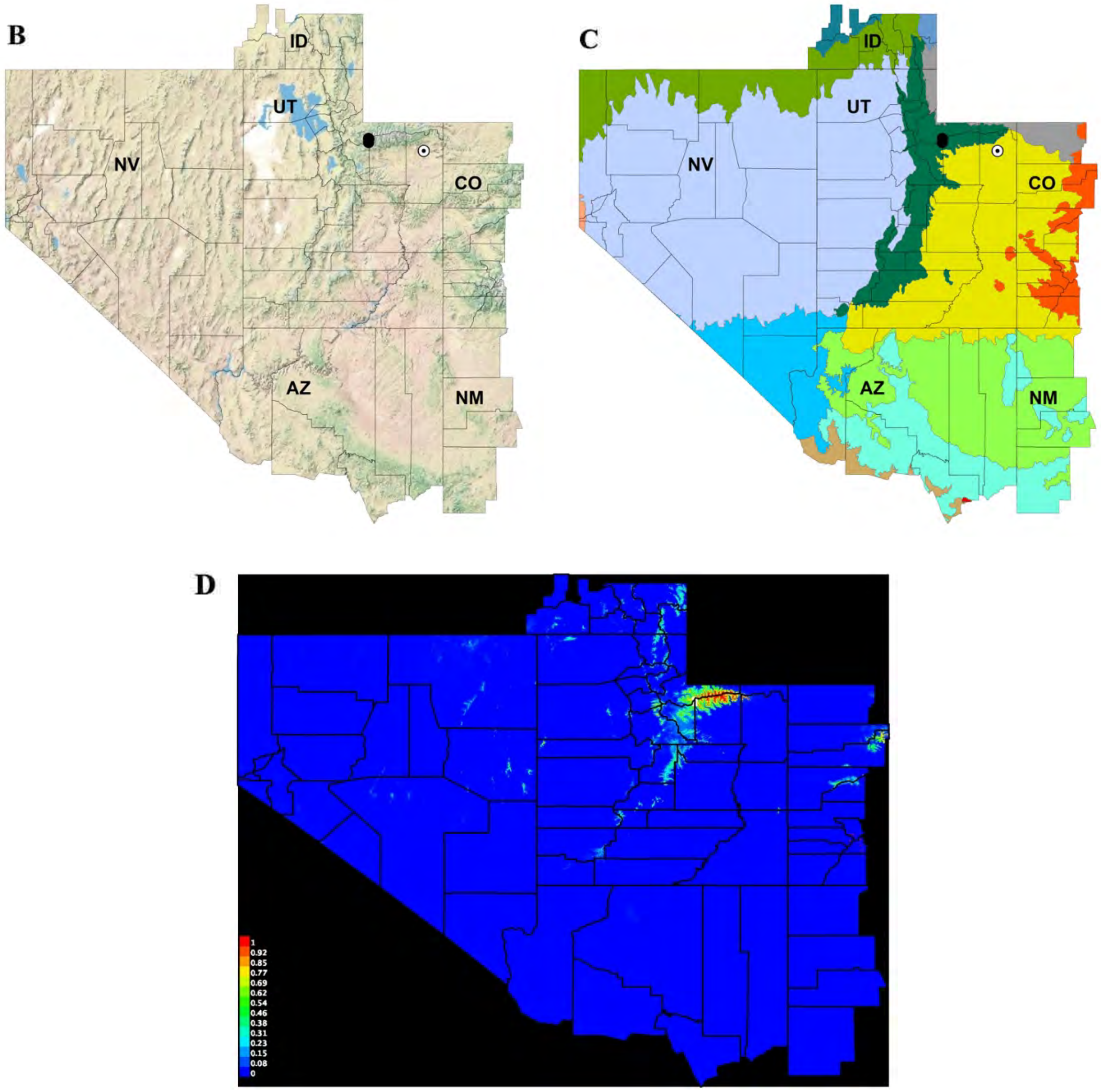


Figure 32. *Arctia yarrowi* A: Specimen images, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Summit and Uintah

Ecoregion Records: Wasatch and Uinta Mountains

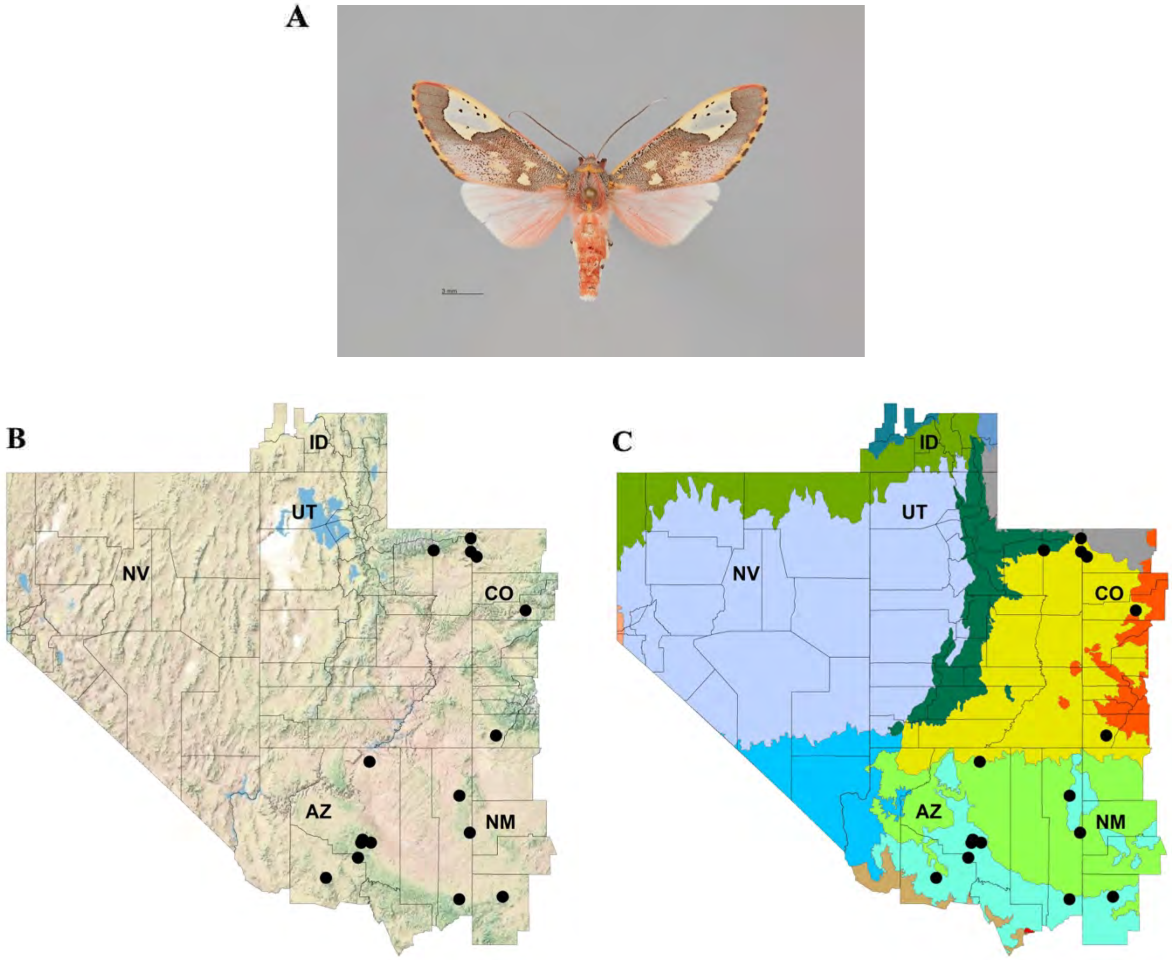
Years Collected: 1933 - 2003

Flight Season: 9 - 24 July

Elevation Range: 1382 – 3558 m

Notes: The species has be found in the north eastern part of Utah. It resemble *Arctia caja,* but can be different by a slightly different forewing and black patched underwing opposed to an orange underwing with iridescent blue spots. The species is most similar to *Arctia lapponica* and taxonomic work is needed to differentiate the two.

Bertholdia trigona (Grote, 1879)



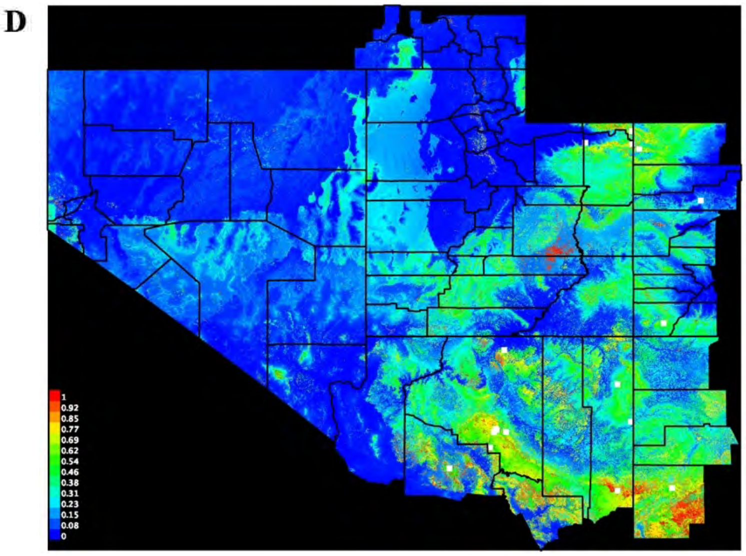


Figure 33. *Bertholdia trigona* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State Records: ARIZONA: Apache, Coconino, and Yavapai; COLORADO: Moffat and Montezuma; NEW MEXICO: Catron; UTAH: Daggett, and Uintah

Ecoregion Records: Arizona/ New Mexico Plateau, Arizona/ New Mexico Mountains, and Colorado Plateaus

Years Collected: 1962 - 2017

Flight Season: 28 June - 9 September

Elevation Range: 1470 – 2285 m

Notes: The species is common in Arizona and northeastern regions of Utah. It is easily recognized by its unique red, gray, and yellow pattern. The moth has red/gray forewings with yellow blotches and a red body. Some have tried to rear the caterpillars on various foods with little success (Powell & Opler 2009).

Bruceia hubbardi (Dyar, 1898)

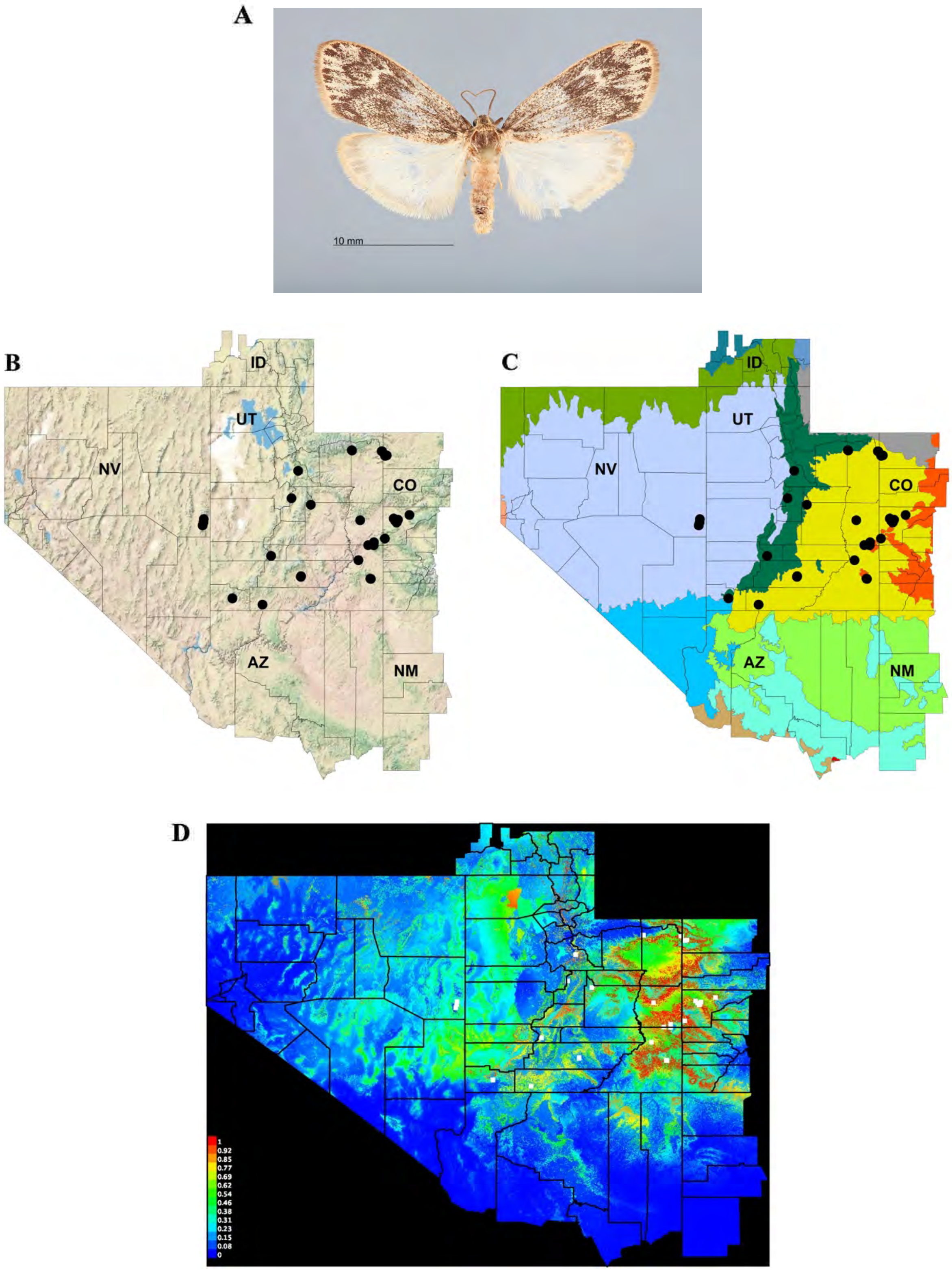


Figure 34. *Bruceia hubbardi* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Mesa and Moffat; NEVADA: White Pine; UTAH: Emery, Garfield, Grand, Kane, Piute, San Juan, Sanpete, Uintah, and Washington

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Southern Rockies, and Wasatch and Uinta Mountains

Years Collected: 1982 - 2014

Flight Season: 9 June - 13 September

Elevation Range: 1513 – 2546 m

Notes: This mottled brown species is one of a few tiger moths that is not aposematically colored. It is very similar to *B. pulverina,* but can be distinguished by the apical margin of the forewing having more of line pattern opposed to *B. pulverina* that has a more random pattern (Robert C. Mower technique). As part of Lithosiini, it is assumed the caterpillars feed on lichen, but the life history the species is unknown (Powell & Opler 2009).

Bruceia pulverina (Neumögen, 1893)

A

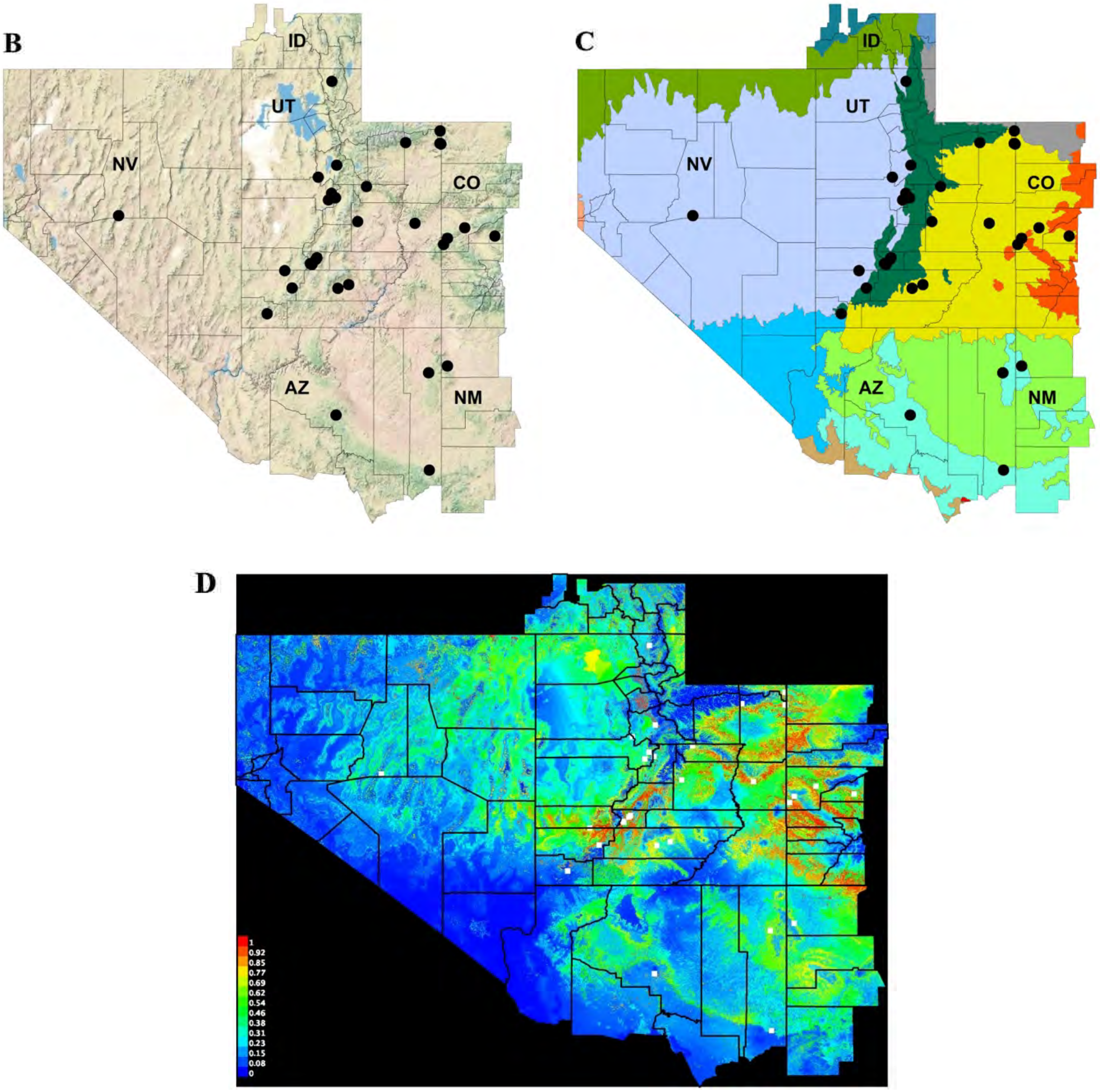


Figure 35. *Bruceia pulverinai* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino; COLORADO: Delta and Mesa; NEVADA: Lander; NEW MEXICO: San Juan; UTAH: Cache, Carbon, Daggett, Delta, Emery, Garfield, Grand, Iron, Juab, Piute, Sanpete, Uinta, Utah, and Washington

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1983 - 2014

Flight Season: 2 July – 17 Aug

Elevation Range: 1513 – 2546 m

Notes: The species is very similar in appearance and range to *Bruceia hubbardi* except it extends further down into Arizona. See 'Notes' of *B. hubbardi* for more information on how to distinguish between the two.

Chelis brucei (Hy. Edwards, 1888)

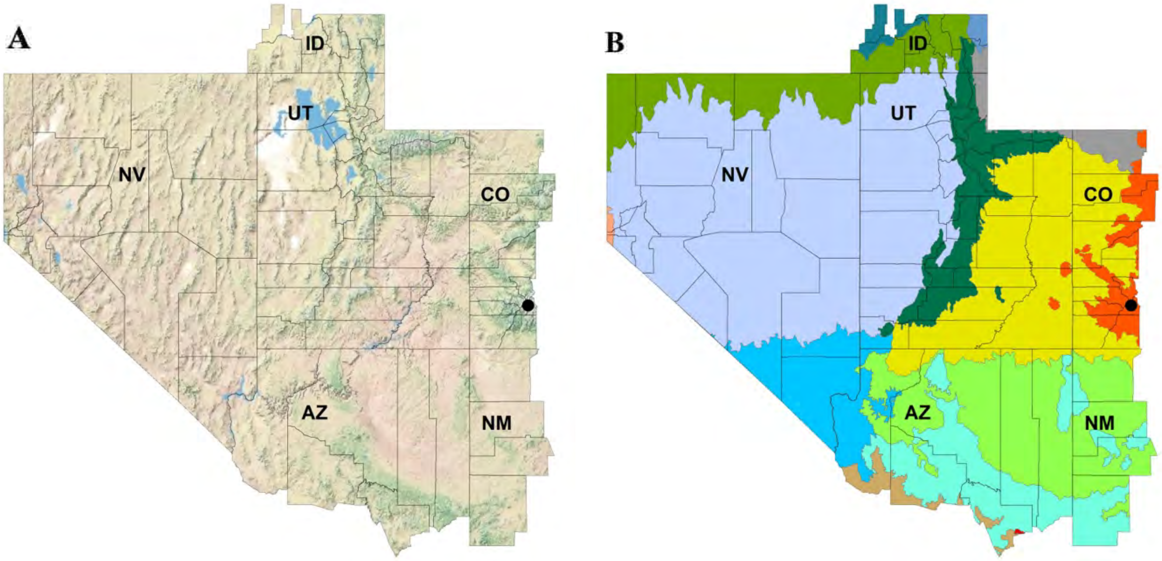


Figure 36. *Chelis brucei* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences

State and County Records: COLORADO: San Juan

Ecoregion Records: Southern Rockies

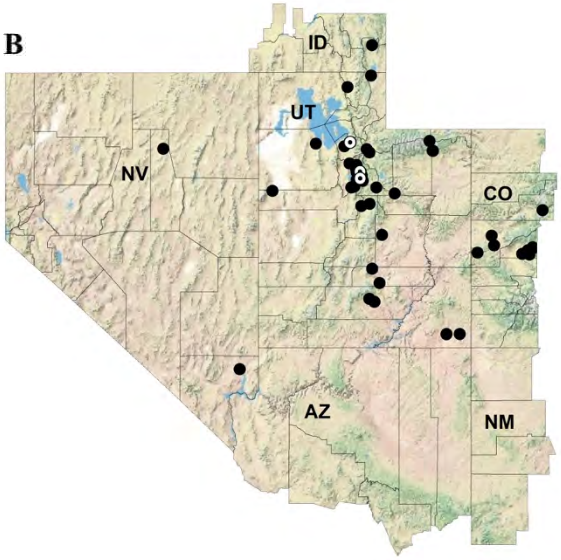
Years Collected: 2003

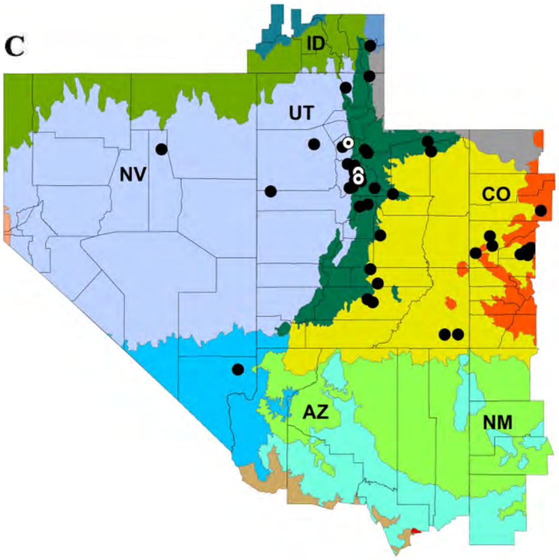
Flight Season: 10 August

Elevation Range: 1391 m

Notes: One record was found in southwestern Colorado. Limited with one record, we did not conduct a ENM analysis.

Cisseps fulvicollis (Hübner, 1818)





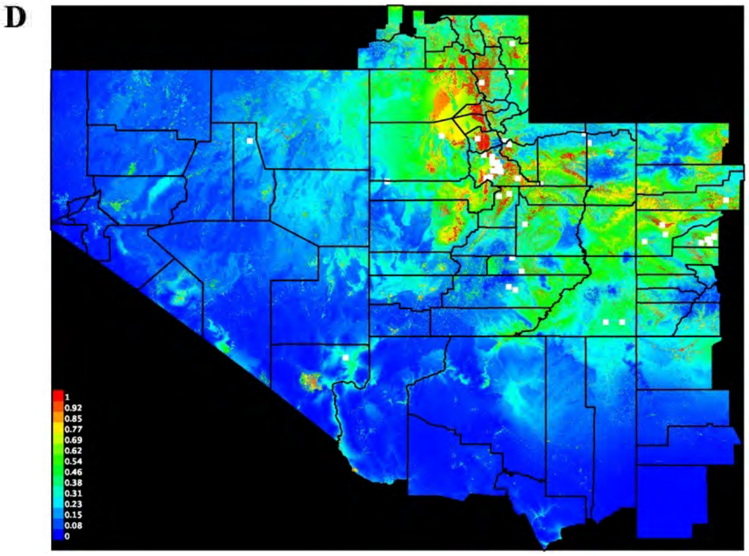


Figure 37. *Cisseps fulvicollis* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State Records: COLORADO: Delta, Garfield, Mesa, and San Juan; IDAHO: Bear Lake; NEVADA: Clark and Eureka; UTAH: Cache, Duchesne Emery, Garfield, Juab, Rich, Salt Lake, San Juan, Sanpete, Tooele, Uintah, Utah, Wasatch, and Wayne

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Middle Rockies, and Southern Rockies, Mojave Basin and Range, and Wasatch and Uinta Mountains

Years Collected: 1922 - 2017

Flight Season: 11 May - 20 September

Elevation Range: 689 – 3220 m

Notes: The moth has a wasp-like appearance and flight (Powell & Opler 2009). It has a "yellow orange collar" near its head with dull black forewings and a glossy black/blue abdomen and hindwing (Powell & Opler 2009). The hindwings also contain large portions that are white.

Cisthene angelus (Dyar, 1904)

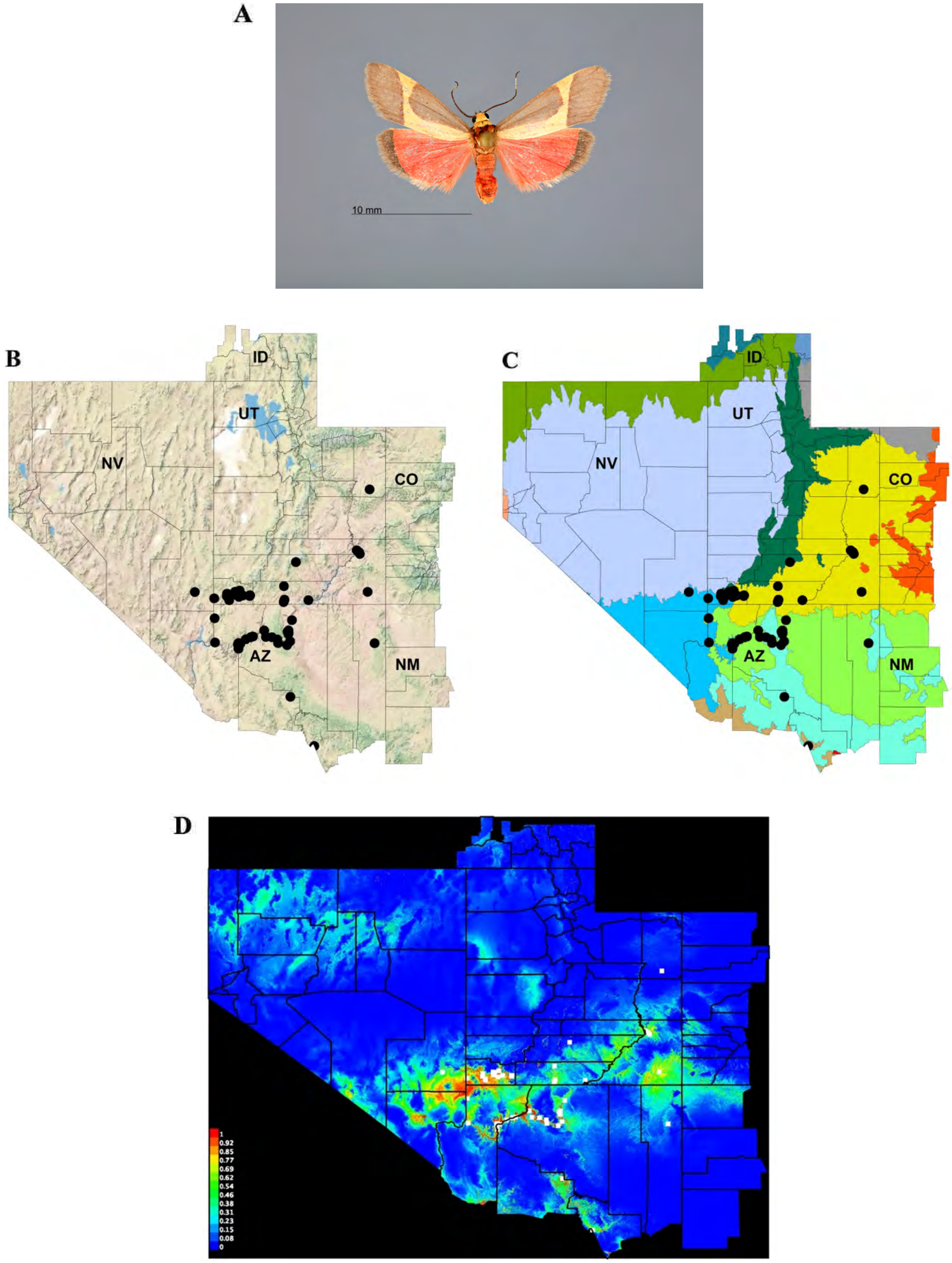


Figure 38. *Cisthene angelus* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Gila, and Mohave; NEVADA: Lincoln; UTAH: Grand, Kane, San Juan, and Washington

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateau, Sonoran Basin Range, and Wasatch and Uinta Mountains

Years Collected: 1964 - 2018

Flight Season: 14 April - June 27 and 27 August - 27 September

Elevation Range: 472 – 2603 m

Notes: The species is one of two *Cisthene* species that occurs within the state of Utah. The species is easily identified by thick yellow forewing bands. Little is published on the species. (Metcalfe 2016) investigated the species in the Grand Canyon and found it to be bivoltine as we did. They also quantified correlation between wing plasticity and elevation. They proposed food availability at the different elevations as the potential reason for the differences in adults though the host work is very limited. This is why we investigated the lichen feeding behavior of this species further in Chapter 3. The species also has an interesting distributional relationship with *C. barnesii* where the populations of the two species appear to be more or less allopatric.

Cisthene barnesii (Dyar, 1904)

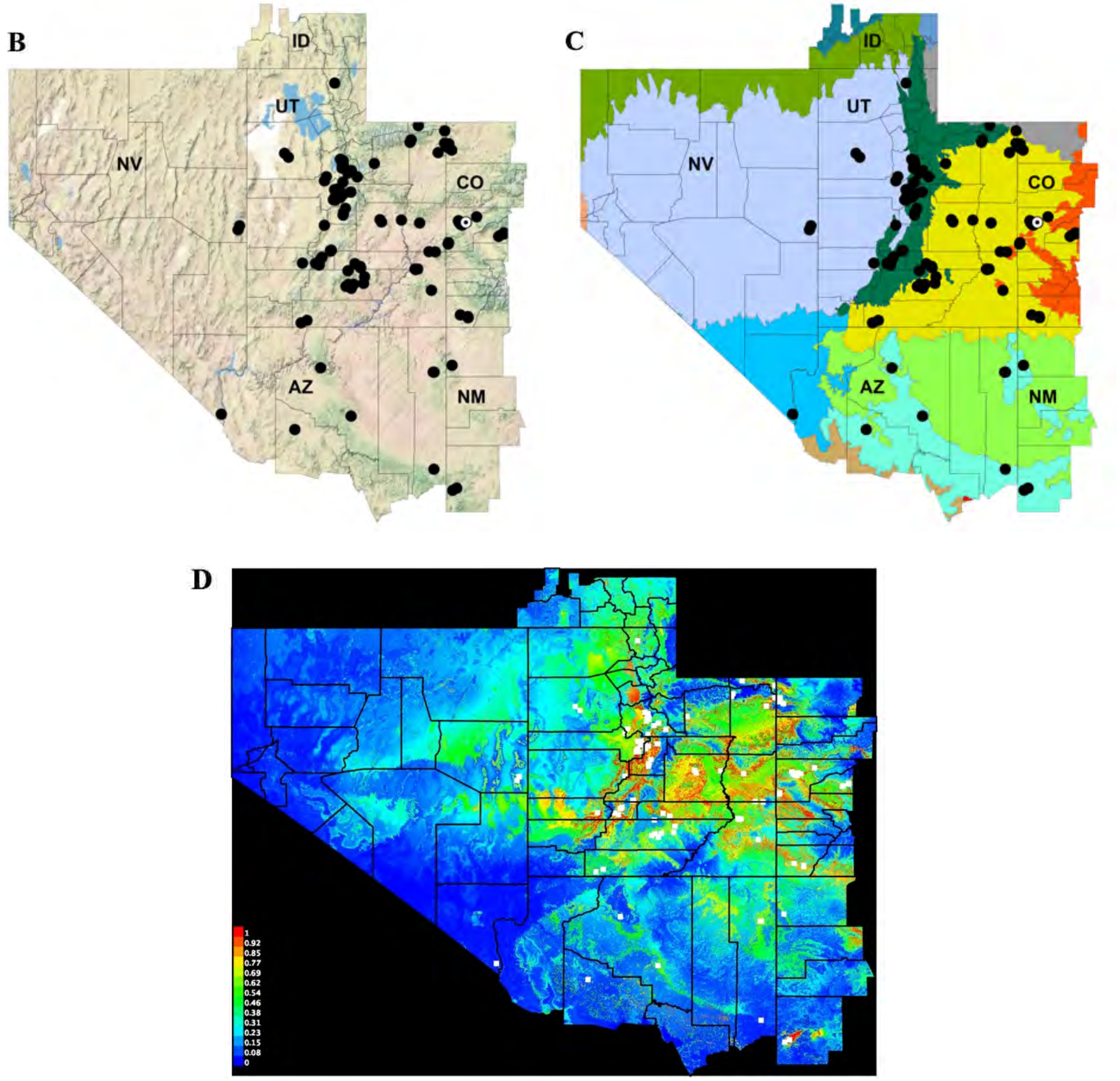


Figure 39. *Cisthene barnesii* A: Specimen image (pink and yellow forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, and Yavapai; COLORADO: Delta, Mesa Moffat, and Montezuma; NEVADA: White Pine; NEW MEXICO: Catron and San Juan; UTAH: Beaver, Cache, Daggett, Duchesne, Emery, Garfield, Grand, Juab, Kane, Millard, Piute, San Juan, Sanpete, Sevier, Tooele, Uintah, Utah, and Wayne, Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Southern Rockies, Mojave Basin and Range, Wasatch and Uinta Mountains

Years Collected: 1925 - 2017

Flight Season: 15 June - 24 September

Elevation Range: 1300 – 3008 m

Notes: The species is the other of the two *Cisthene* found in Utah, though it can be found everywhere and has a much wider distribution than *Cisthene angelus.* The species has not been heavily investigated by researchers. The species also has varying color morphs and can be both pink and yellow.

Cisthene juanita (Barnes & Benjamin, 1925)

A

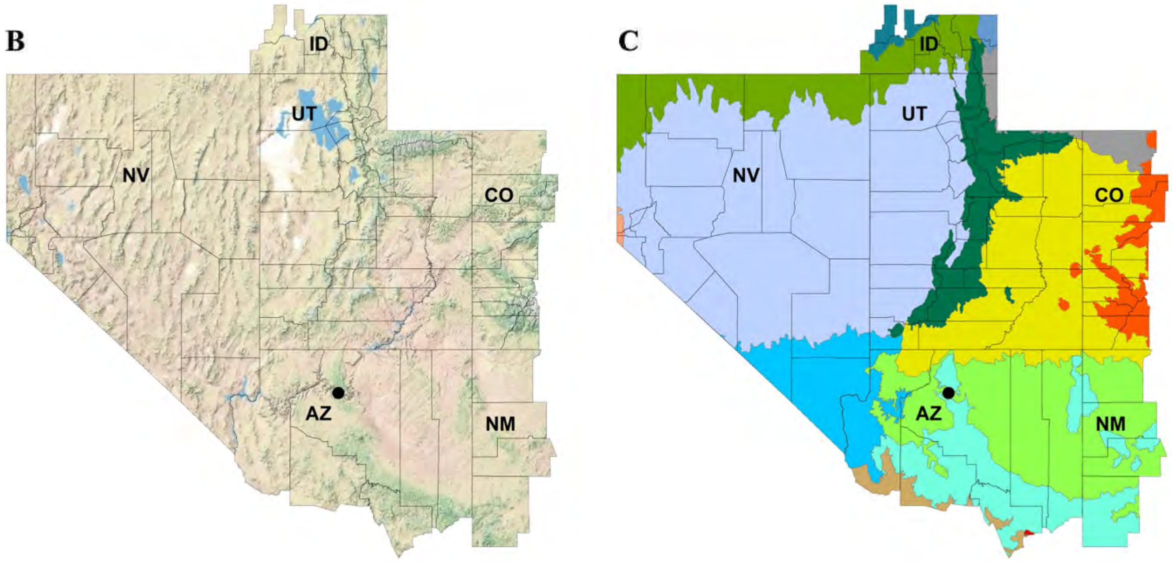


Figure 40. *Cisthene juanita* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Plateau

Years Collected: 2003

Flight Season: 24 August

Elevation Range: 2104 m

Notes: This species is distinguished by its forewring being mostly black and flight time from August to October (Powell & Opler 2009). Limited with one record, we did not conduct a ENM analysis.

Cisthene tenuifascia (Harvey, 1875)

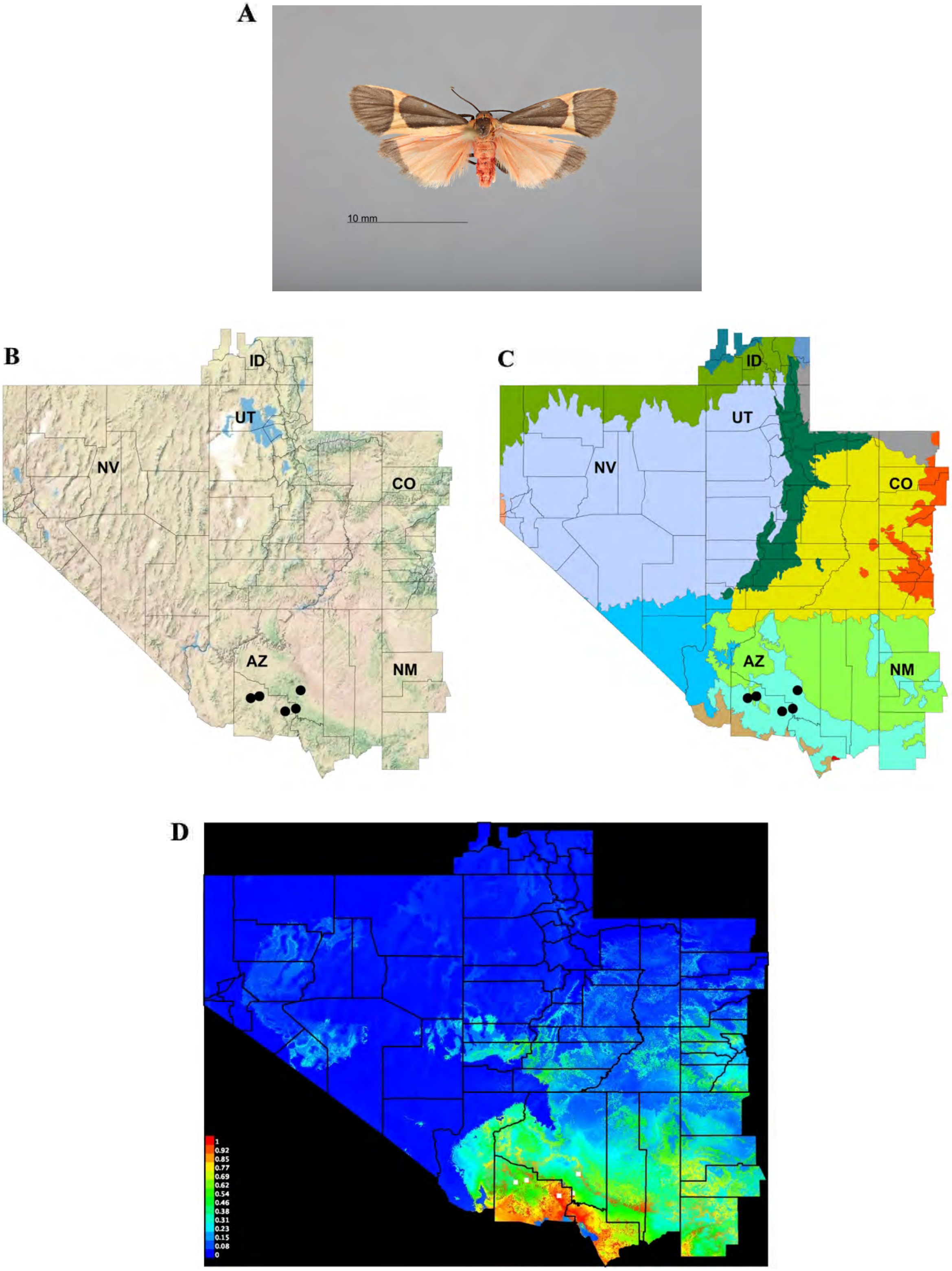


Figure 41. *Cisthene tenuifascia* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino and Yavapai

Ecoregion Records: Arizona/ New Mexico Mountains and Arizona/ New Mexico Plateau

Years Collected: 1993, 2004, 2006, and 2007

Flight Season: 8 - 11 June and 9 - 27 September

Elevation Range: 992 – 2785 m

Notes: The species is known to occur in southern Arizona (Powell & Opler 2009). We found several specimens in northern Arizona. The species is difficult to distinguish between other *Cisthene* species in Arizona and could use some taxonomic attention.

Crambidia casta (Packard, 1869)

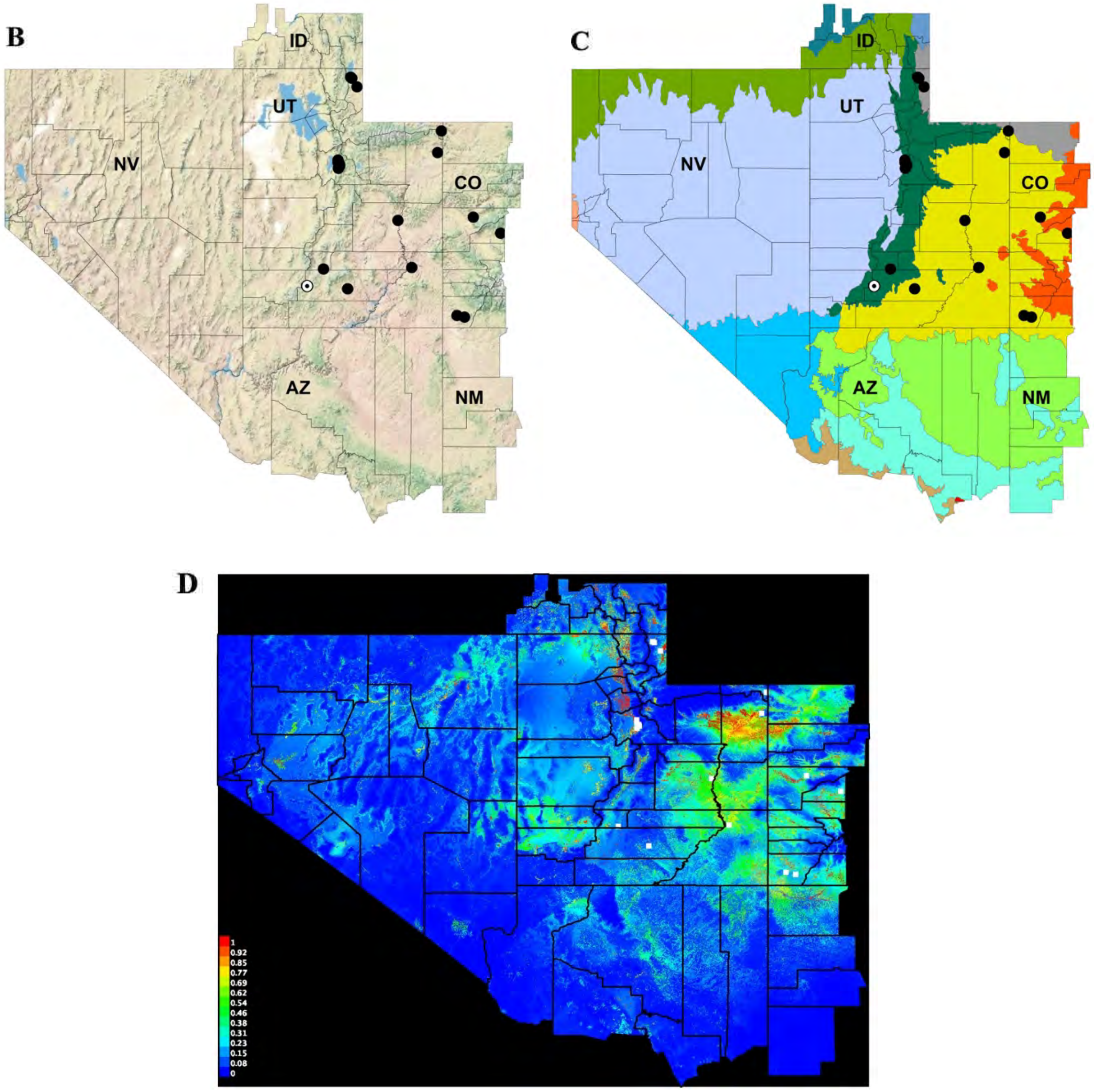


Figure 42. *Crambidia casta* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta, Mesa, and Montezuma; UTAH: Daggett, Garfield, Grand, Piute, Rich, San Juan, Uintah, and Utah

Ecoregion Records: Colorado Plateaus, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

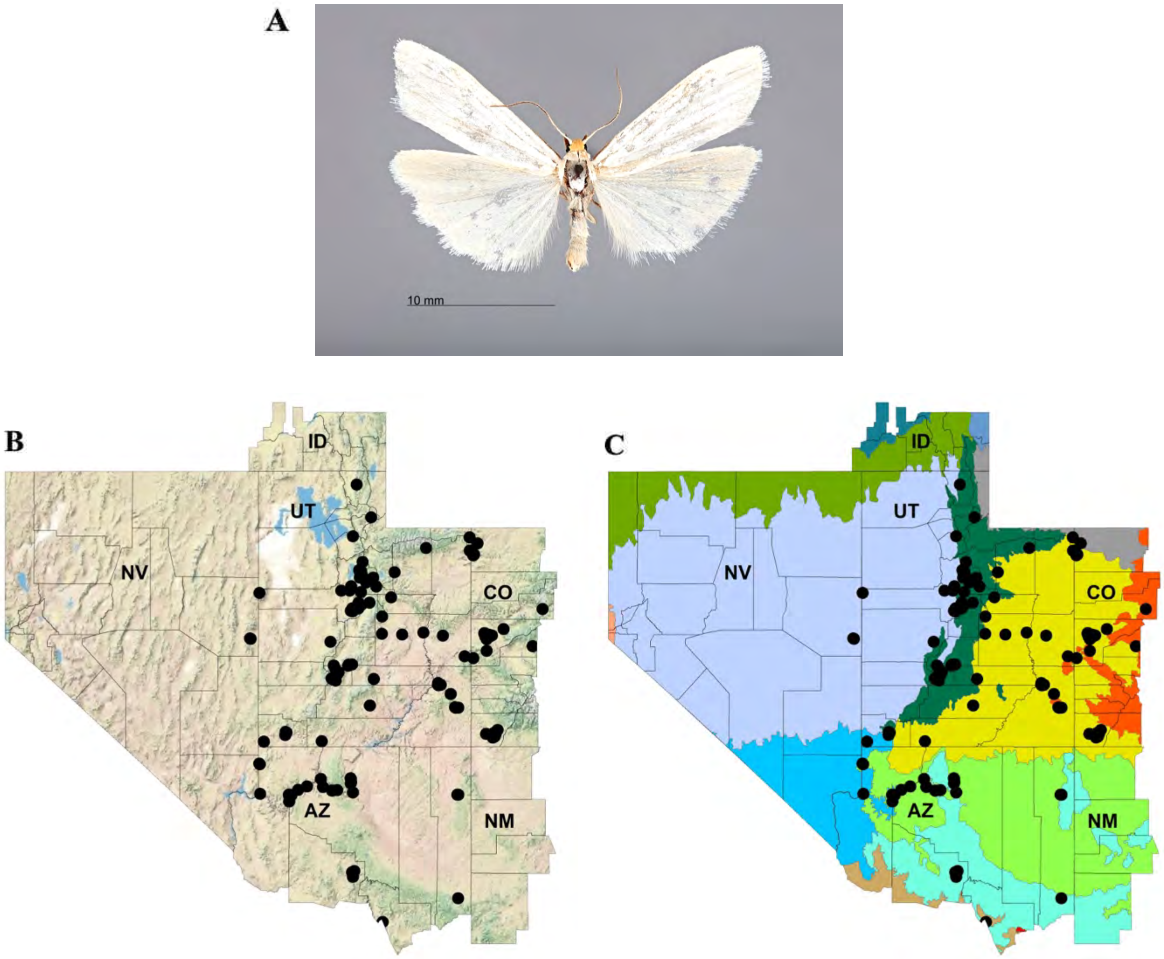
Years Collected: 1925 - 2003

Flight Season: 5 July - 4 September

Elevation Range: 1370 – 2178 m

Notes: The species is one of a few *Crambidia* species in the area. It can be distinguished by having more shiny or glossy wings and no orange on the head like *Crambidia cephalica* (Powell & Opler 2009).

Crambidia cephalica (Grote & Robinson, 1870)



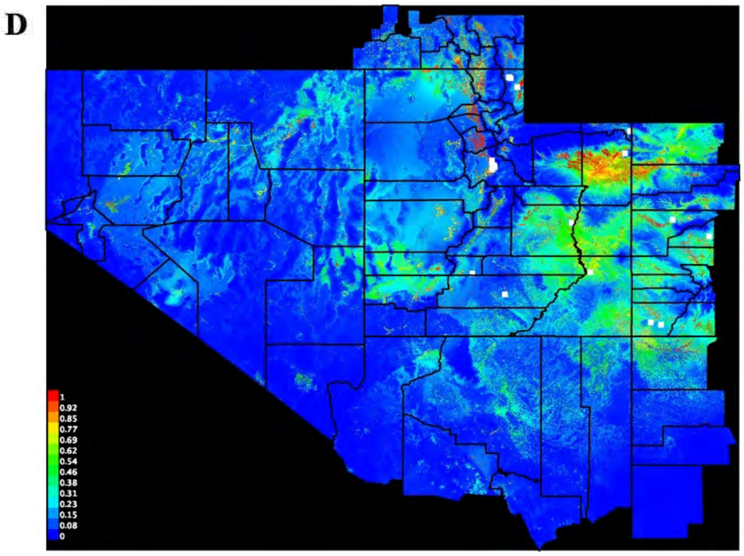


Figure 43. *Crambidia cephalica* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Gila, Mohave, and Yavapai; COLORADO: Delta, Garfield, Mesa, Moffat, and Montezuma; NEVADA: White Pine; UTAH: Cache, Carbon, Daggett, Duchesne, Emery, Garfield, Grand, Juab, Kane, Millard, Piute, San Juan, Sanpete, Sevier, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateau, Mojave Basin and Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1925 - 2017

Flight Season: 4 May - 12 October

Elevation Range: 453 – 3735 m

Notes: The species can be distinguished from other *Crambidia* by having an orange/yellow patch on its vertex (Powell & Opler 2009). The species occurs throughout eastern Utah, western Colorado, and into Arizona. Both males and females can be quite abundant at lights (personal observation).

Crambidia impura (Barnes & McDunnough, 1913)

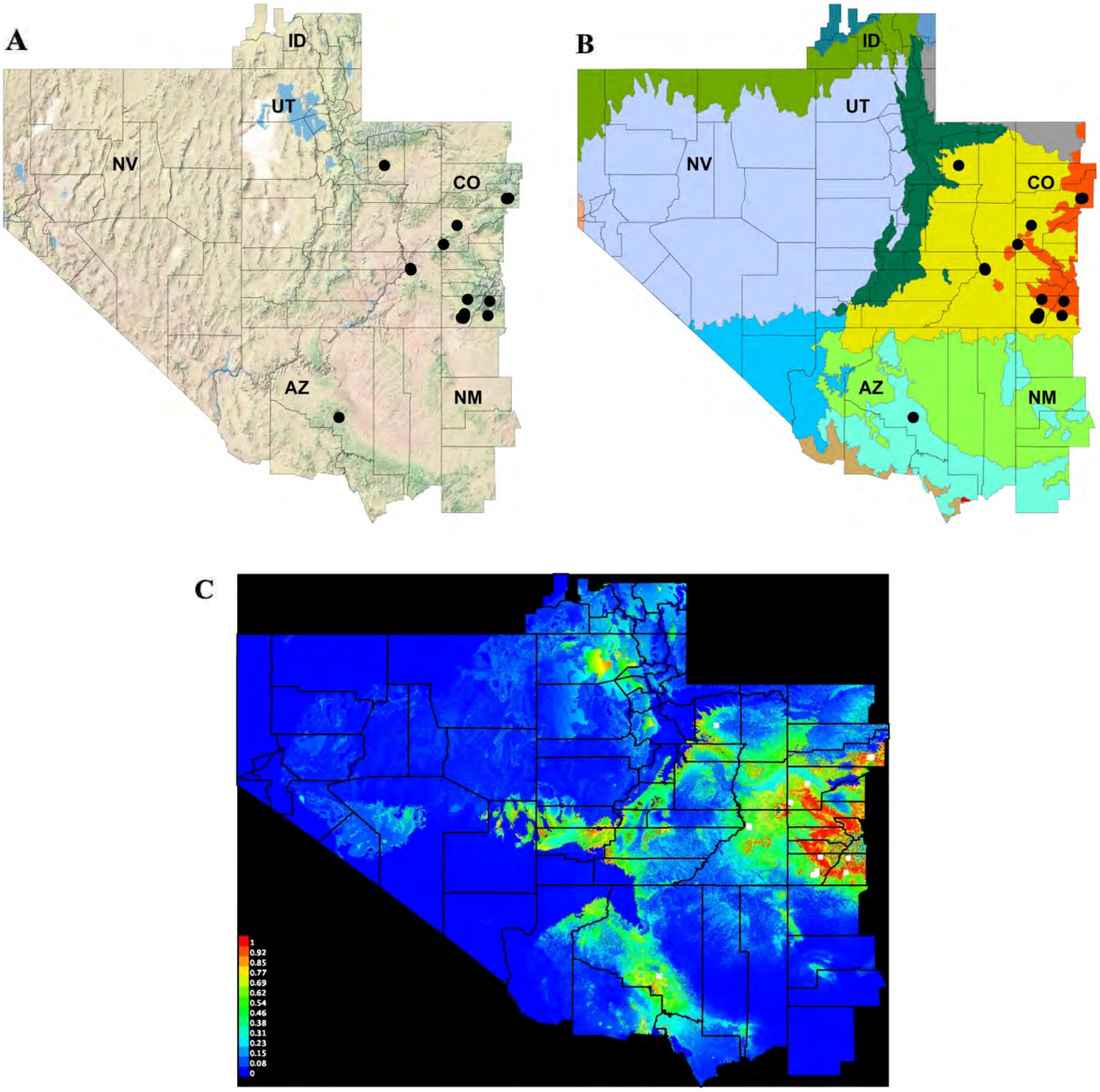


Figure 44. *Crambidia impura* A: Topographic map of documented occurrences, B: Level III ecoregion map of documented occurrences and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino; COLORADO: Garfield, La Plata, Mesa, and Montezuma; UTAH: Duchesne, San Juan, Juab, Uintah, and Utah

Ecoregions: Arizona/ New Mexico Mountains, Colorado Plateaus, and Southern Rockies

Years Collected: 1984 - 2017

Flight Season: 17 June - 1 October

Elevation Range: 1519 – 2943 m

Notes: The species are similar to other *Crambidia* though they tend to be a more “dirty” white.

Ctenucha cressonana (Grote, 1863)

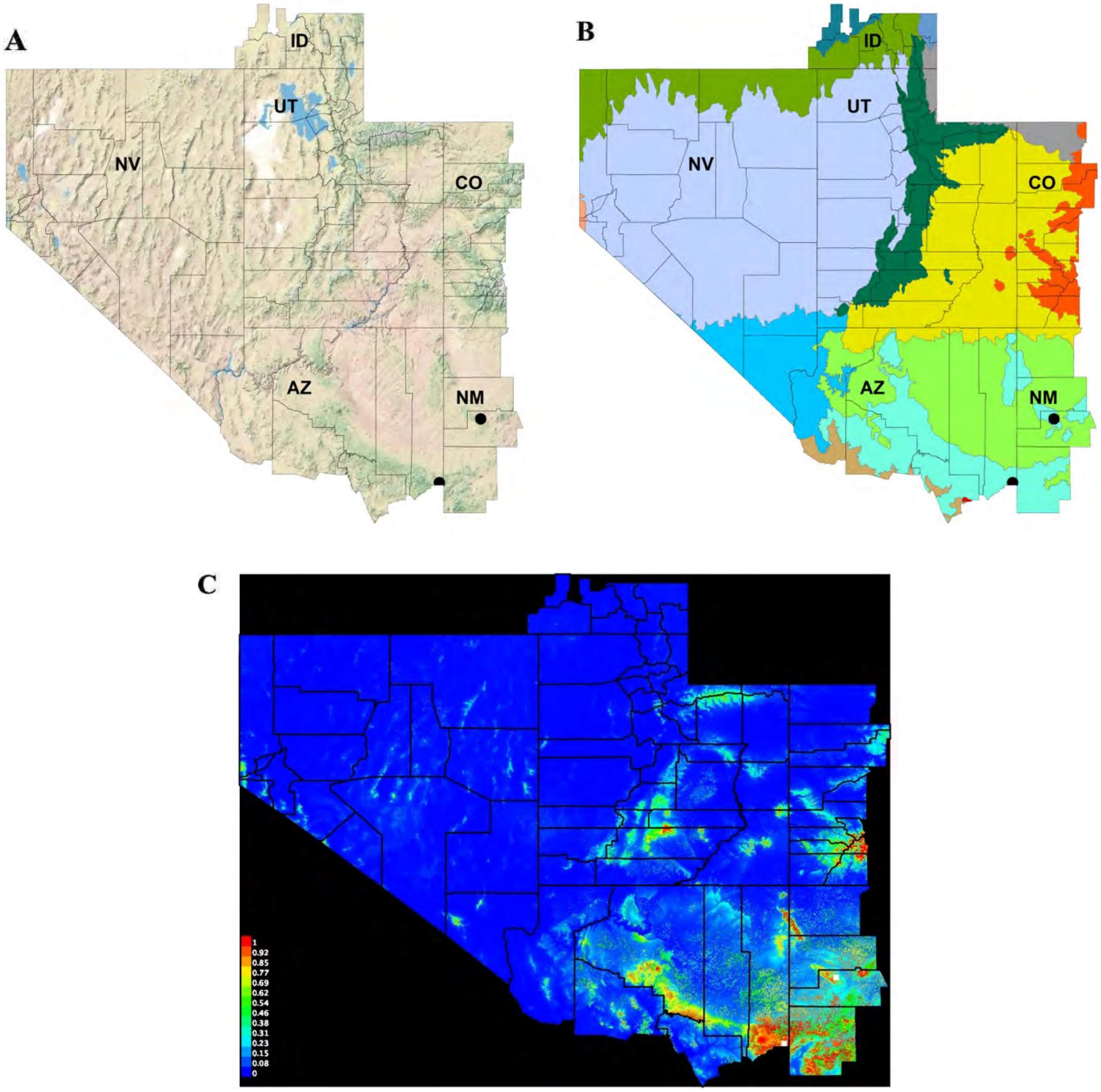


Figure 45. *Ctenucha cressonana* A: Topographic map of documented occurrences, B: Level III ecoregion map of documented occurrences, and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache; NEW MEXICO: Cibola

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1977 and 2005

Flight Season: 30 July - 1 August

Elevation Range: 2441 – 2651 m

Notes: The species is rarely collected in the Intermountain West and occurs only in a few locations in our New Mexico regions.

Ctenucha rubroscopus (Ménétriés, 1857)

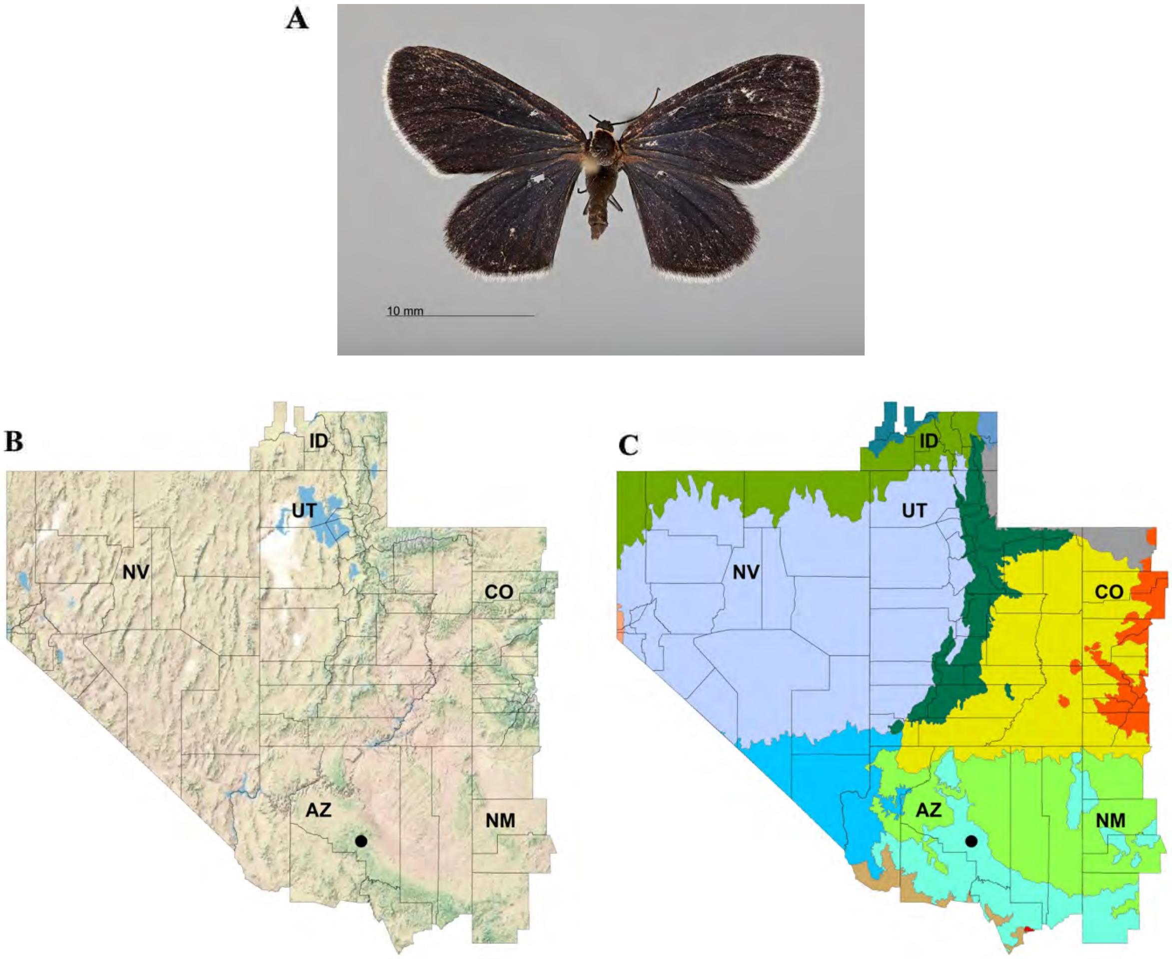


Figure 46. *Ctenucha rubroscopus* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Mountains

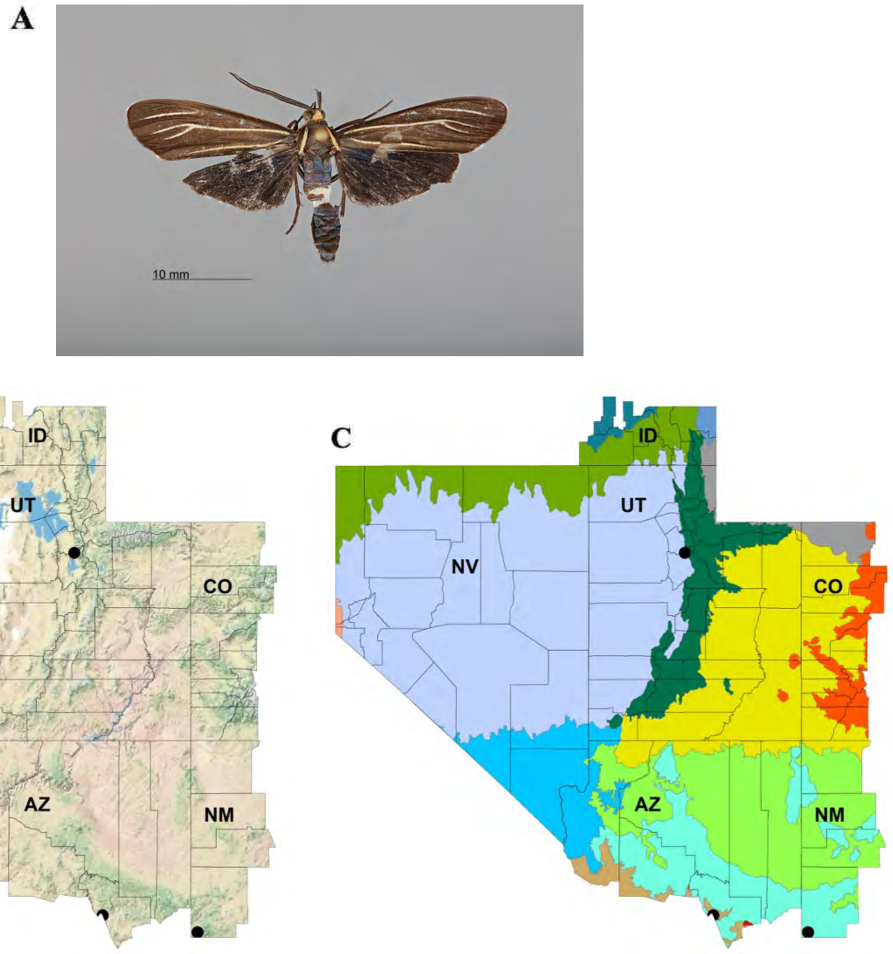
Years Collected: 2000

Flight Season: 14 - 15 July

Elevation Range: 762 – 860 m

Notes: The species is a coastal species known from Washington to California (Powell & Opler 2009). To find one in Arizona is peculiar. The species has some white patches on the outer margin, red lines on the thorax, and red head though the image depicts a worn specimen. Limited with one record, we did not conduct an ENM analysis.

Ctenucha venosa (Walker, 1854)



D

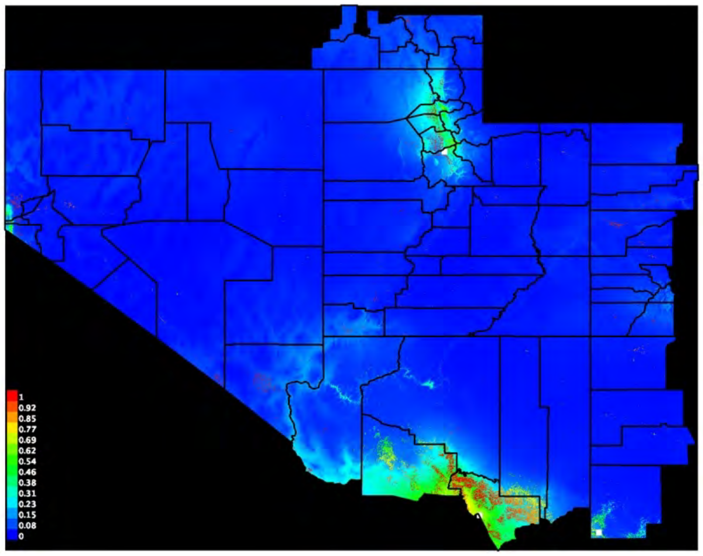


Figure 47. *Ctenucha venosa* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Gila; NEW MEXICO: Catron; UTAH: Utah

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, and Sonoran Basin Range

Years Collected: 1966, 1993, and 1999

Flight Season: 31 July, 3 September, and 15 October

Elevation Range: 1402 – 1509 m

Notes: The species is very colorful with a red head, iridescent blue body, and yellow lines across the forewings and thorax. The species is documented only a few times in the study area.

Cycnia oregonensis (Hübner, 1818)

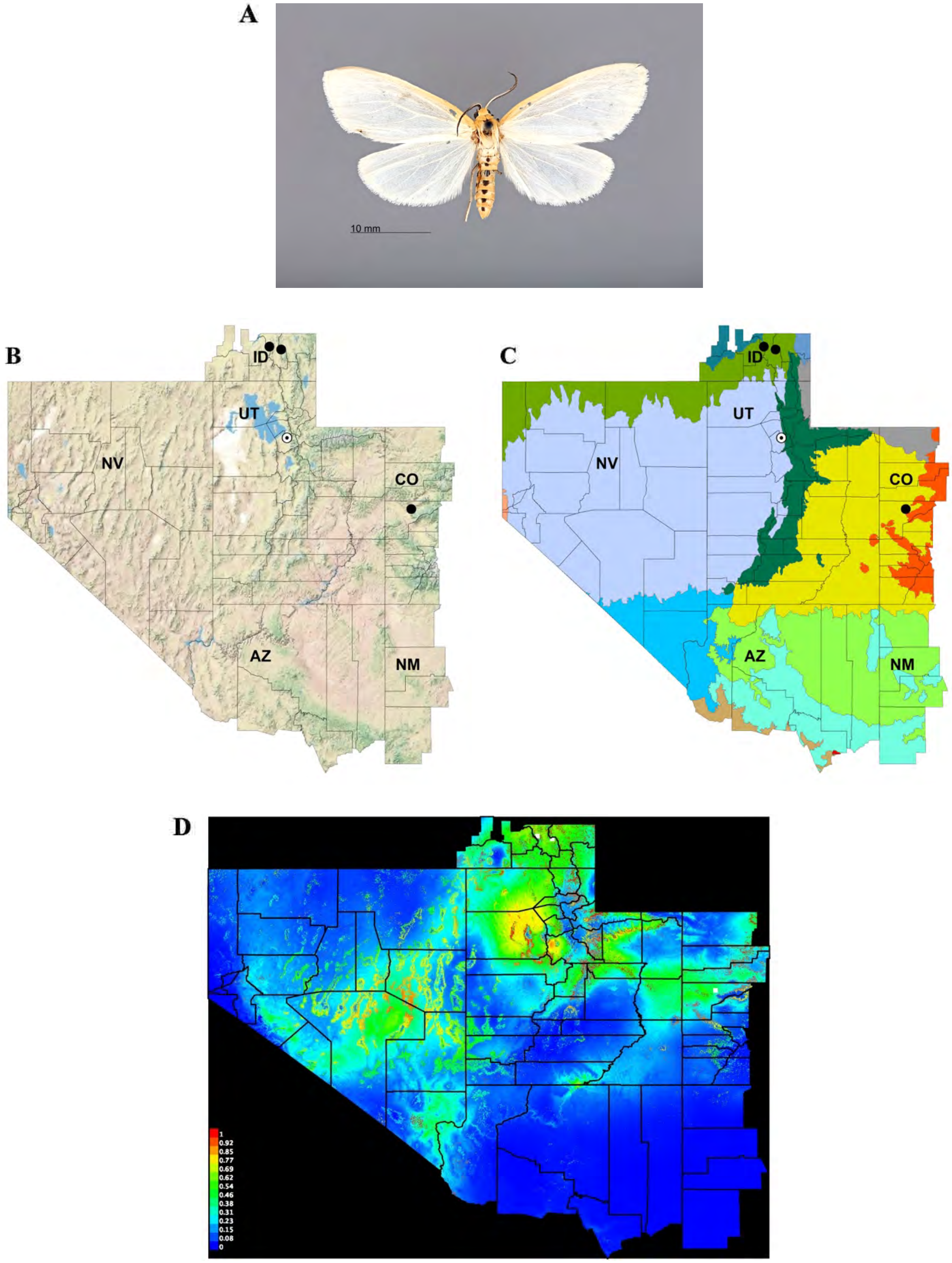


Figure 48. *Cycnia oregonensis* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Mesa; IDAHO: Bannock and Power; UTAH: Salt Lake

Ecoregion Records: Northern Basin Range

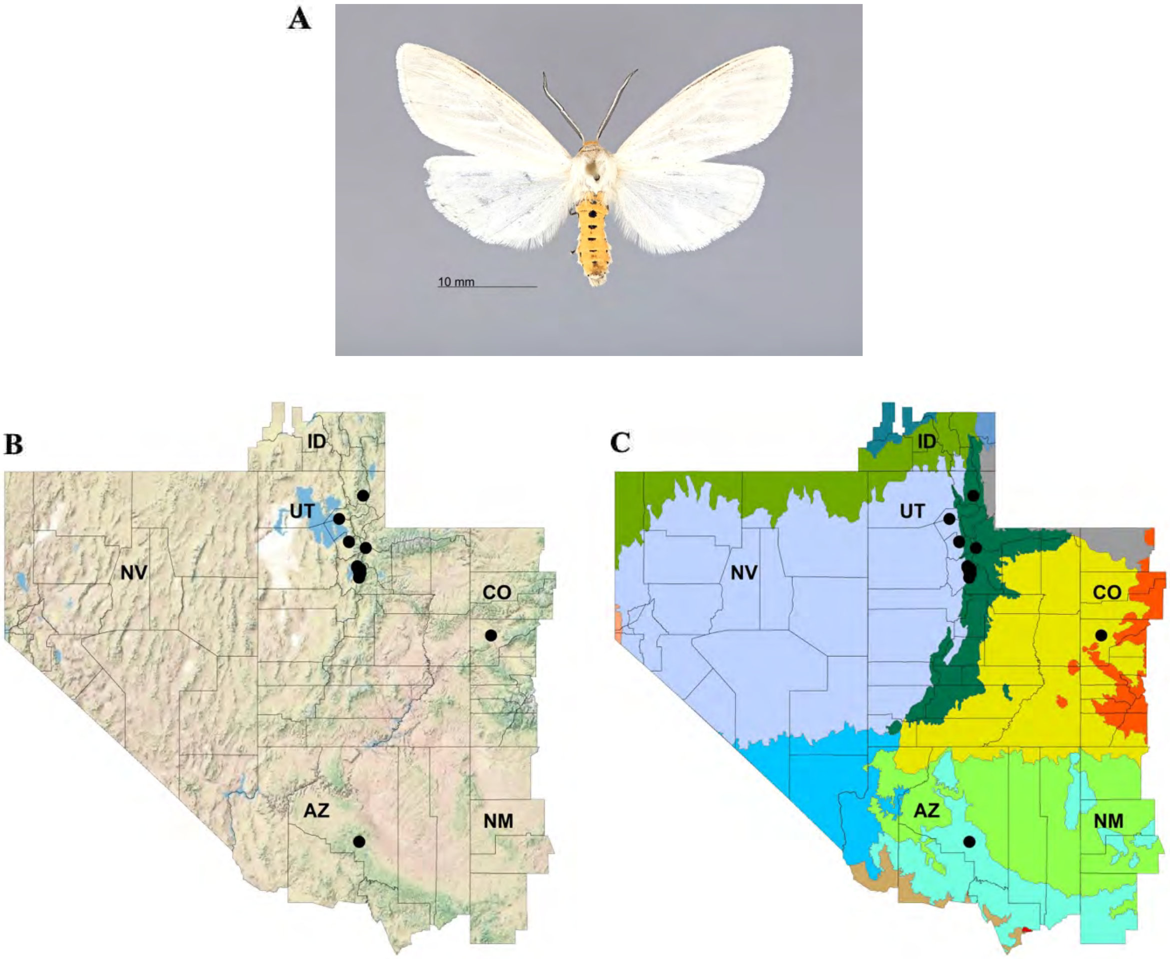
Years Collected: 1961, 1988, 1995, and 1997

Flight Season: 28 May - 10 July

Elevation Range: 1303 – 1768 m

Notes: The species is similar to *Cycnia tenera*, but less abundant. See 'Notes' of *Cycnia tenera* for more details on distinguishing the two species.

Cycnia tenera (Stretch, 1874)



D

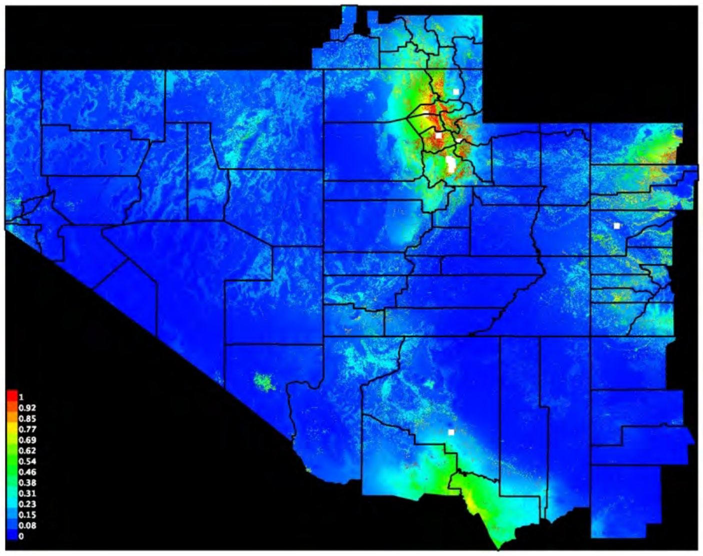


Figure 49. *Cycnia tenera* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino; COLORADA: Mesa; UTAH: Cache, Salt Lake, Utah, and Weber

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateaus, and Wasatch and Uinta Mountains

Years Collected: 1937 - 2016

Flight Season: 10 May - 11 September

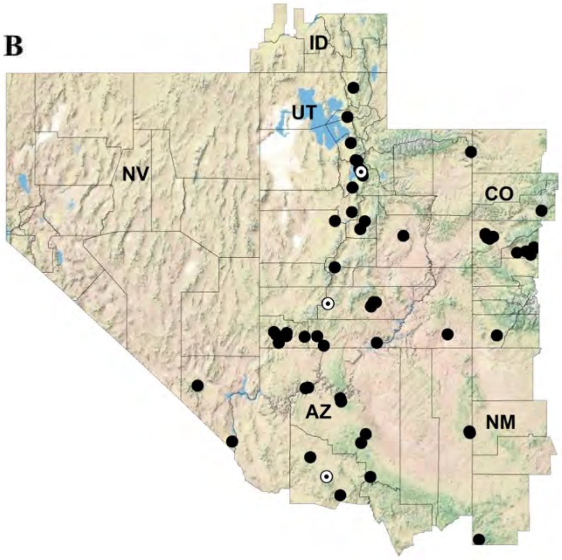
Elevation Range: 1304 – 2865 m

Notes: The species has a similar distribution to *Cycnia oregonensis,* but is more abundant. It is found similarly in Utah, but also in Colorado and Arizona. The species is similar in appearance to *Cycnia oregonensis* and can be distinguished by its yellow costal margin on the forewings (Powell & Opler 2009).

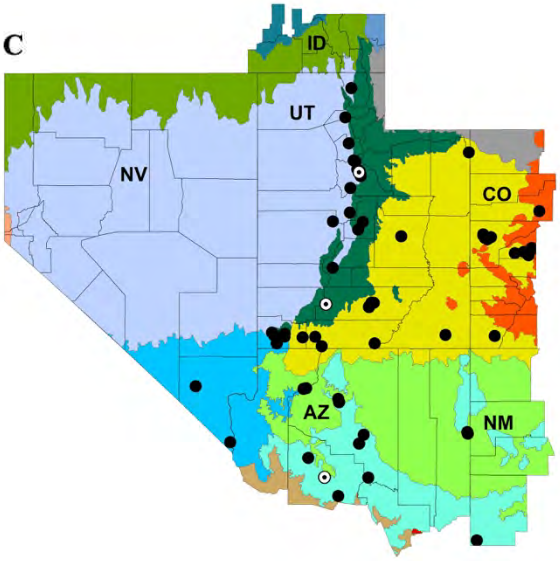
Ectypia clio (Packard, 1864)

A

B



C



D

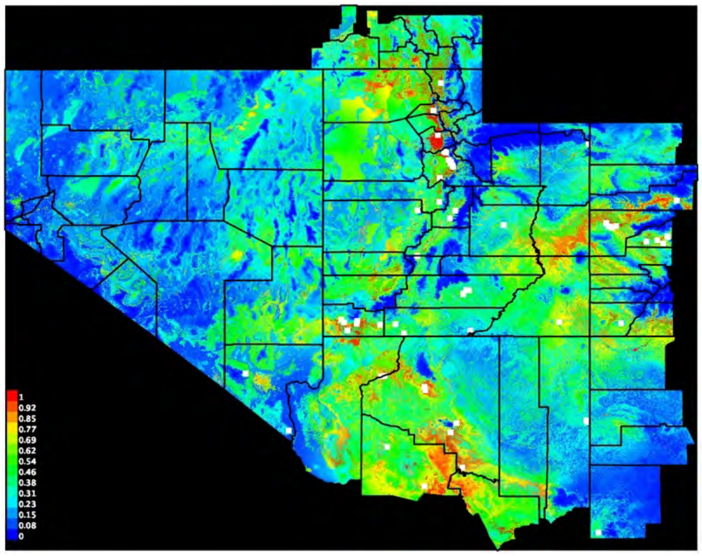


Figure 50. *Ectypia clio* A: Specimen image (light and dark forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Mohave, and Yavapai; COLORADO: Delta, Garfield, Mesa, and Montezuma; NEVADA: Clark; NEW MEXICO: Catron; UTAH: Cache, Emery, Garfield, Juab, Kane, Millard, Salt Lake, San Juan, Sanpete, Sevier, Utah, Washington, and Weber

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, and Wasatch and Uinta Mountains

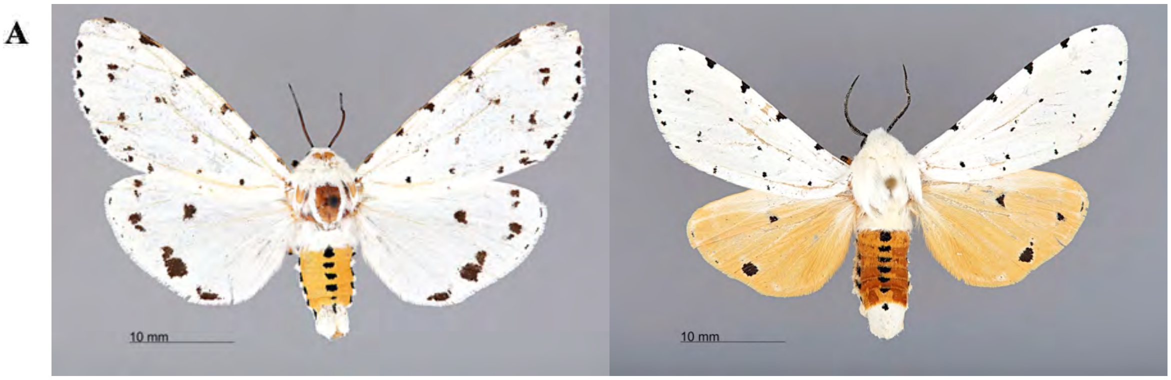
Years Collected: 1937 - 2013

Flight Season: 8 April - 20 September

Elevation Range: 479 – 2165 m

Notes: The species is wide spread through the Intermountain West. It has white forewings with black lateral lines and can have either a completely white underwing or an extensive amount of black. The species life history is unknown (Powell and Opler 2009).

Estigmene acrea (Drury, 1773)



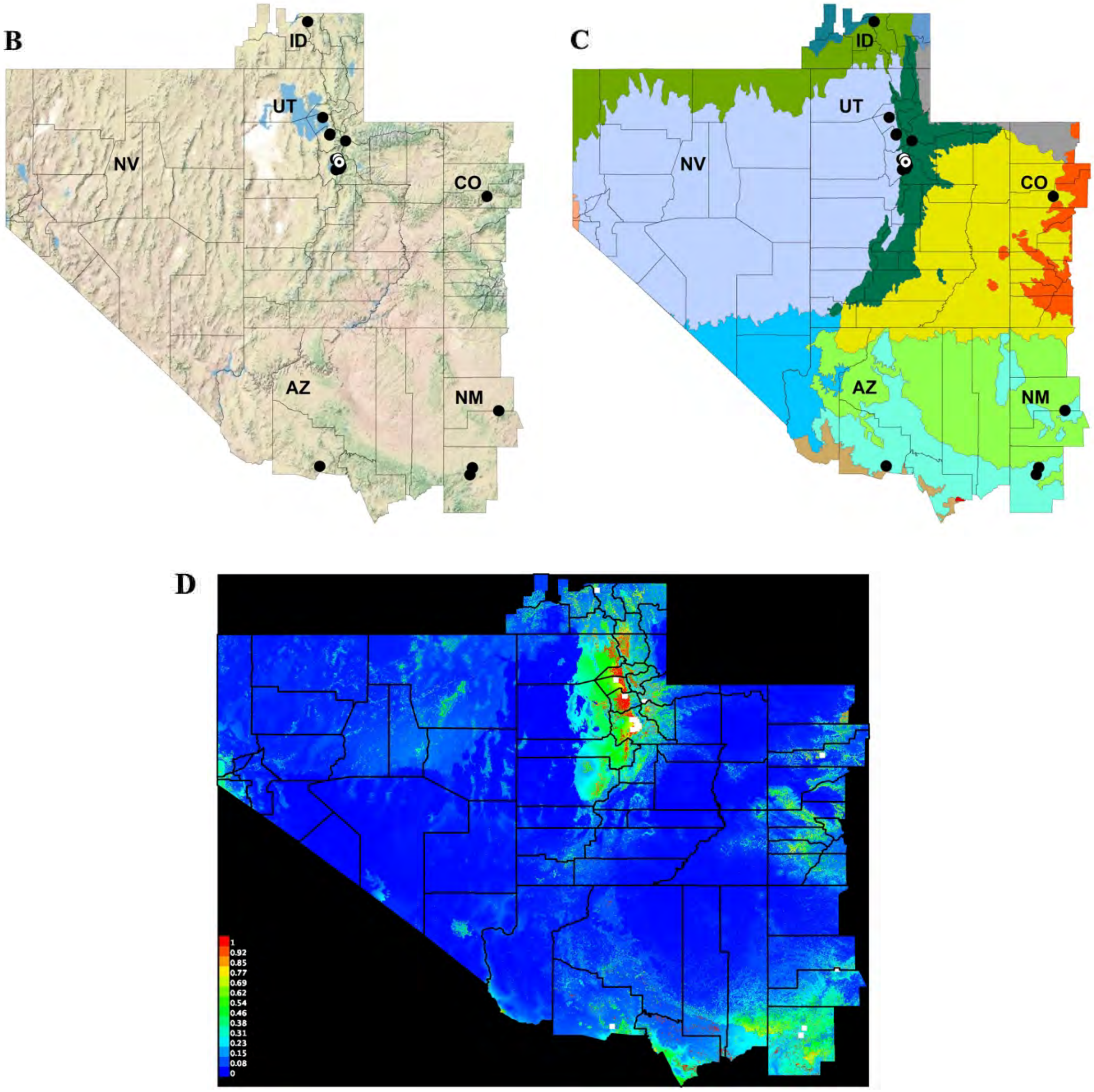


Figure 51. *Estigmene acrea* A: Specimen image (Male and Female), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino; COLORADO: Garfield; IDAHO: Bannock; NEW MEXICO: Catron and Cibola; UTAH: Davis, Salt Lake, and Utah

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateau, Northern Basin Range, and Wasatch and Uinta Mountains

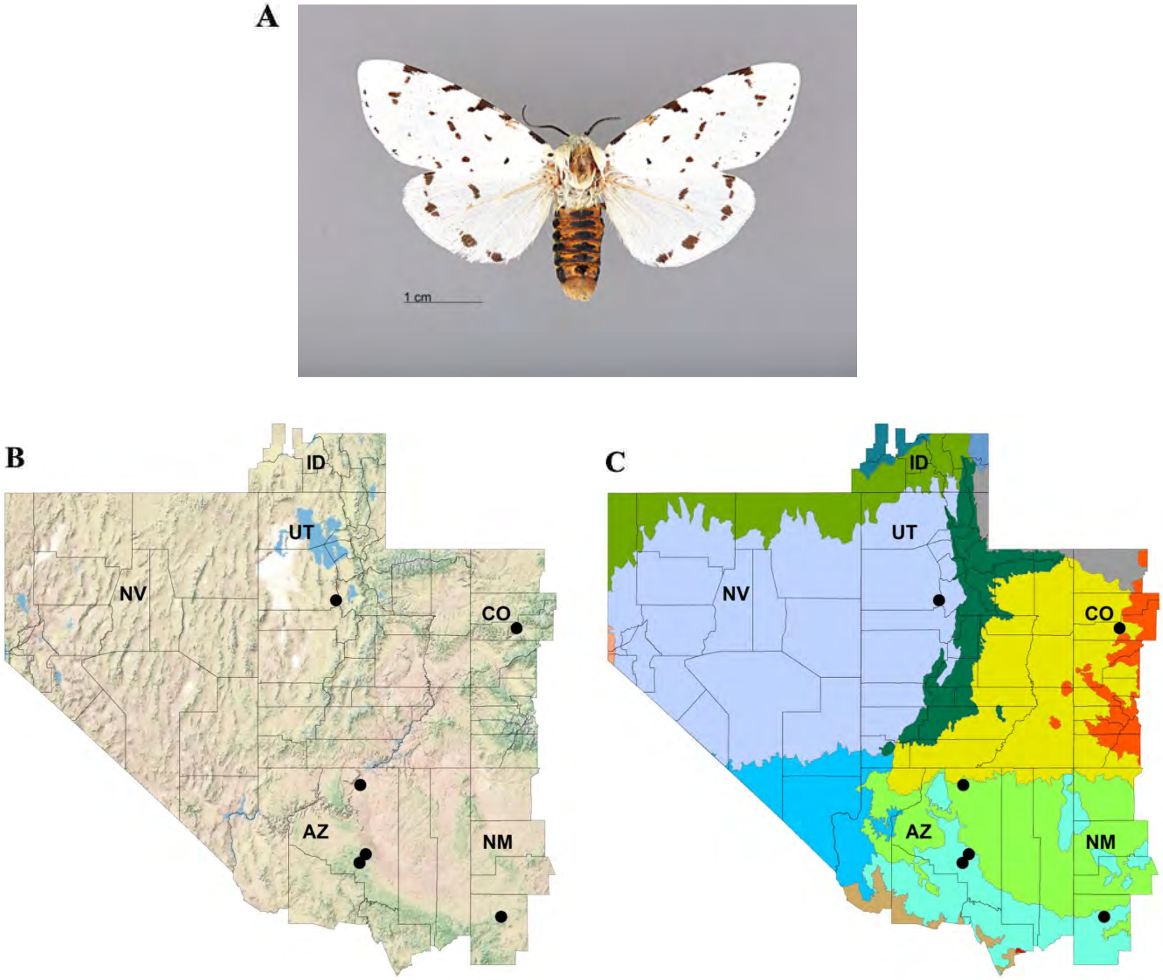
Years Collected: 1895 - 1996

Flight Season: 20 May – 11 August

Elevation Range: 1828 - 4290 m

Notes: The species has received a lot of attention into its coremata and pheromone production (Davenport & Conner 2003; Jordan et al. 2007). Its success in production of these by males is correlated with the larvae's ability to acquire hosts with pyrrolizidine alkaloids. This moth is commonly confused with *Estigmene albida*, but can be distinguished by having dorsal spots on the abdomen as opposed to stripes in *E. albida.* Males of this species can also be readily identified by having orange as opposed to white underwing (Powell & Opler 2009).

Estigmene albida (Stretch, 1873)



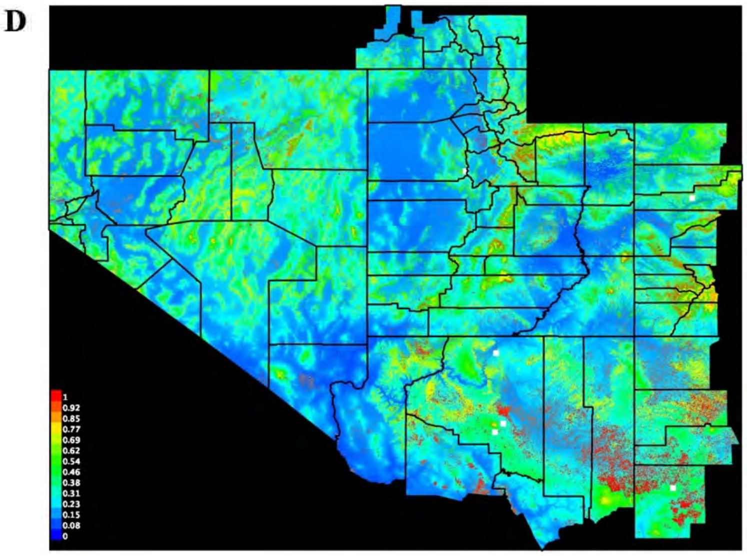


Figure 52. *Estigmene albida* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino; COLORADO: Garfield; NEW MEXICO: Catron; UTAH: Salt Lake

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateaus, Central Basin and Range, and Colorado Plateaus

Years Collected: 1977 - 1999

Flight Season: 29 June – 1 August

Elevation Range: 1652 – 2104 m

Notes: Not much is published about the species. Powell & Opler (2009) mention that it occurs in more natural and arid habitats than *E. acrea,* though we found them to occur in similar habitats and the same ecoregions. Although, there were much fewer records for the species then there were of *E. acrea*. The character of the dots versus stripes was difficult at times as intermediates do exist.

Euchaetes antica (Walker, 1856)

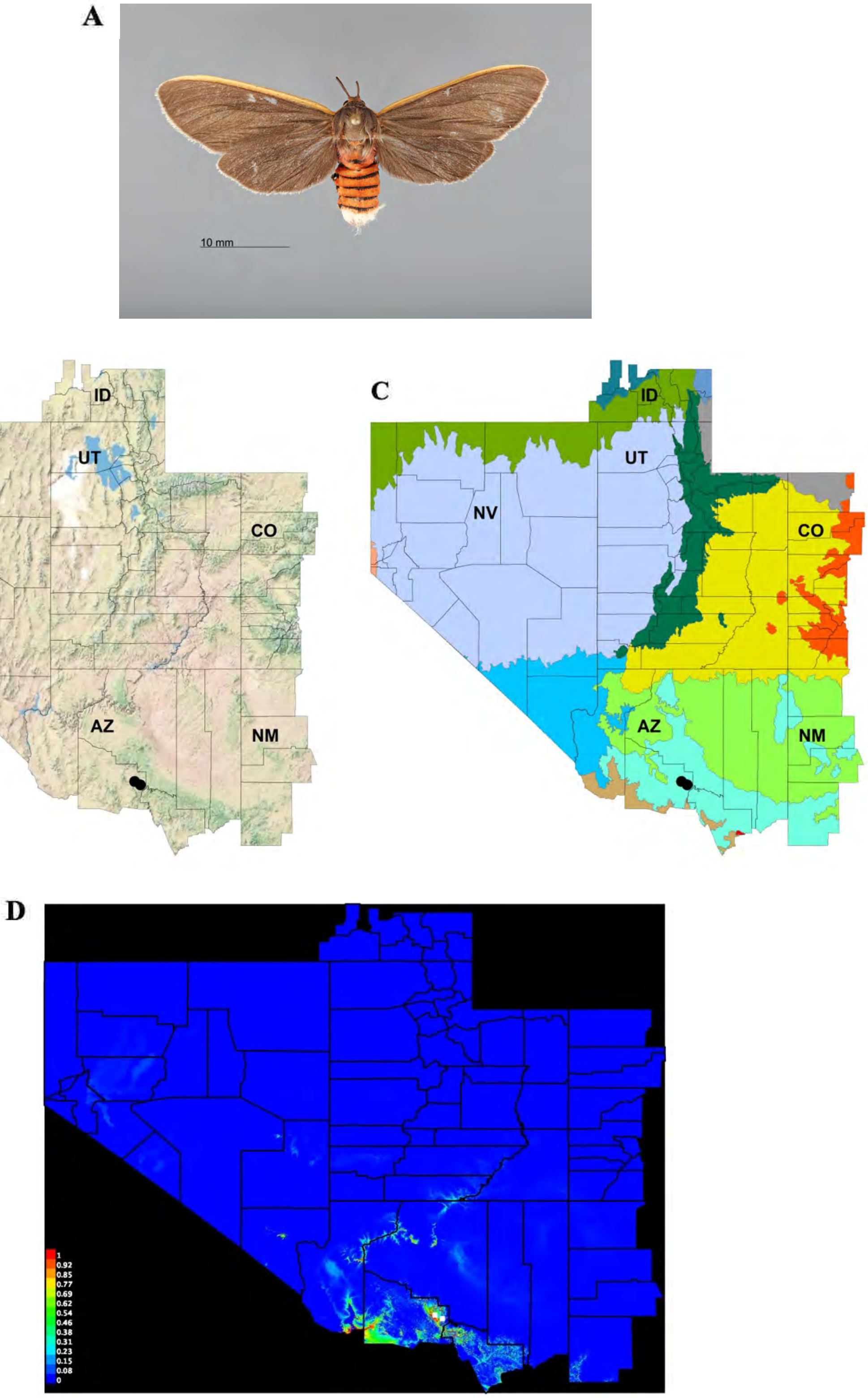


Figure 53. *Euchates antica* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Yavapai

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1968, 1993

Flight Season: 11 - 12 July

Elevation Range: 988 m

Notes: The known range occurs from southern to central Arizona (Powell & Opler 2009). We found it to extend into Yavapai county of Arizona in the Arizona/New Mexico Mountains Level III ecoregion.

Euchaetes fusca (Rothschild, 1910)

A

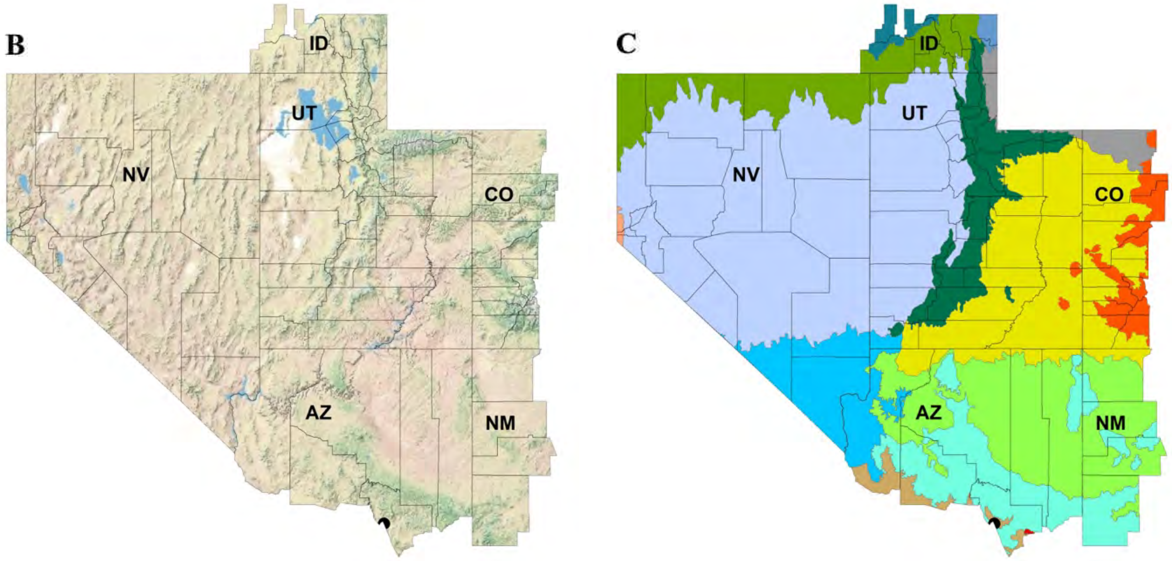


Figure 54. *Euchaetes fusca* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Gila

Ecoregion Records: Sonoran Basin Range

Years Collected: 1993

Flight Season: June 21

Elevation Range: 897 m

Notes: Limited with one record, we did not conduct an ENM analysis

Euchaetes zella (Schmidt, 2009)

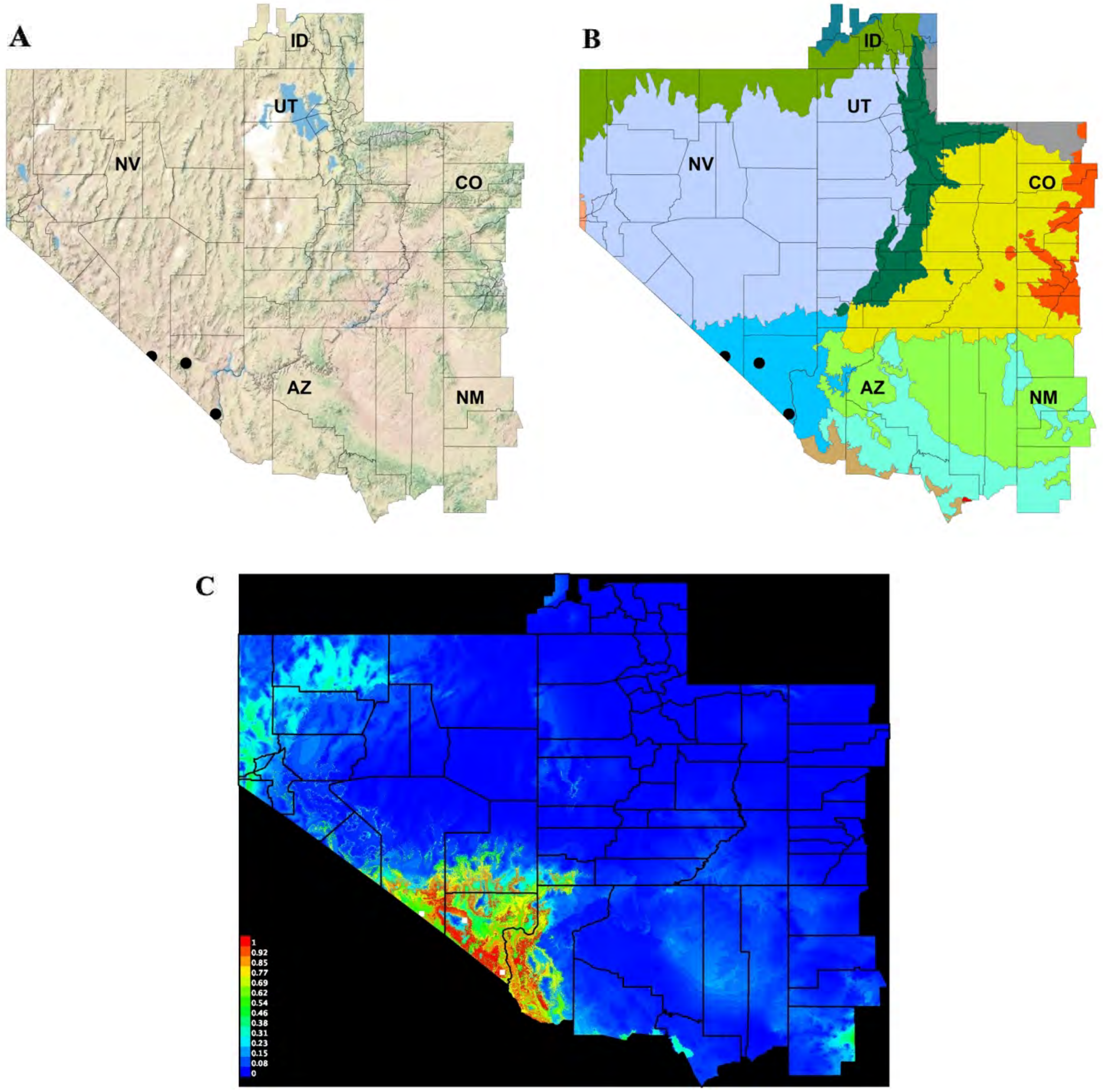


Figure 55. *Euchates zella* A: Topographic map of documented occurrences, B: Level III ecoregion map of documented occurrences, and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: NEVADA: Clark and Nye;

Ecoregion Records: Mojave Basin and Range

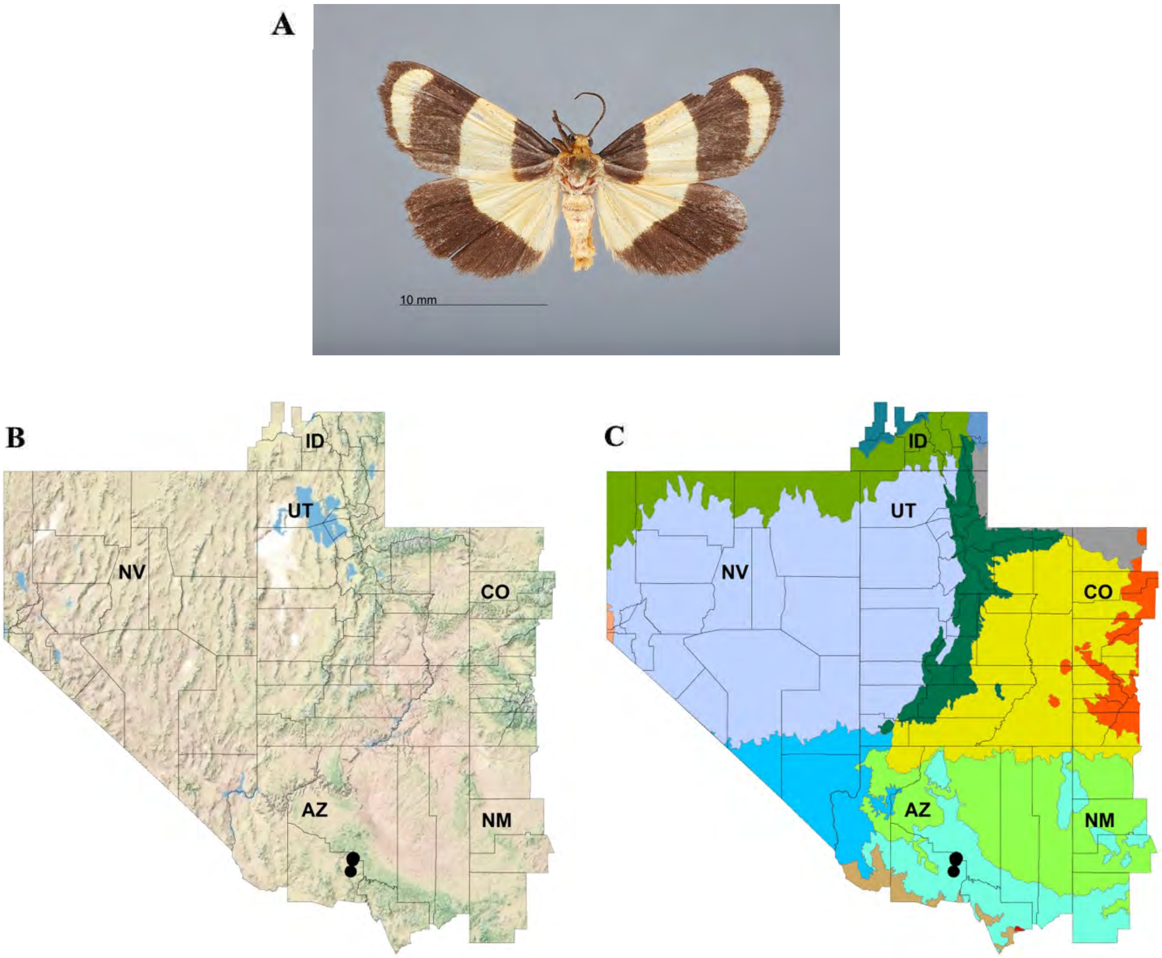
Years Collected: 1930 - 2005

Flight Season: 13 April - 30 June, and 16 - 19 September

Elevation Range: 655 – 1556 m

Notes: The species resembles *Pygarctia murina,* but can be distinguished by having a light triangle in the forewing.

Eudesmia arida (Skinner, 1906)



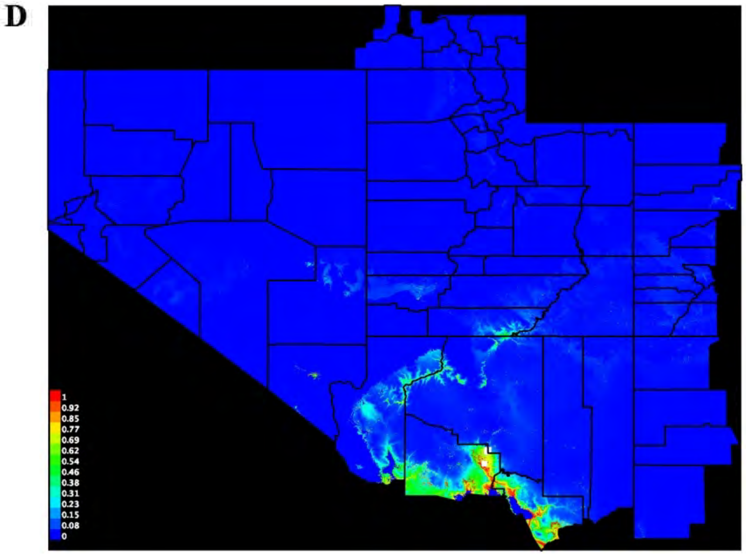


Figure 56. *Eudesmia arida* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino and Yavapai

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1664 - 1968, 1993

Flight Season: 2 August - 17 September

Elevation Range: 1044 - 1762 m

Notes: The species is a Neotropical species that occurs from the south into central Arizona (Powell & Opler 2009). We found two records in Yavapai county, but the species is likely not very common.

Gnophaela discreta (Stretch, 1875)

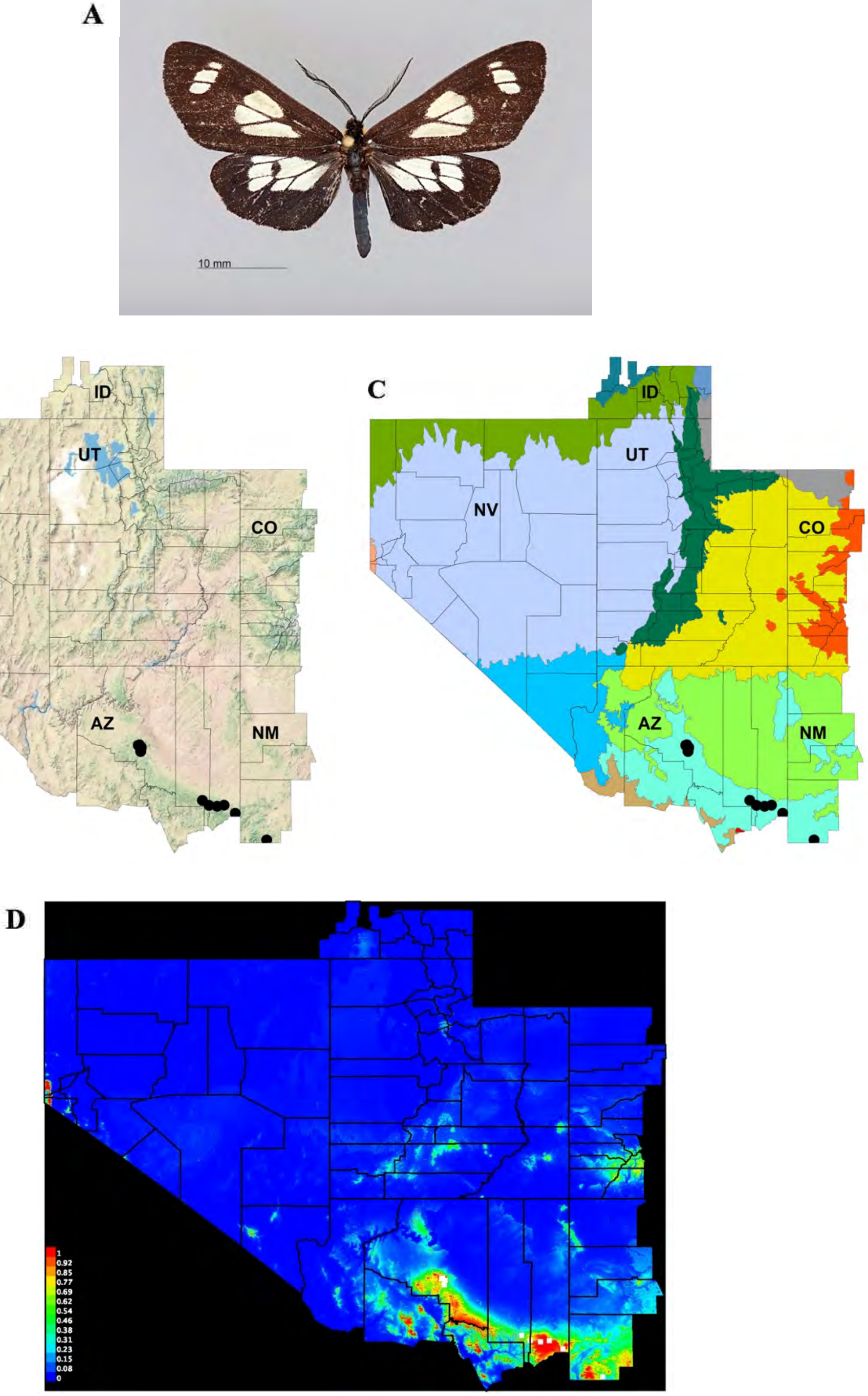


Figure 57. *Gnophaela discreta* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, and Navajo; NEW MEXICO: Catron

Ecoregion Records: Arizona/ New Mexico Mountains

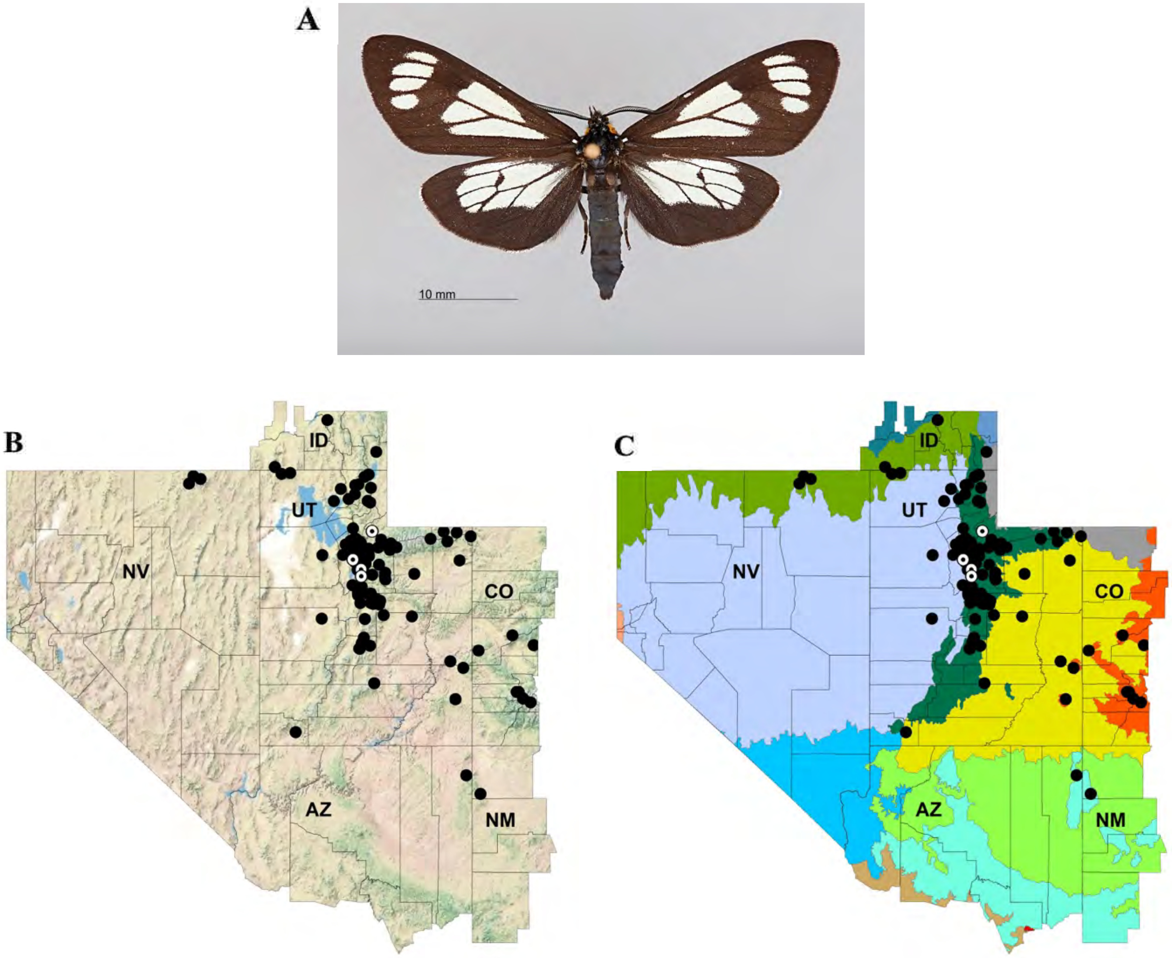
Years Collected: 1966 - 2007

Flight Season: 17 July - 4 September

Elevation Range: 2036 – 2865 m

Notes: The species is similar in appearance to *G. vermiculata,* but with smaller white patches and a black streak in the hindwings patch.

Gnophaela vermiculata



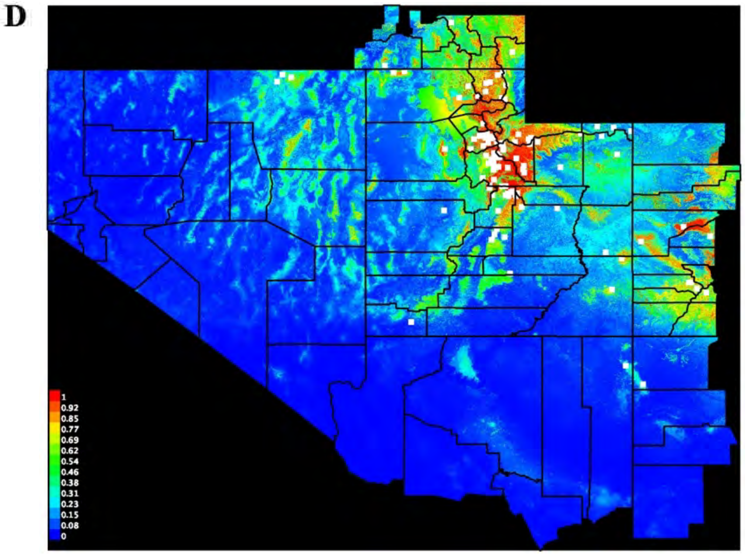


Figure 58. *Gnophaela vermiculata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache; COLORADO: Delta, Mesa San Juan, and San Miguel; IDAHO: Bannock, Bear Lake, and Cassia; NEVADA: Elko; NEW MEXICO: San Juan; UTAH: Cache, Daggett, Davis, Duchesne, Emery, Grand, Juab, Kane, Millard, Rich, Salt Lake, San Juan, Sanpete, Sevier, Summit, Tooele, Uintah, Utah, Wasatch, Washington, and Wayne.

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateaus, Northern Basin Range, Southern Rockies, Wasatch and Uintah Mountain, and Wyoming Basin

Years Collected: 1929 - 2015

Flight Season: 22 April - 11 September , 20 November

Elevation Range: 689 - 3367m

Notes: Commonly known as the police car moth, the species is black and white with orange patches on the lateral sides of its thorax. The forwings are black with large patches of white with white spots on also found on its thorax. The moth is diurnal and has been collected in every state of study area though is not strongly found in Arizona or New Mexico like *Gnophaela discreta.*

See ‘Notes’ for *G. discreta* for more information on how to distinguish between the two.

Halysidota davisii (Edwards, 1874)

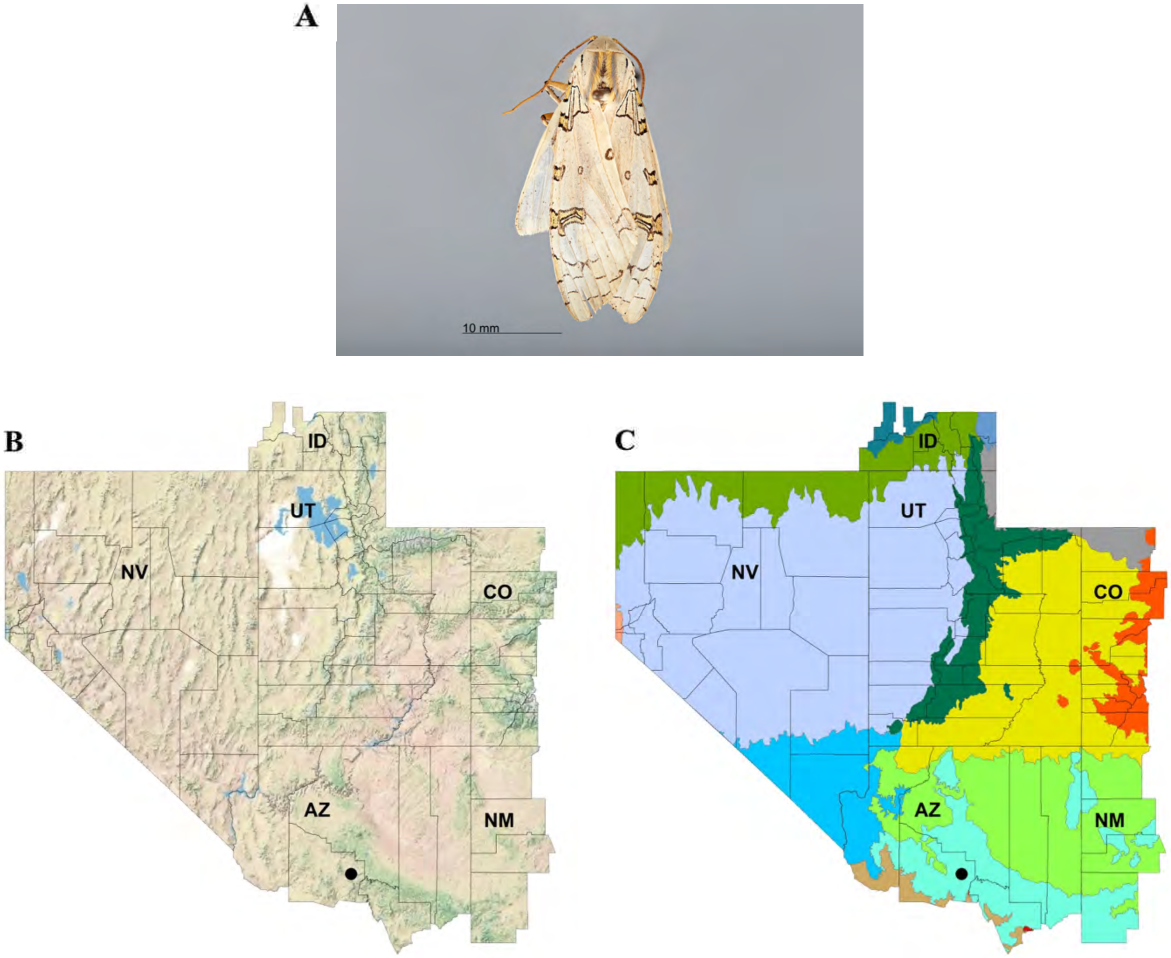


Figure 59. *Halysidota davisii* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Yavapai

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1964

Flight Season: 26 July

Elevation Range: 1571 m

Notes: The species is not typically found in this area, but one record from Arizona was confirmed. Limited with one record, we did not conduct an ENM analysis.

Halysidota harrisii (Walsh, 1864)

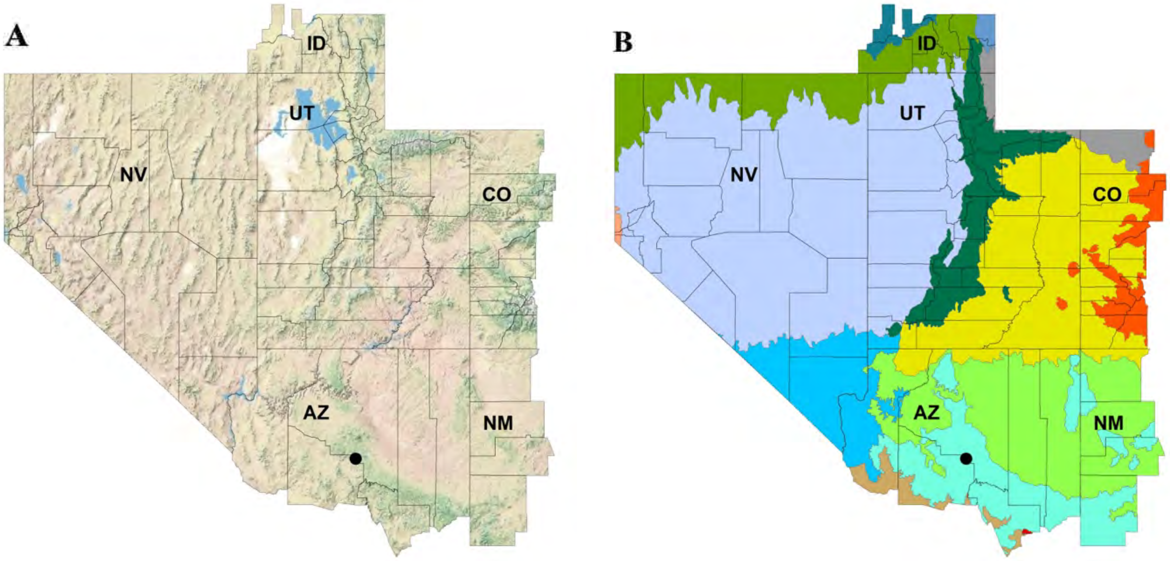


Figure 60. *Halysidota harrisii* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1993

Flight Season: 17 July

Elevation Range: 1395 m

Notes: The species is very similar to *Halysidota tessallaris,* but is generally restricted to the east. Limited with one record, we did not conduct an ENM analysis.

Halysidota tessallaris (Smith, 1797)

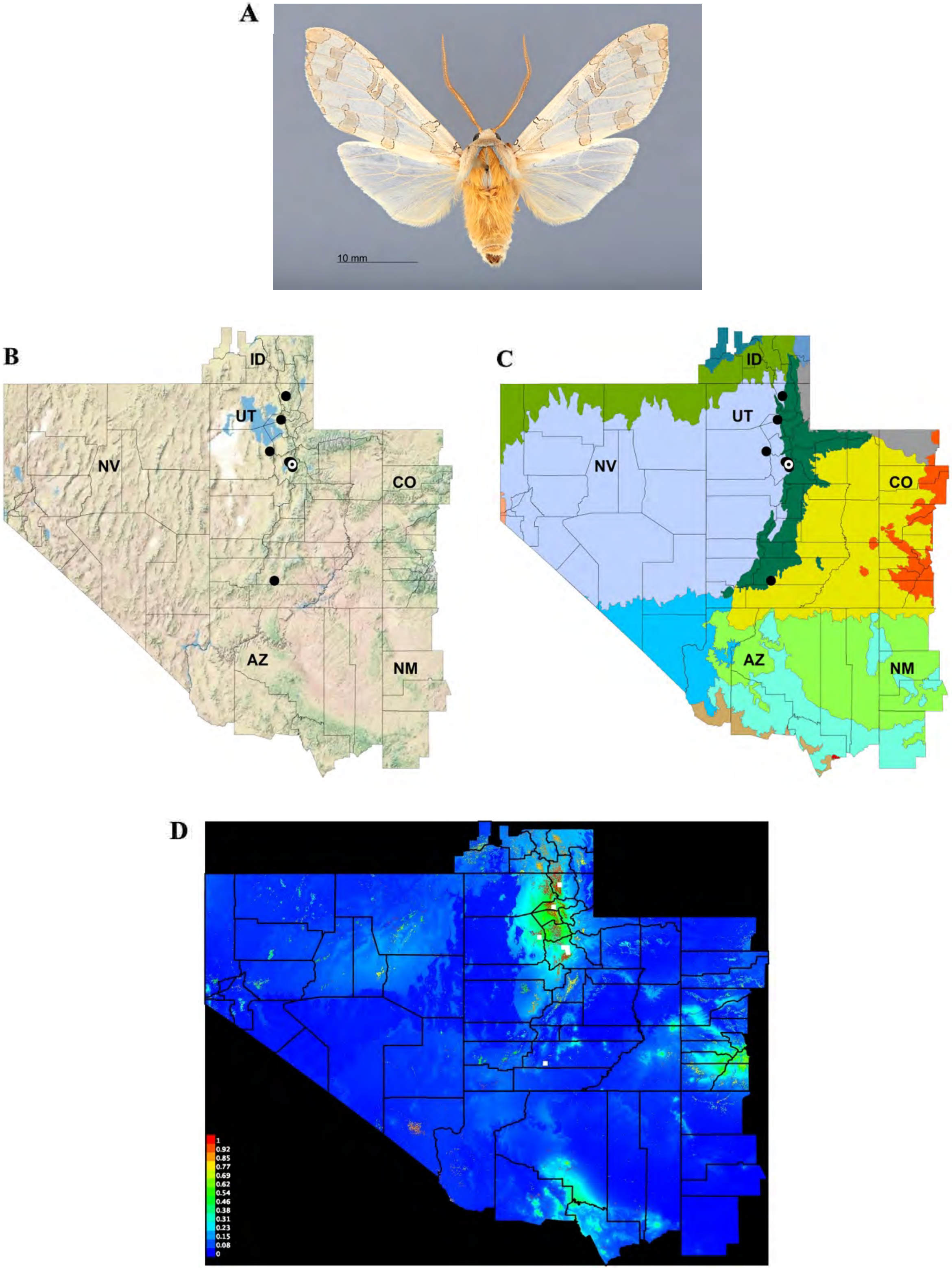


Figure 61. *Halysidota tessallaris* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Cache, Garfield, Utah, Tooele, and Weber

Ecoregion Records: Central Basin and Range

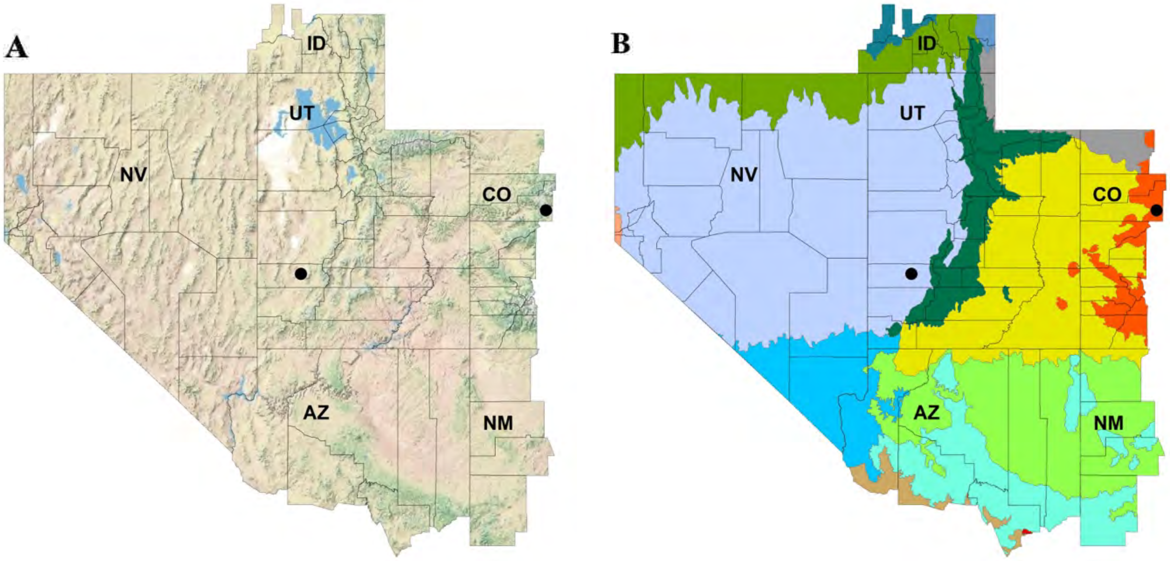
Years Collected: 1928 - 1999

Flight Season: 2 June - 6 August, 14 November

Elevation Range: 1311 – 2492 m

Notes: Considered the pale tussock moth, the species is the only one in the *Halysidota* genus that Powell & Opler (2009) report for the west, but is still not very common.

Haploa lecontei (Guérin-Méneville, 1832)



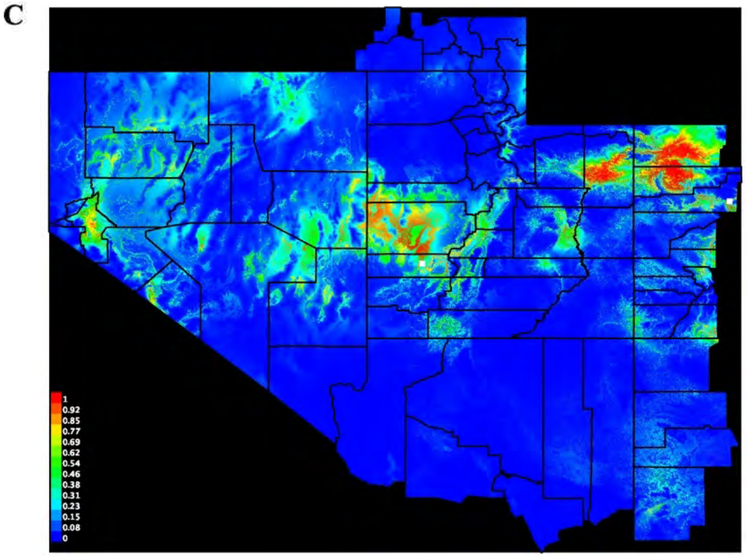


Figure 62. *Haploa lecontei* A: Topographic map of documented occurrences, B: Level III ecoregion map of documented occurrences, and C: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Garfield; UTAH: Beaver

Ecoregion Records: Central Basin and Range and Southern Rockies

Years Collected: 1930 and 2001

Flight Season: 26 June - 1 August

Elevation Range: 1513 – 1899 m

Notes: The species is not commonly collected in the Intermountain West and we found only two records.

Hypercompe permaculata (Packard, 1872)

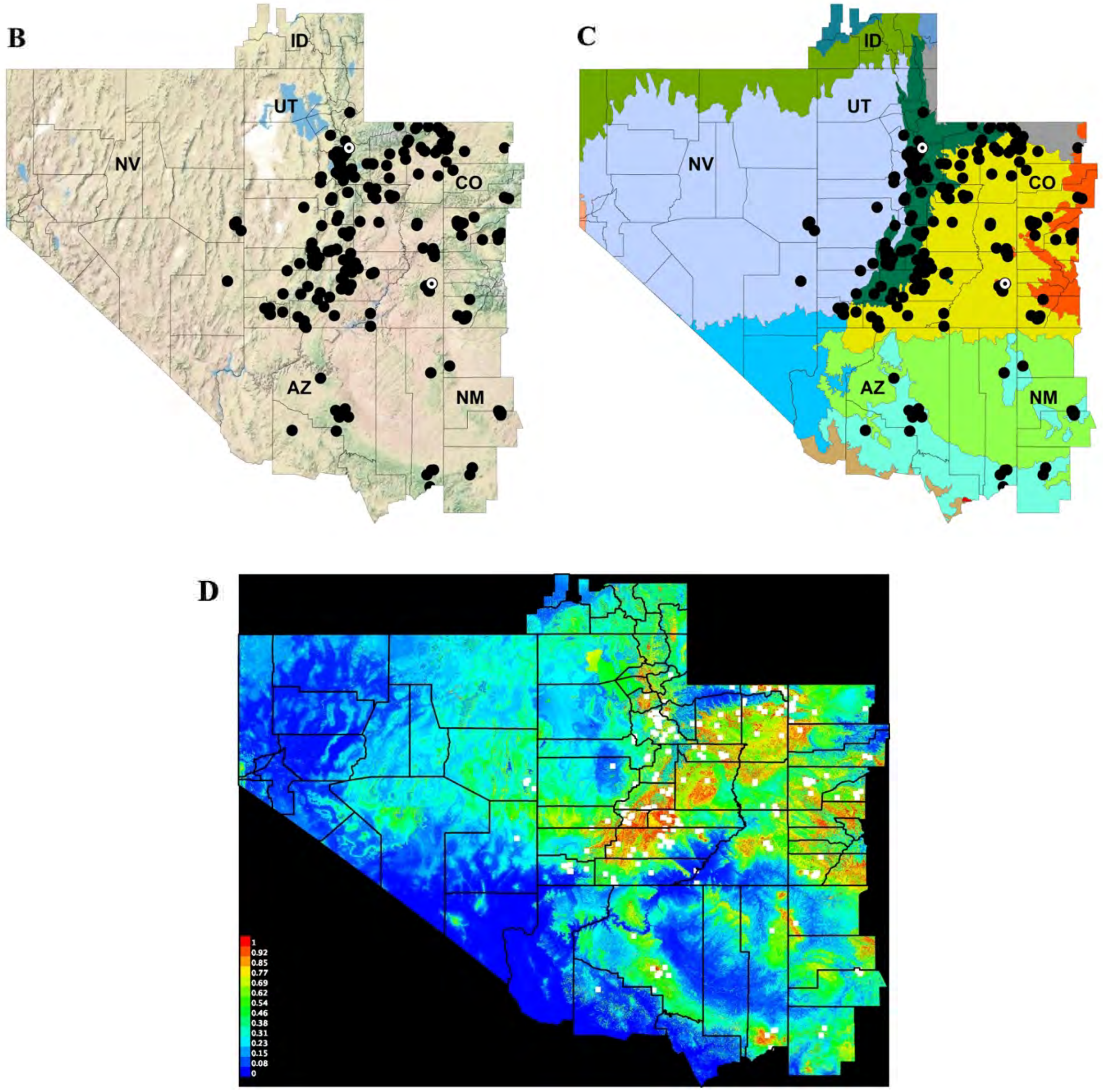


Figure 63. *Hypercompe permaculata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, and Yavapai; COLORADO: Delta, Garfield, Gunnison, Mesa, Moffat, Montezuma, and Rio Blanco; NEVADA: Lincoln and White Pine; NEW MEXICO: Catron Cibola, and San Juan; UTAH: Beaver, Carbon, Daggett, Duchesne, Emery, Garfield, Grand, Iron; Juab, Kane, Millard, Morgan, Piute, Salt Lake; San Juan, Sanpete, Sevier, Summit, Uintah, Utah, Wasatch; Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateaus, Southern Rockies, Wasatch and Uinta Mountains, Wyoming Basin

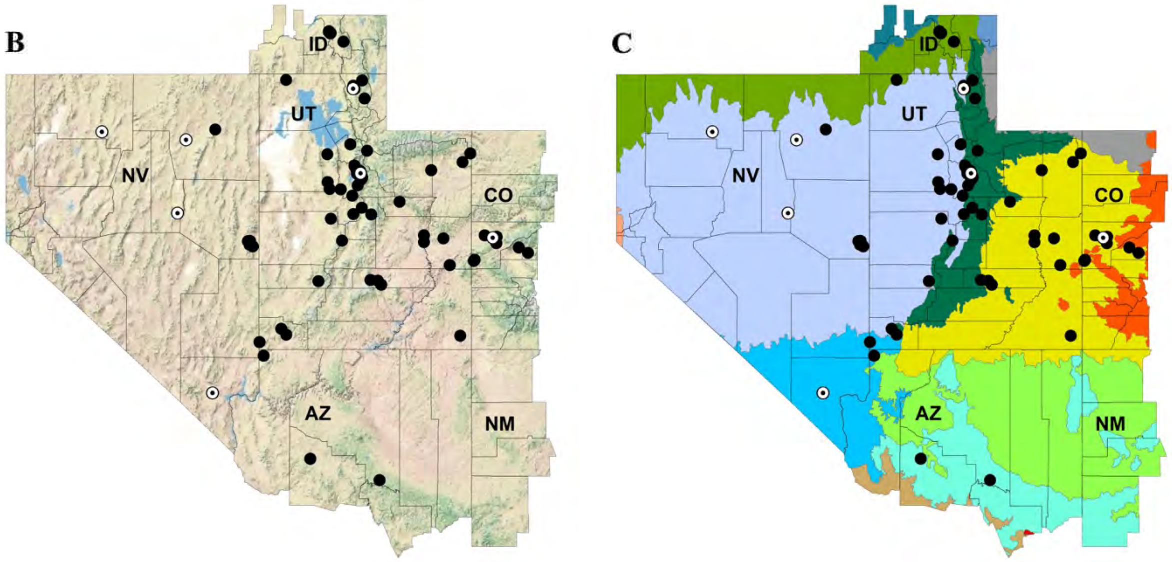
Years Collected: 1925 - 2017

Flight Season: 24 February, 16 May - 13 October

Elevation Range: 795 – 3388 m

Notes: The species is very easy to recognize with its white body and many black spots. Also known as the many spotted tiger moth, this white, spotted moth is one of the most ubiquitous moths in the area and can be in very large numbers at lights (personal experience).

Hyphantria cunea (Drury, 1773)



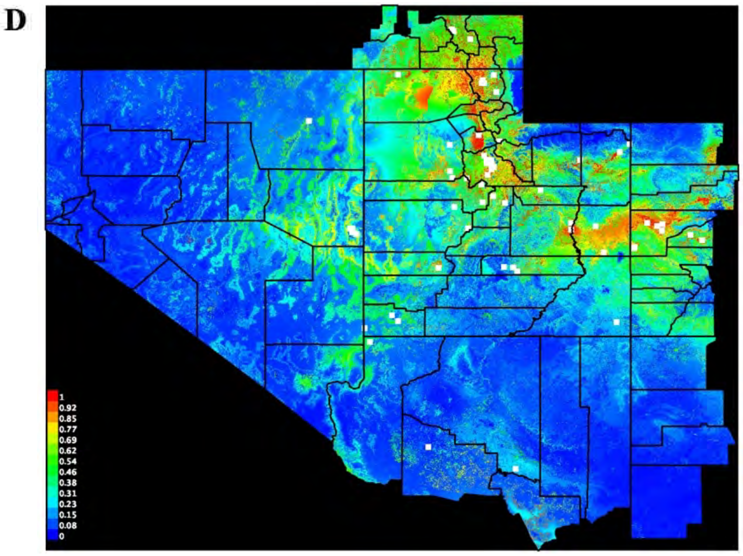


Figure 64. *Hyphantria cunea* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State Records: ARIZONA: Coconino, Mohave, and Yavapai; COLORADO: Delta and Mesa; IDAHO: Bannock; NEVADA: Clark, Elko, Eureka, Humboldt, and White Pine; UTAH: Beaver, Box Elder, Cache, Carbon, Duchesne, Emery, Garfield, Grand, Juab, Millard, Salt Lake San Juan, Sanpete, Summit, Tooele, Uintah, Utah, Washington, and Wayne.

Ecoregion Records: Arizona/ New Mexico, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Northern Basin Range, and Wasatch and Uinta Mountains

Years Collected: 1905 - 2017

Flight Season: 15 May - 6 September, 1 November

Elevation Range: 609 – 3104 m

Notes: The species is one of the most ubiquitous moths in the Intermountain West. It is generally completely white, but we did see a couple of specimens with black/gray spots across the forewings. The species can also be distinguished by having yellow tibia on its forelegs. The species also resembles a bleached white *Spilosoma virginica*. See 'Notes' of *S. virginica* for more details on how to distinguish between the two.

Hypoprepia cadaverosa (Strecker, 1878)

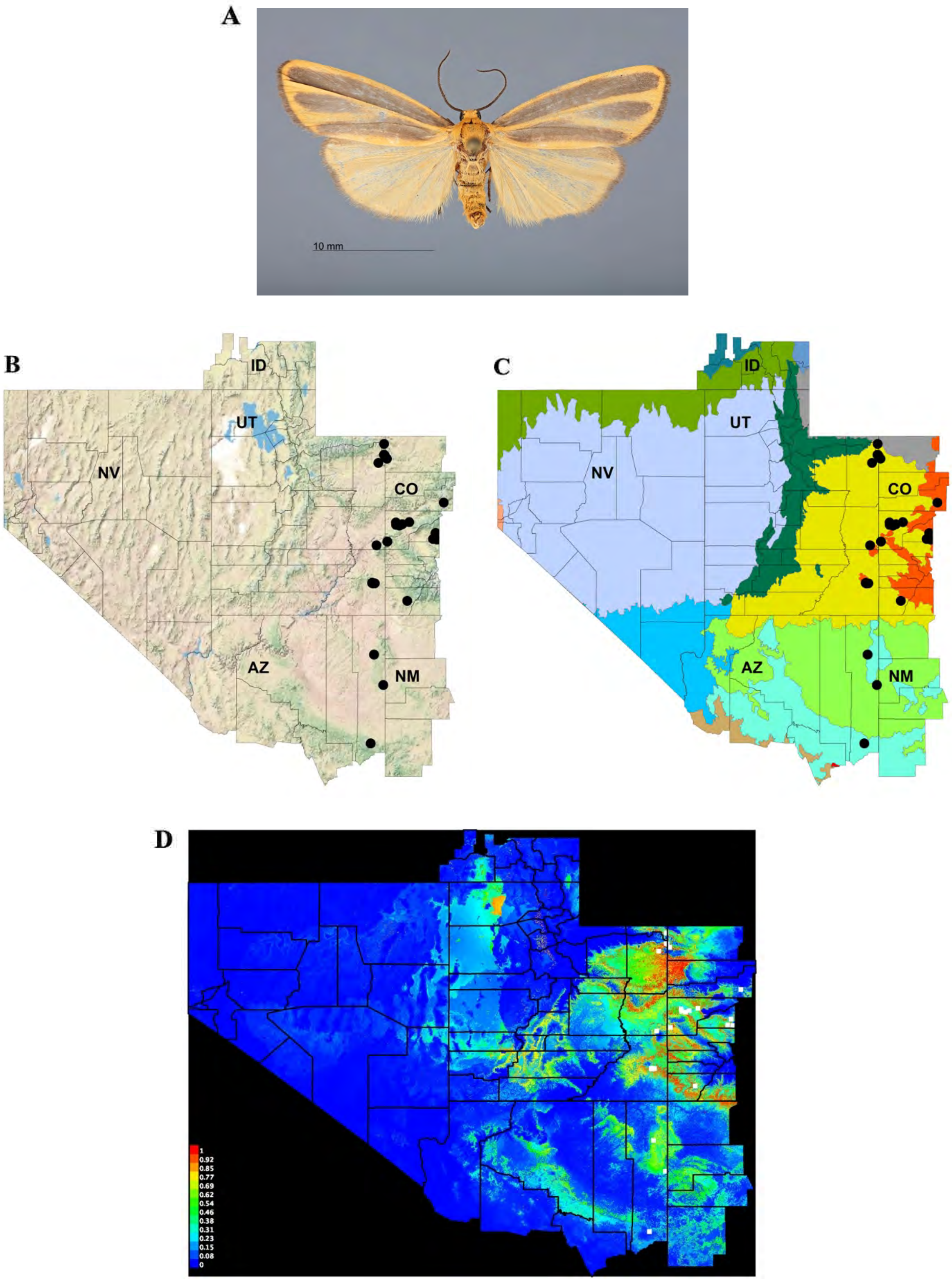


Figure 65. *Hypoprepia cadaverosa* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino; COLORADO: Delta, Garfield, Mesa, and Montezuma; UTAH: Daggett, Grand, San Juan, and Uintah

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Colorado Plateaus, and Southern Rockies

Years Collected: 1925 - 2017

Flight Season: 6 June - 28 August

Elevation Range: 541 – 2624 m

Notes: One of the two *Hypoprepia* species that occurs in the west (Powell & Opler 2009). It can be easily be distinguished from *H. inculta* by having sooty yellow lateral stripes in its forewings.

Hypoprepia inculta (Edwards, 1882)

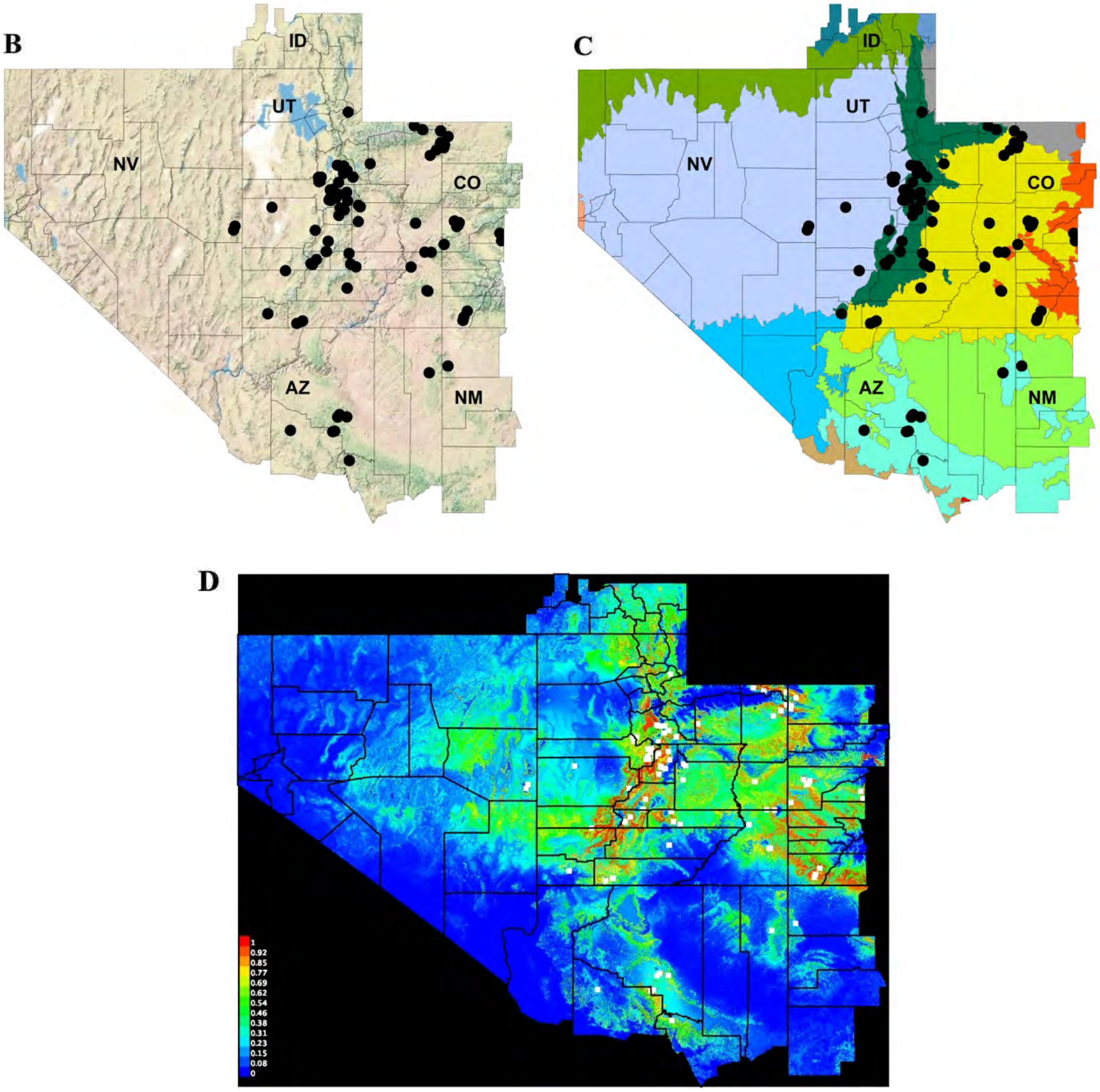


Figure 66. *Hypoprepia inculta* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Gila, and Yavapai; COLORADO: Delta, Mesa, Moffat, Montezuma; NEVADA: White Pine; NEW MEXICO: San Juan; UTAH: Daggett, Duchesne, Emery, Garfield, Grand, Iron, Juab, Kane, Millard, Morgan Piute, San Juan, Sanpete, Sevier, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1969 - 2017

Flight Season: 27 May - 16 August

Elevation Range: 1208 - 2604m

Notes: The species is one of a few tiger moths that is not aposematically colored. The moths has dark brown forewings with a light beige stripe. The hindwings are white, but can have a light pink hue.

Kodiosoma fulvum (Stretch, 1872)

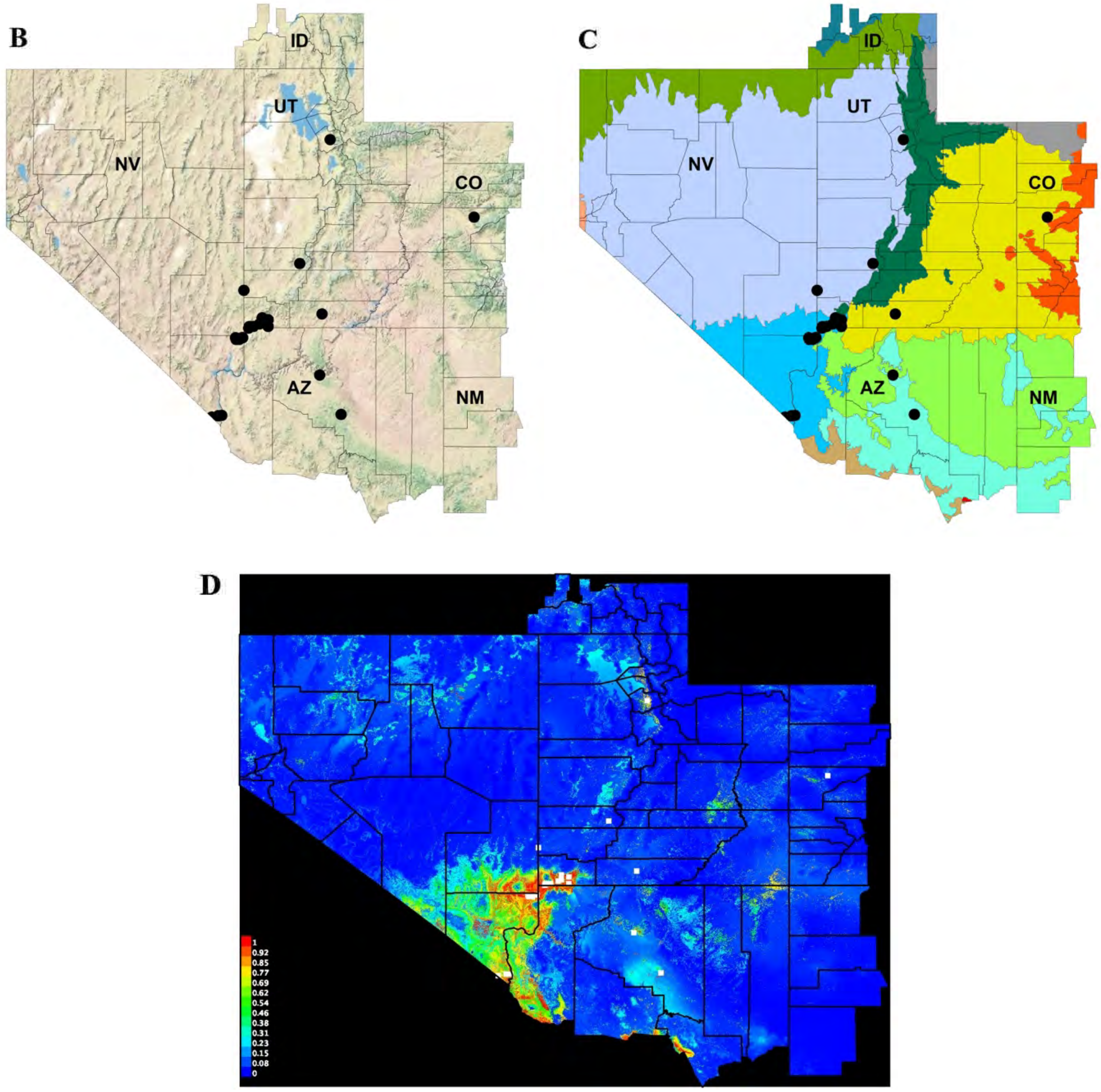


Figure 67. *Kodiosoma fulvum* A: Specimen image (various forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino and Yavapai; COLORADO: Mesa; NEVADA: Clark; UTAH: Beaver, Kane, and Washington

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, and Mojave Basin and Range

Years Collected: 1948 - 2014

Flight Season: 19 March - 25 May

Elevation Range: 199 – 2222 m

Notes: The species has been commonly collected in southern Utah and northern Arizona. Many of them have been collected on the border between the two states in the Mojave Desert in the larval form. The moth also varies in color from red, yellow, and black. The wings also range from being solidly colored to being more transparent.

Leptarctia californiae (Walker, 1855)

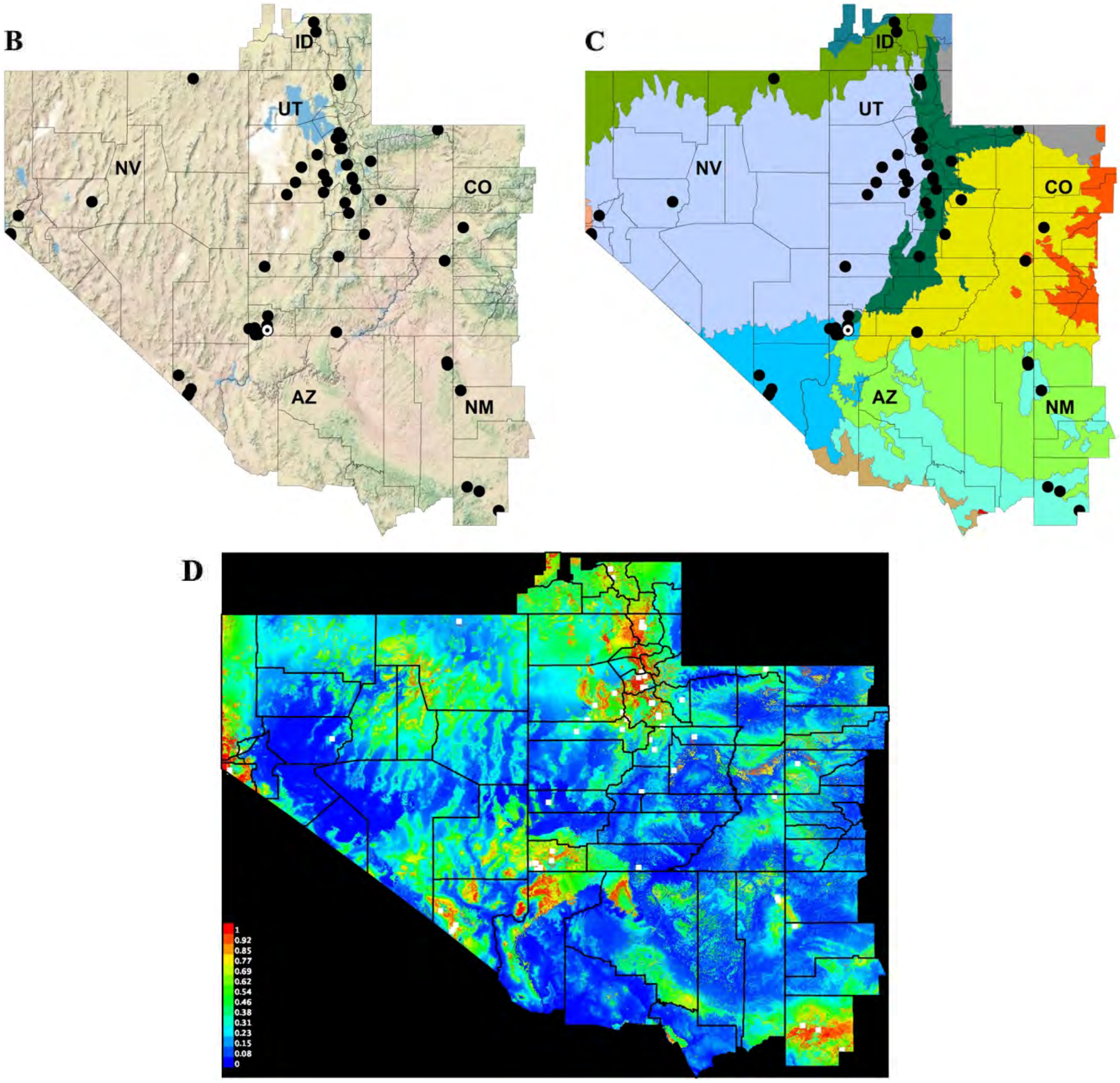


Figure 68. *Leptarctia californiae* A: Specimen image (various forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache; COLORADO: Mesa; IDAHO: Bannock; NEVADA: Churchill, Clark, Douglas, Elko, and Storey; NEW MEXICO: Catron, McKinley; UTAH: Beaver, Cache, Carbon, Daggett, Davis, Grand, Juab, Kane, Millard, Salt Lake, Sanpete, Sevier, Tooele, Utah, Wasatch, and Washington

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Northern Basin Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1934 - 2005

Flight Season: 10 February - 30 May

Elevation Range: 822 – 3259 m

Notes: One of the more ubiquitous species found in the Intermountain West. The species has quite some variety in wing colors and patterns. They are smaller moths with gray forewings with white dashes and colorful underwings with various color patterns.

Leucanopsis lurida (Edwards, 1887)

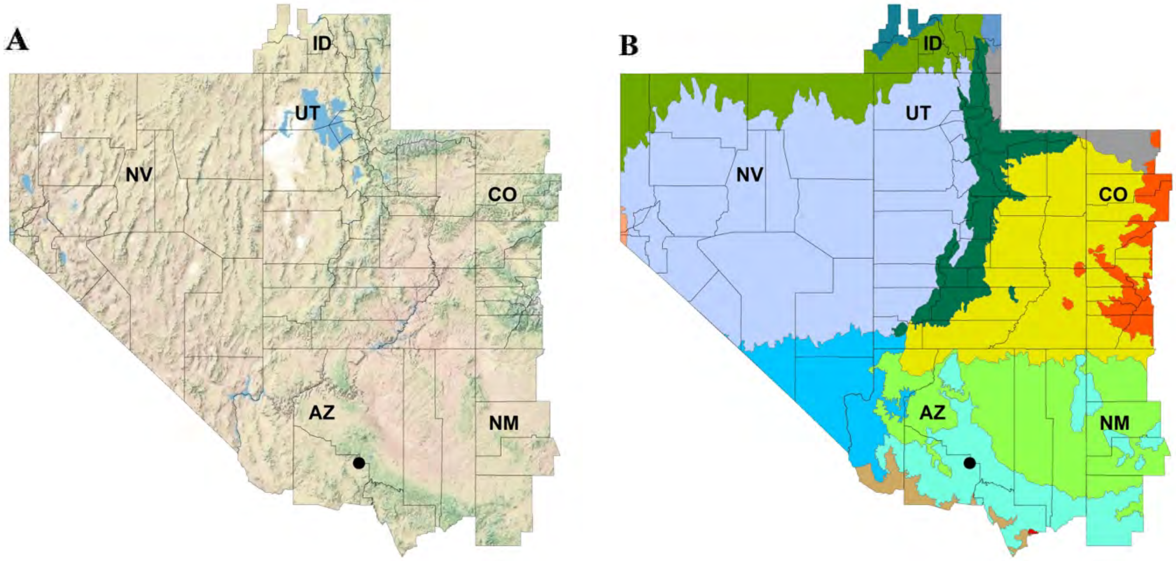


Figure 69. *Leucanopsis lurida* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Yavapai

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1967

Flight Season: 2 August

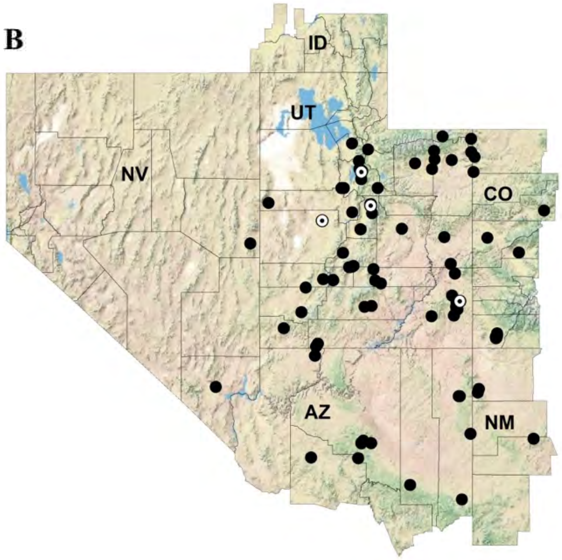
Elevation Range: 1571m

Notes: Limited with one record, we did not conduct and ENM analysis

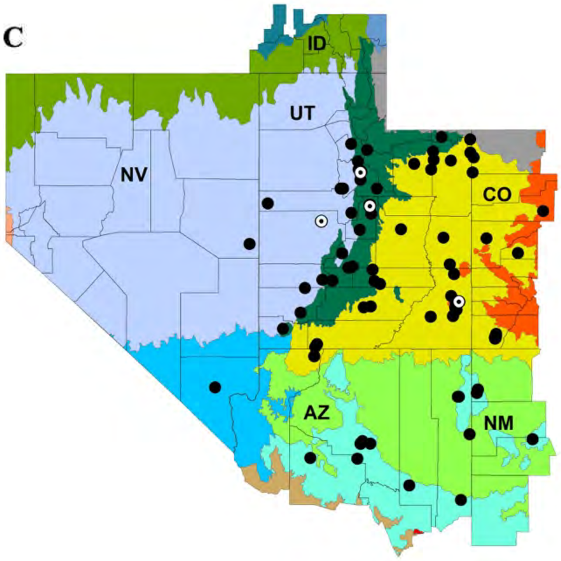
Lophocampa argentata (Packard, 1864)

A

B



C



D

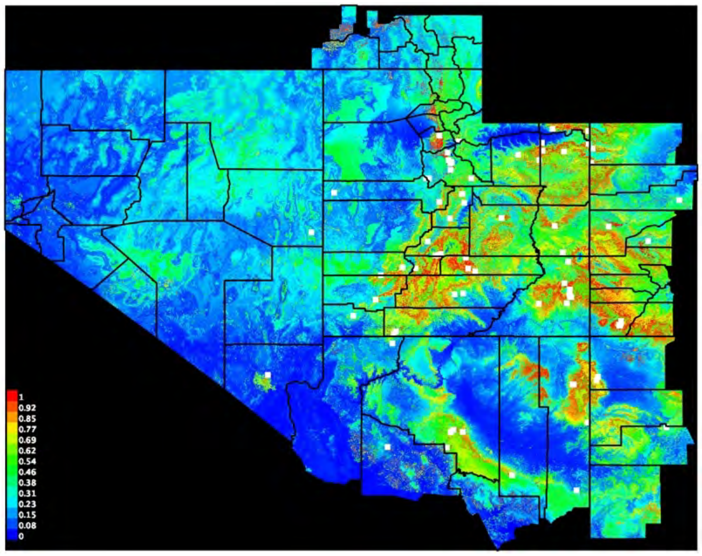


Figure 70. *Lophocampa argentata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Mohave, and Yavapai; COLORADO: Delta, Garfield, Mesa, Moffat, and Montezuma; NEVADA: Douglas and White Pine; NEW MEXICO: Cibola and San Juan; UTAH: Beaver, Daggett, Duchesne, Emery, Garfield, Grand, Iron, Juab, Kane, Piute, Salt Lake, San Juan, Sanpete, Sevier, Summit, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, and Wasatch and Uinta Mountains

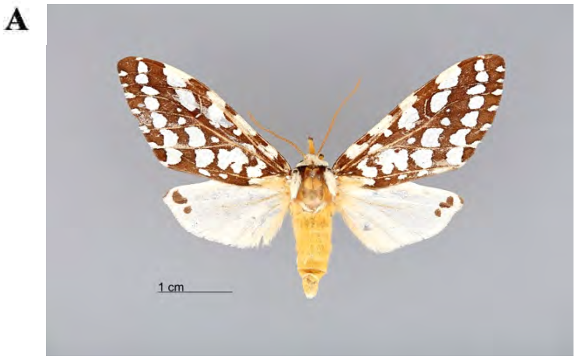
Years Collected: 1922 - 2017

Flight Season: 26 May - 6 September

Elevation Range: 541 - 3213

Notes: The species occurs quite commonly across the region. The larvae are recorded to feed on Pines, firs, and Douglas-fir, but have been reported on Junipers (Powell & Opler 2009), a behavior also observed by the author Makani L. Fisher in his own sampling efforts.

Lophocampa ingens (Edwards, 1881)



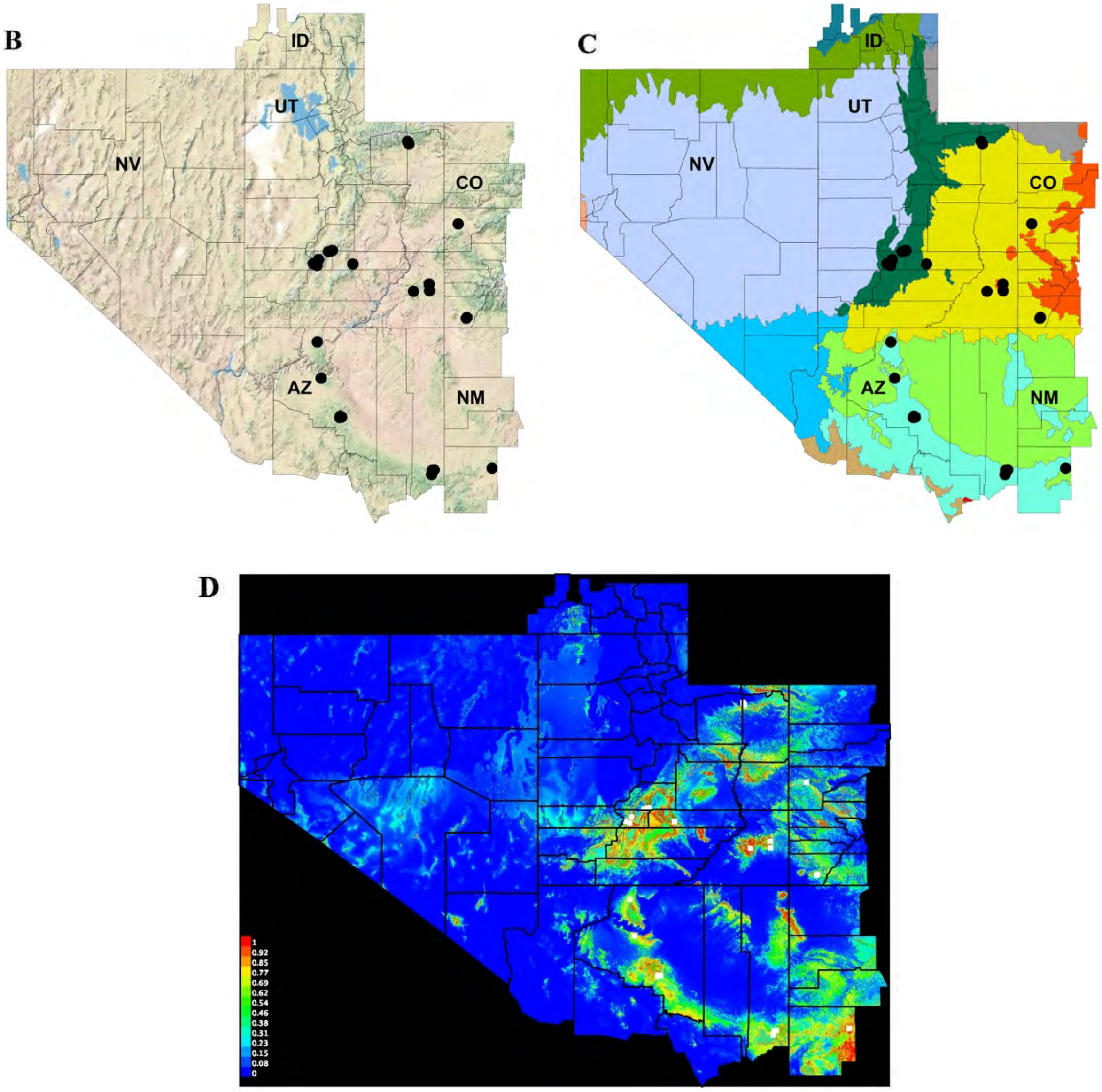


Figure 71. *Lophocampa ingens* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino; COLORADO: Mesa and Montezuma; NEW MEXICO: Catron; UTAH: Piute, San Juan, Sevier, Uintah, Utah, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Colorado Plateaus, Southern Rockies, and Wasatch and Uinta Mountains

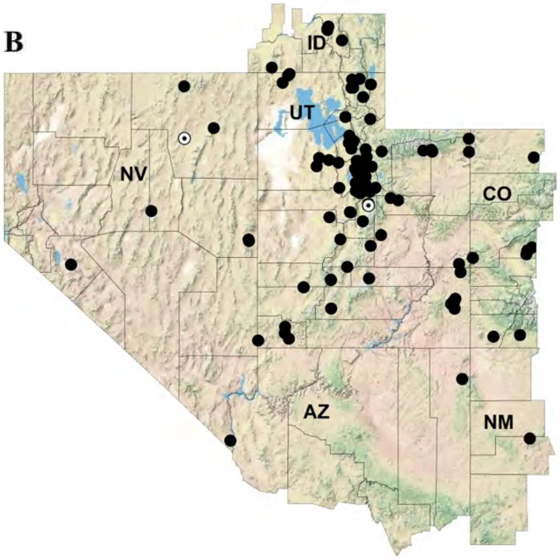
Years Collected: 1964 - 2013

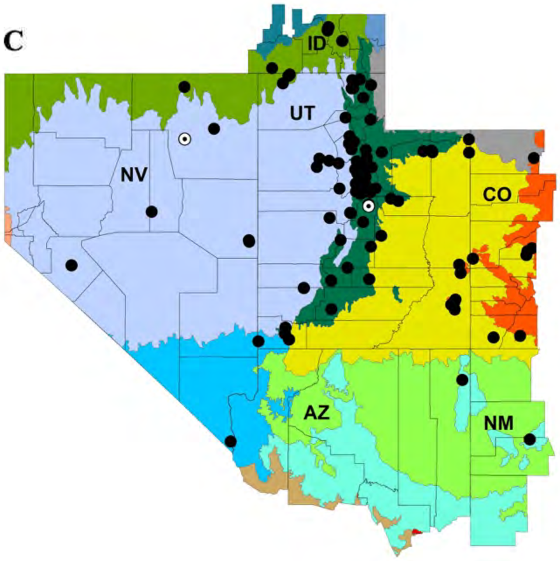
Flight Season: 28 February, 20 May - 26 September, 1 November

Elevation Range: 472 – 2602 m

Notes: The species is larger than others in the genus in the area, with brown forewings with a white spot pattern. The species resembles *L. argentata,* but is a much darker brown and slightly different spot pattern.

Lophocampa maculata (Harris, 1841)





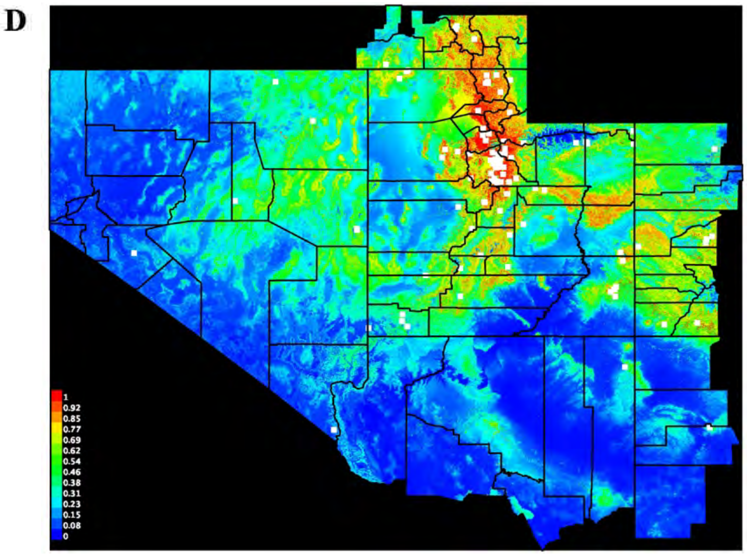


Figure 72. *Lophocampa maculata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache; COLORADO: Delta, La Plata, Mesa, Moffat, and Montezuma; IDAHO: Bannock and Cassia; NEVADA: Douglas, Elko, Nye, and White Pine; NEW MEXICO: Cibola; UTAH: Box Elder, Cache, Carbon, Daggett, Davis, Duchesne, Emery, Garfield, Grand, Iron, Juab, Millard, Morgan, Piute, Rich, Salt Lake, San Juan, Sanpete, Sevier, Summit, Tooele, Uintah, Utah, Wasatch, Washington, and Weber

Ecoregion Records: Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Northern Basin Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1909 - 2017

Flight Season: 14 May - 25 September

Elevation Range: 822 - 3108m

Notes: The species is common across the Intermountain West.

Lophocampa pura (Neumögen, 1882)

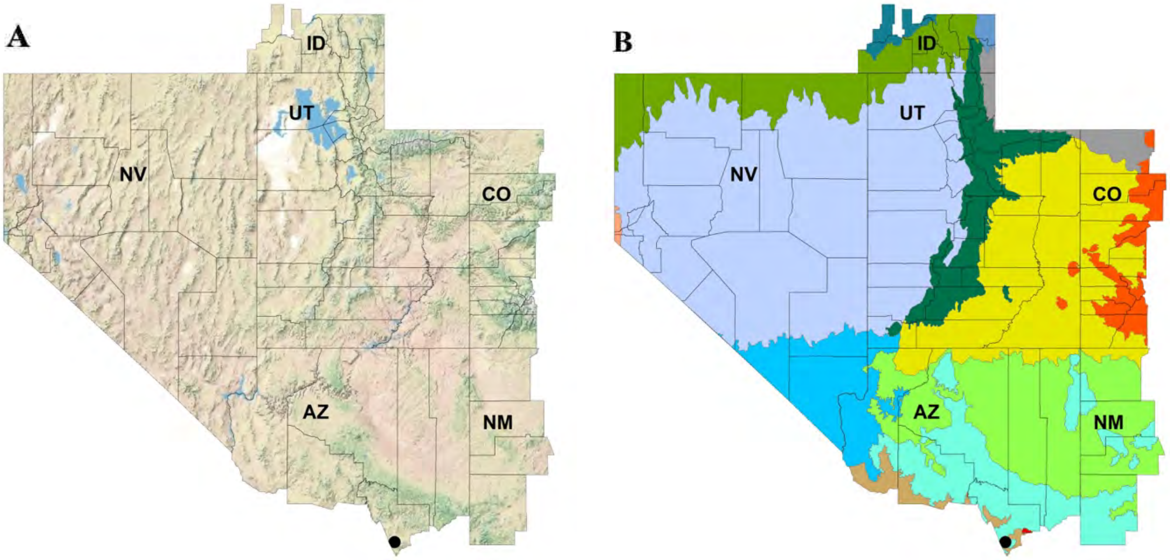


Figure 73. *Lophocampa pura* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Record: ARIZONA: Gila

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 2000

Flight Season: 18 July

Elevation Range: 897 m

Notes: The species has the general *Lophocampa* genus body shape, but its wing patterns are reduced to one main spot on the forewing with potential spots lightly spread throughout. Limited with one specimen, we did not conduct an ENM analysis.

Lophocampa roseata (Walker, 1866)

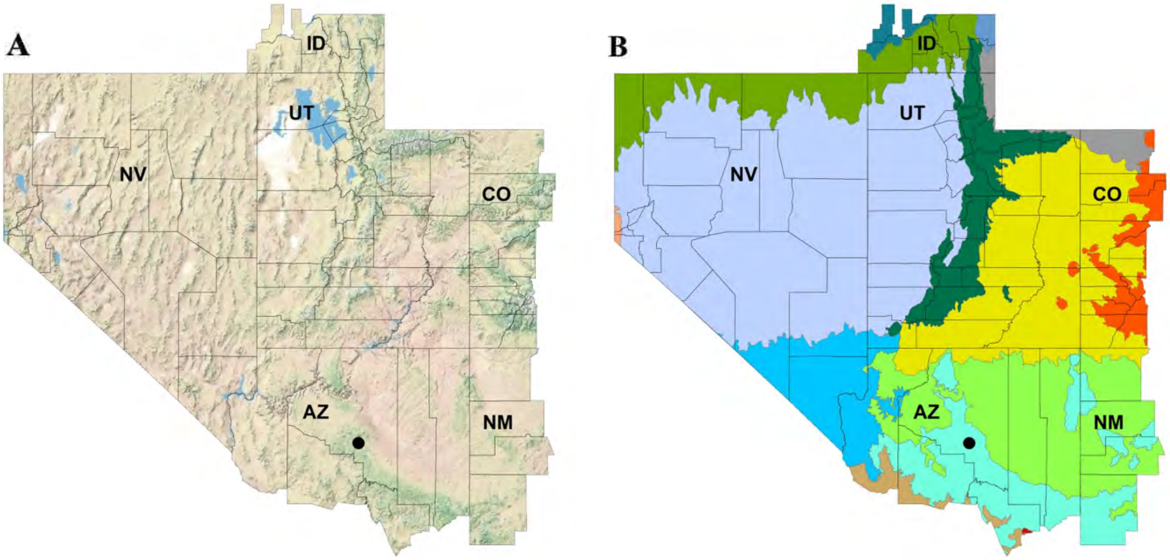


Figure 74. *Lophocampa roseata* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Coconino

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1967

Flight Season: 26 July

Elevation Range: 2104 m

Notes: The species is small with brilliant iridescent red and silver color. The species is difficult to distinguish from *Lophocampa significans* and some taxonomic work may be needed. Although the speces is not common here, geography may also help in distinguishing the two. Limited with one species record we did not conduct an ENM analysis.

Lophocampa significans (Edwards, 1888)

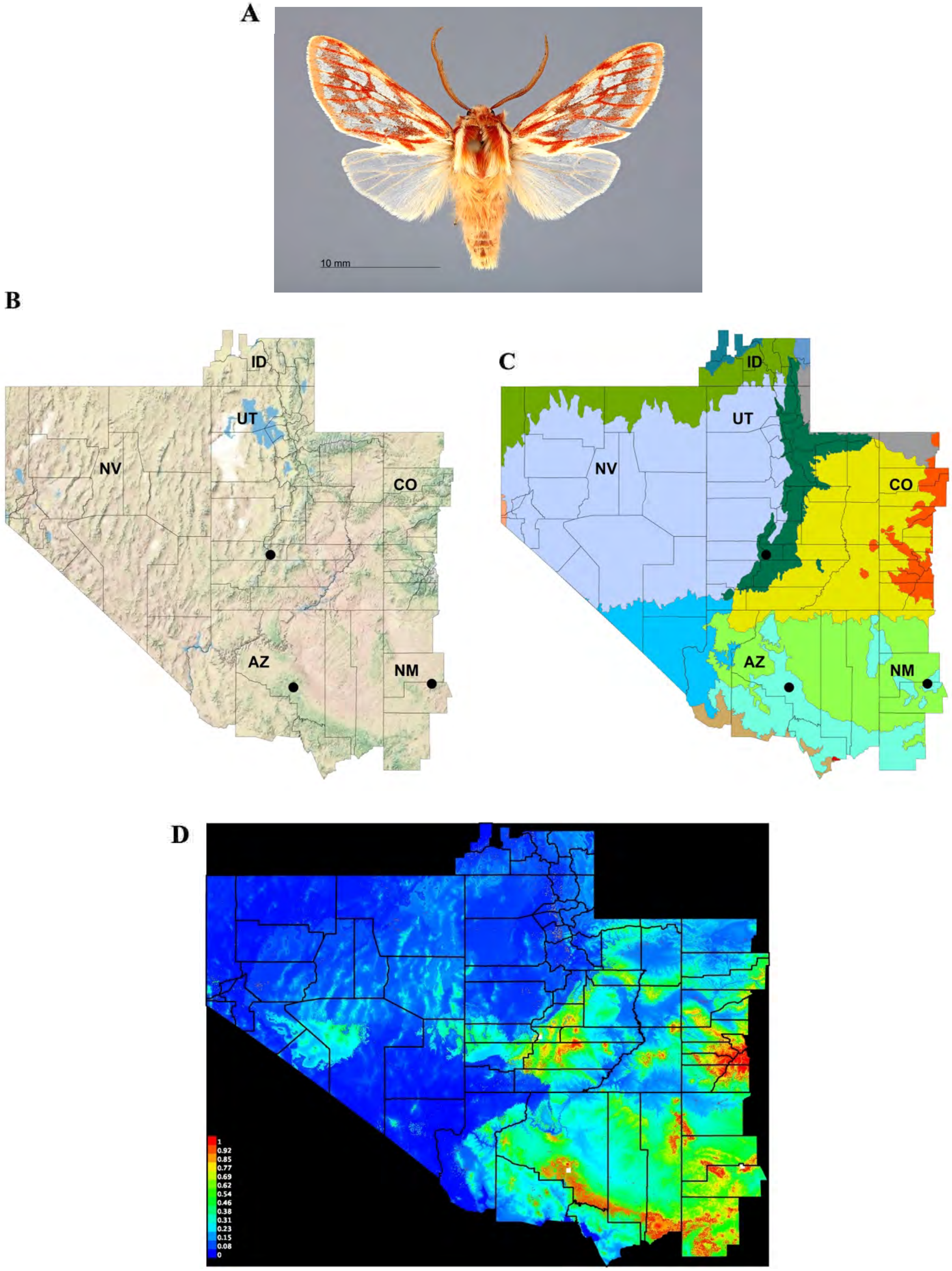


Figure 75. *Lophocampa significans* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino; NEW MEXICO: Cibola; UTAH: Piute

Ecoregion Records: Arizona/ New Mexico Mountains and Wasatch and Uinta Mountains

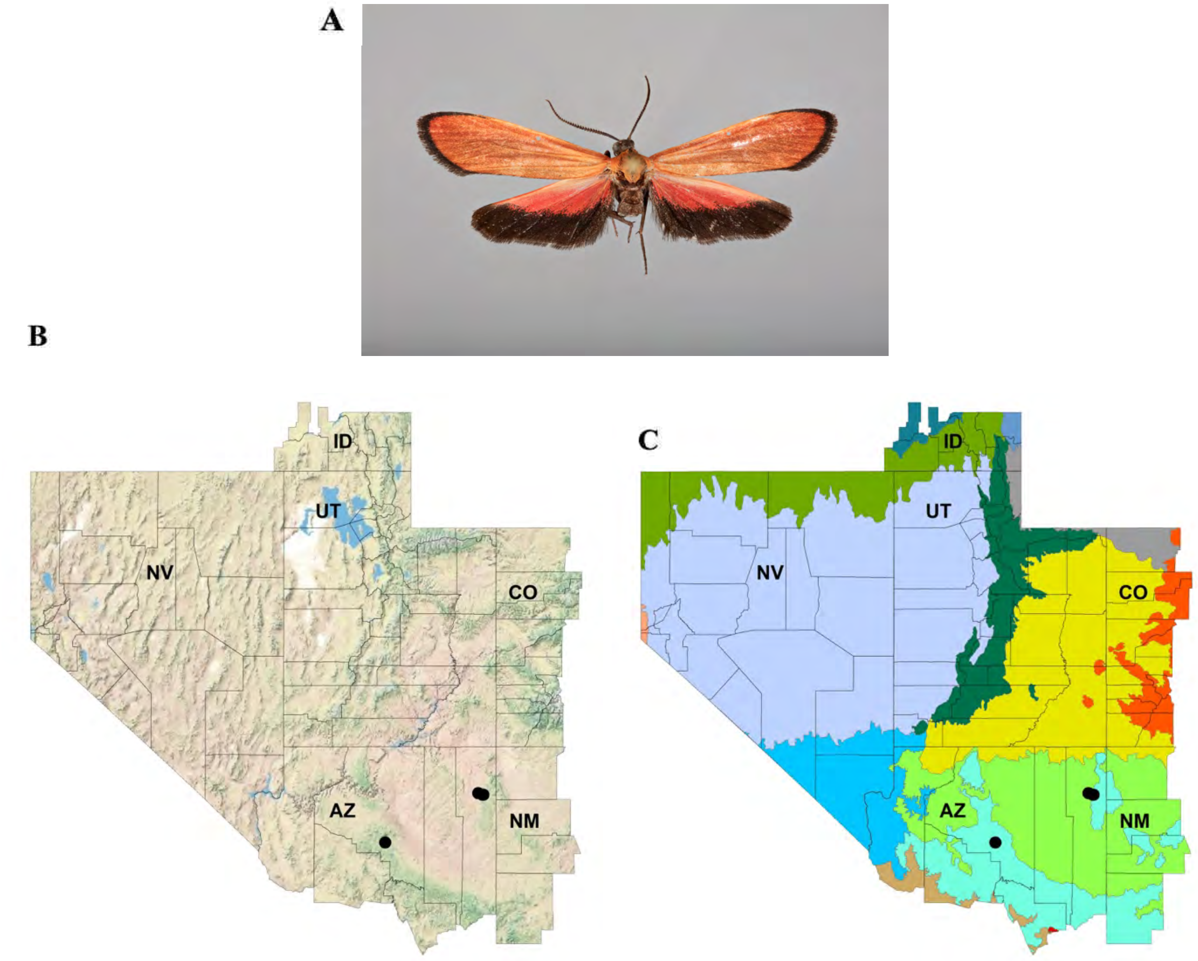
Years Collected: 1966, 1991, and 2000

Flight Season: 15 June - 15 July

Elevation Range: 2180 – 2560 m

Notes: The species is very similar to the uncommon *Lophocampa roseata* and some taxonomic work on the two is needed.

Lycomorpha fulgens (Hy. Edwards, 1881)



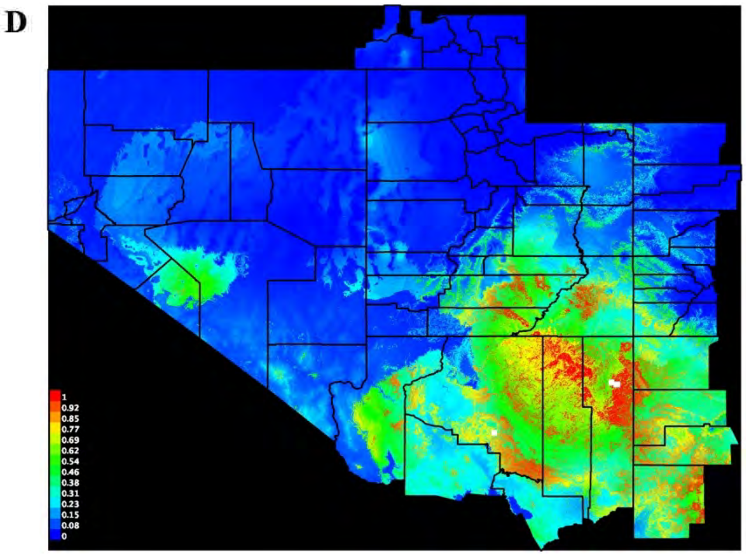


Figure 76. *Lycomorpha fulgens* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino

Ecoregion Records: Arizona/ New Mexico Mountains and Arizona/ New Mexico Plateau

Years Collected: 2005 - 2009

Flight Season: 27 May - 17 September

Elevation Range: 1724 – 2104 m

Notes: The species resembles *Lycomorpha grotei* and *Lycomorpha regulus,* with the hindwing almost black. We left these identifications as collections had them because they are certainly in need of taxonomic work to distinguish or synonymize the three species (Powell & Opler 2009).

Lycomorpha grotei (Packard, 1864)

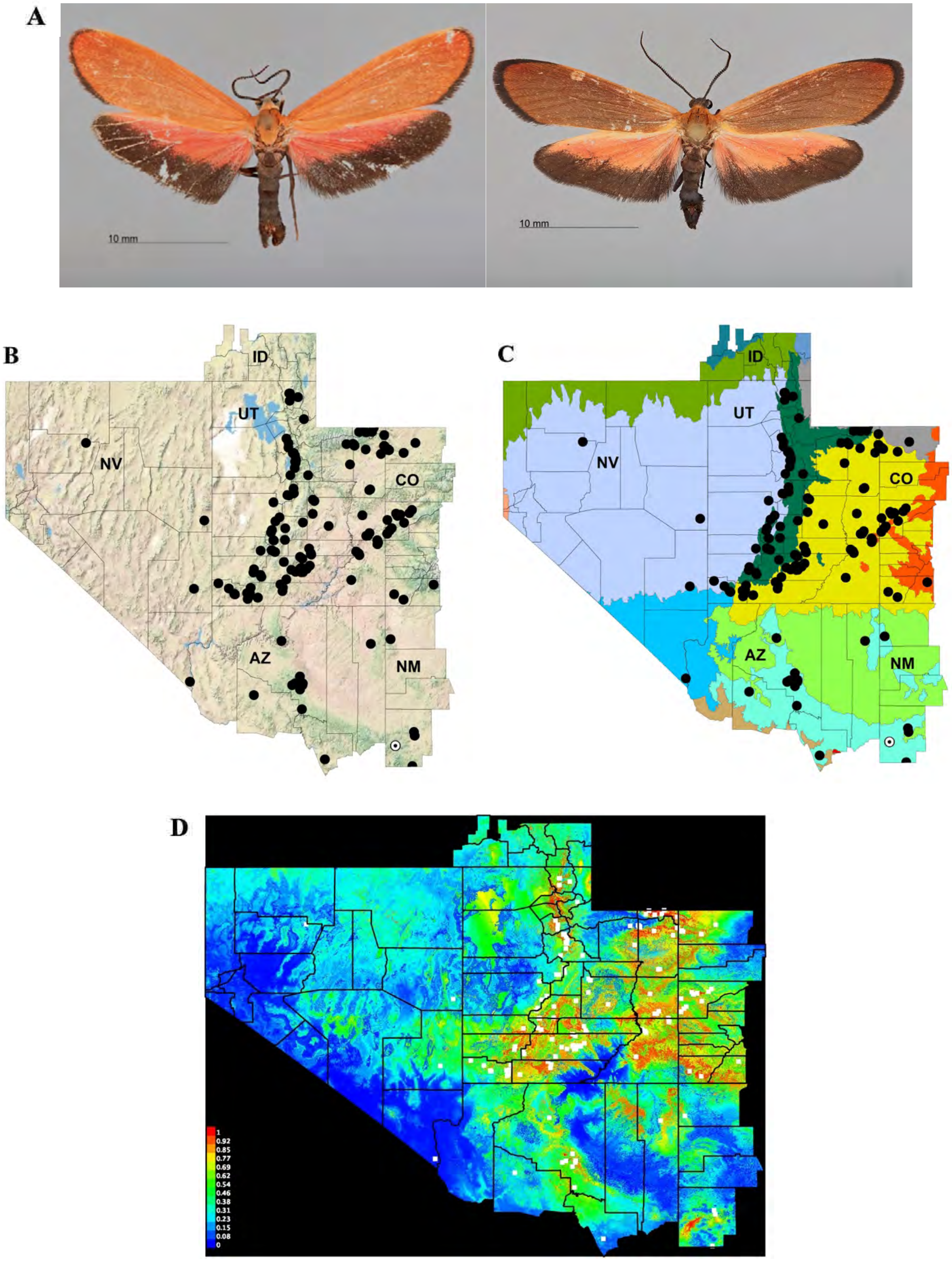


Figure 77. *Lycomorpha grotei* A: Specimen images (light and dark form), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, and Gila; COLORADO: Garfield, La Plata, Mesa, and Moffat; NEVADA: Lincoln and White Pine; NEW MEXICO: Catron and San Juan; UTAH: Beaver, Cache, Carbon, Daggett, Duchesne, Emery, Garfield, Grand, Iron Juab, Kane, Millard, Morgan, Piute, Salt Lake, San Juan, Sanpete, Sevier, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1927 - 2017

Flight Season: 28 April - 27 September

Elevation Range: 487 – 3388 m

Notes: The species is primarily nocturnal, but sometime found on flowers (Powell & Opler 2009). The species is also difficult to differentiate between *Lycomorpha grotei* and *Lycomorpha fulgens.* We left these identifications as collections had them because they are certainly in need of taxonomic work to distinguish or synonymize the three species (Powell & Opler 2009).

Lycomorpha pholus (Drury, 1773)

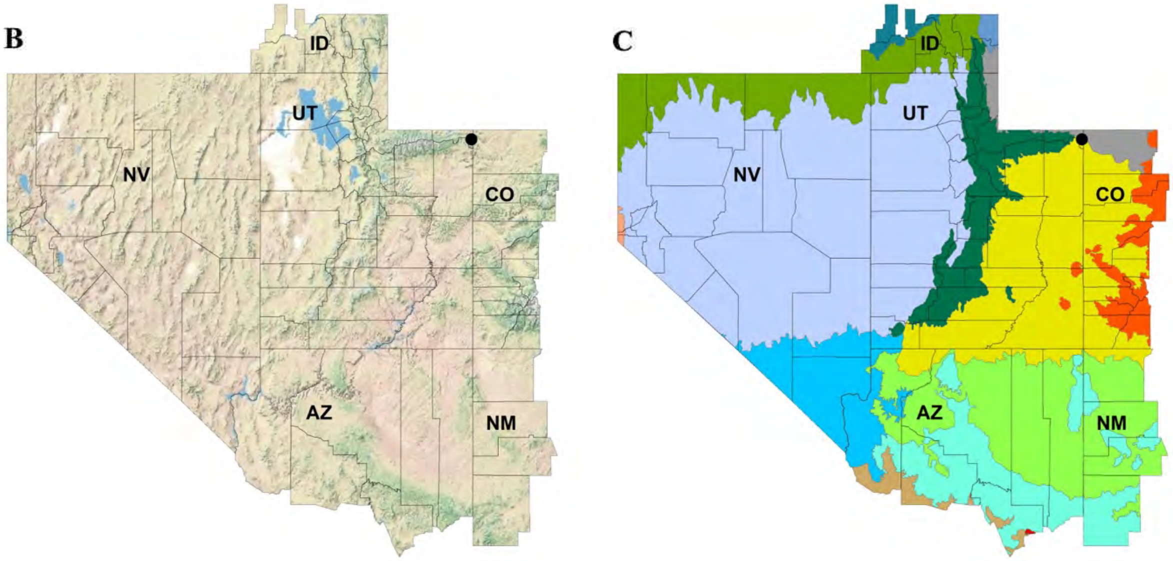


Figure 78. *Lycomorpha pholus* A: Specimen images (light and dark form), B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: UTAH: Daggett

Ecoregion Records: Colorado Plateaus

Years Collected: 1980

Flight Season: 5 August

Elevation Range: 1907 m

Notes: The species is easily identifiable with its color pattern. Limited with one record, we did not conduct an ENM analysis.

Lycomorpha regulus (Grinnell, 1903)

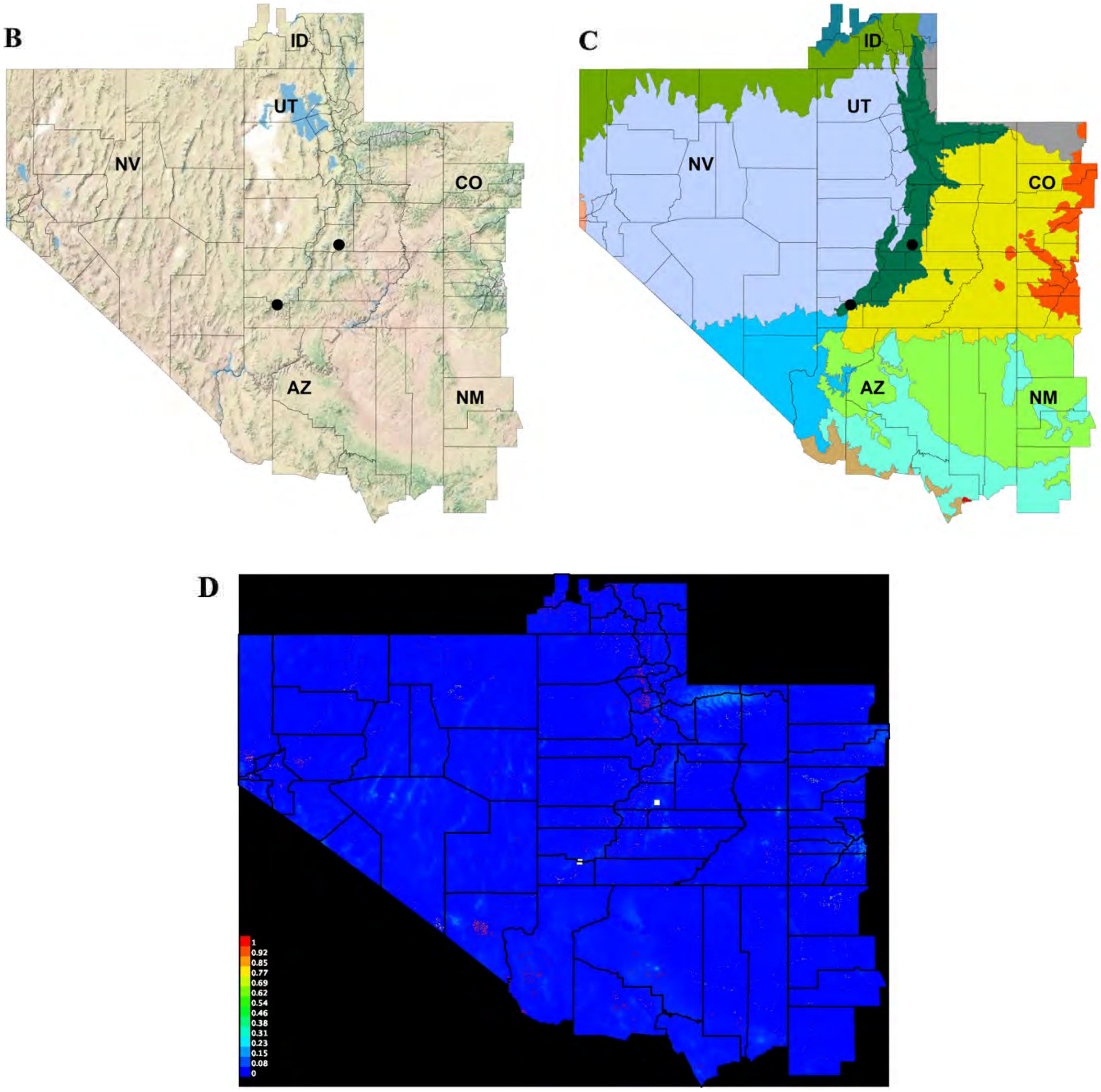


Figure 79. *Lycomorpha regulus* A: Specimen images (red and yellow form), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range

State and County Records: UTAH: Sevier and Washington

Ecoregion Records: Wasatch and Uinta Mountains

Years Collected: 2009 - 2010

Flight Season: 29 July and 15 October

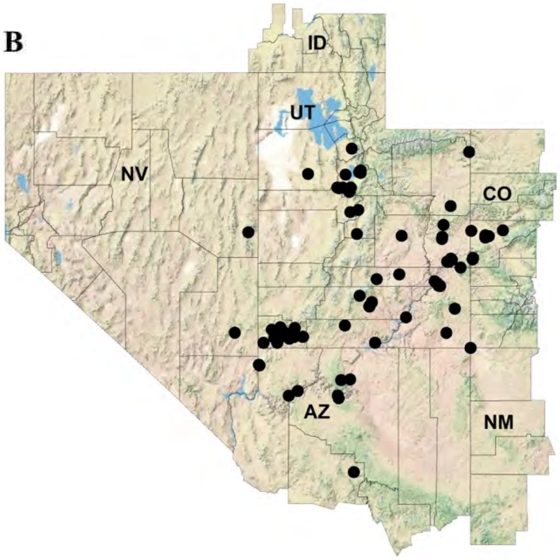
Elevation Range: 1841 – 2714 m

Notes: The species is not predicted to be in many areas. The species is also difficult to differentiate between *Lycomorpha grotei* and *Lycomorpha fulgens.* We left these identifications as collections had them because they are certainly in need of taxonomic work to distinguish or synonymize the three species (Powell & Opler 2009).

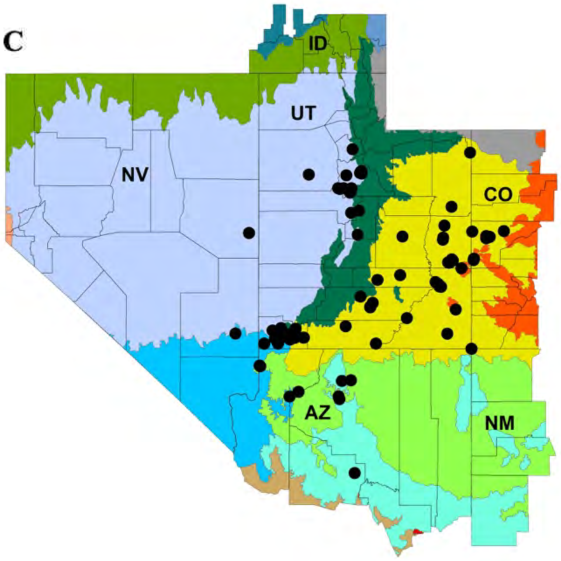
Lycomorpha splendens (Barnes & McDunnough, 1912)

A

B



C



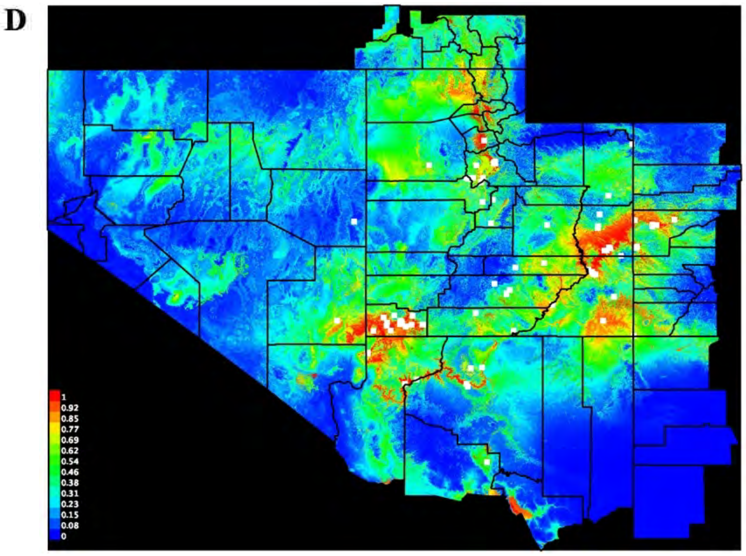


Figure 80. *Lycomorpha splendens* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range

State and County Records: ARIZONA: Coconino; Mohave, and Yavapai; COLORADO: Mesa and Montezuma; NEVADA: Lincoln and White Pine; UTAH: Garfield, Grand, Juab, Kane, Millard, Salt Lake, San Juan, Sanpete, Tooele, Uintah, Utah, Washington, and Wayne

Ecoregion Records: Colorado Plateaus

Years Collected: 1919 - 2017

Flight Season: 29 April - 27 October

Elevation Range: 367 – 2785 m

Notes: The species has been been widely collected across the Intermountain West, especially in southern Utah. It can occur in good numbers at lights. The species is easily distinguishable from other *Lycomorpha* species by having completely black forewings and completely red underwings with red spots on the thorax.

Pseudohemihyalea ambigua (Strecker, 1878)

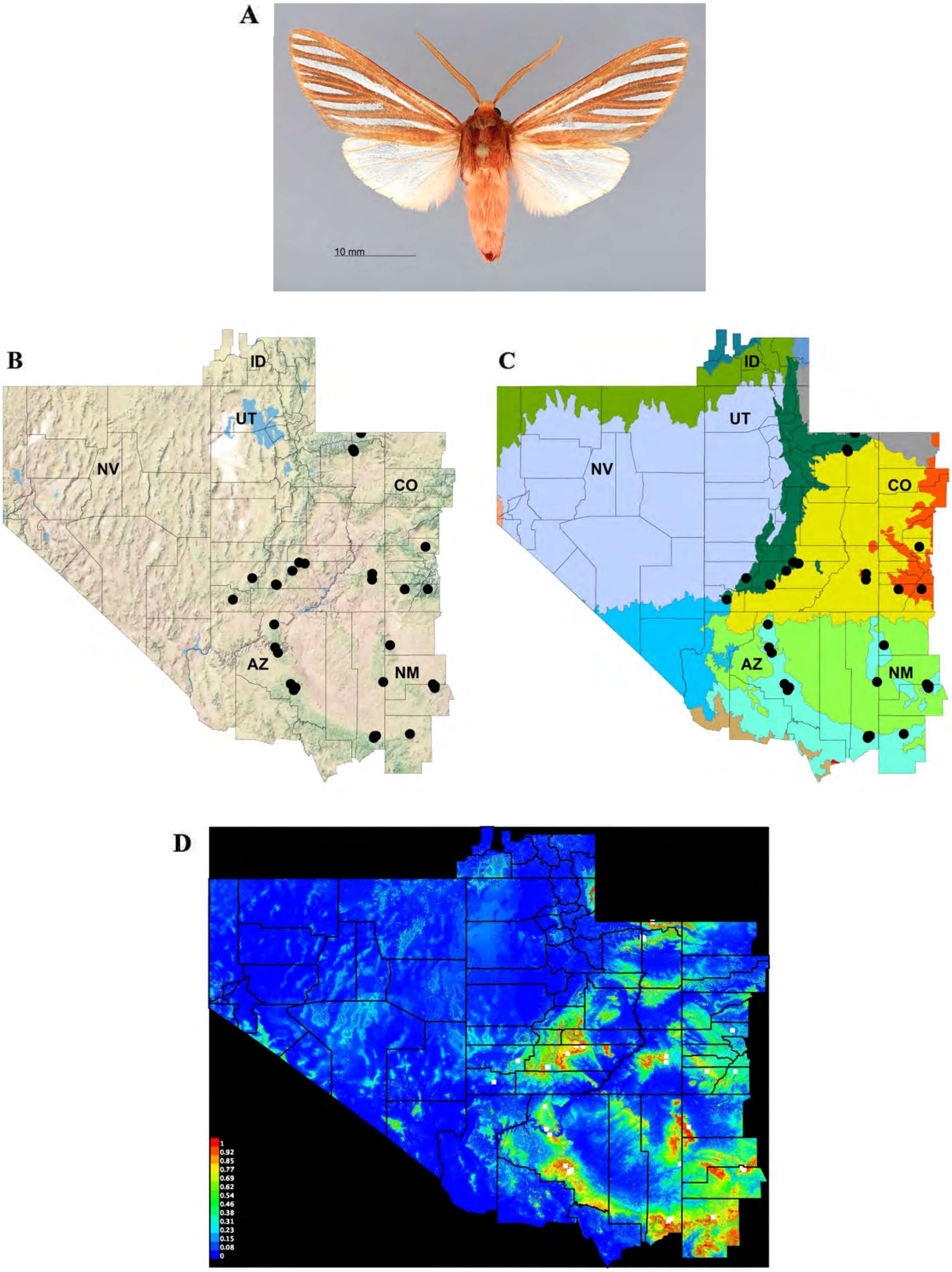


Figure 81. *Pseudohemihyalea ambigua* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range

State and County Records: ARIZONA: Apache and Coconino; COLORADO: La Plata, Montezuma, and Montrose; NEW MEXICO: Catron and Cibola; UTAH: Daggett, Garfield, Iron, San Juan, Uintah, Washington, and Wayne

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Colorado Plateaus, Southern Rockies, and Wasatch and Uinta Mountains

Years Collected: 1919 - 2013

Flight Season: 22 February, 12 June - 30 August

Elevation Range: 927 – 2682 m

Notes: The species has a tight association with pine, which are believed to the larvae's host (Powell & Opler 2009; Schmidt 2009). The species also has an interesting forewing pattern with longitudinal lines that differs from other members of the genus (Schmid 2009). It is believed that they are to mimic the dead pine needs of its habitat (Schmidt 2009). We found the association between the moth and pines to hold true within the Intermountain West and to largely occur in southern Utah and northern Arizona.

Pseudohemihyalea edwardsii (Packard, 1864)

A

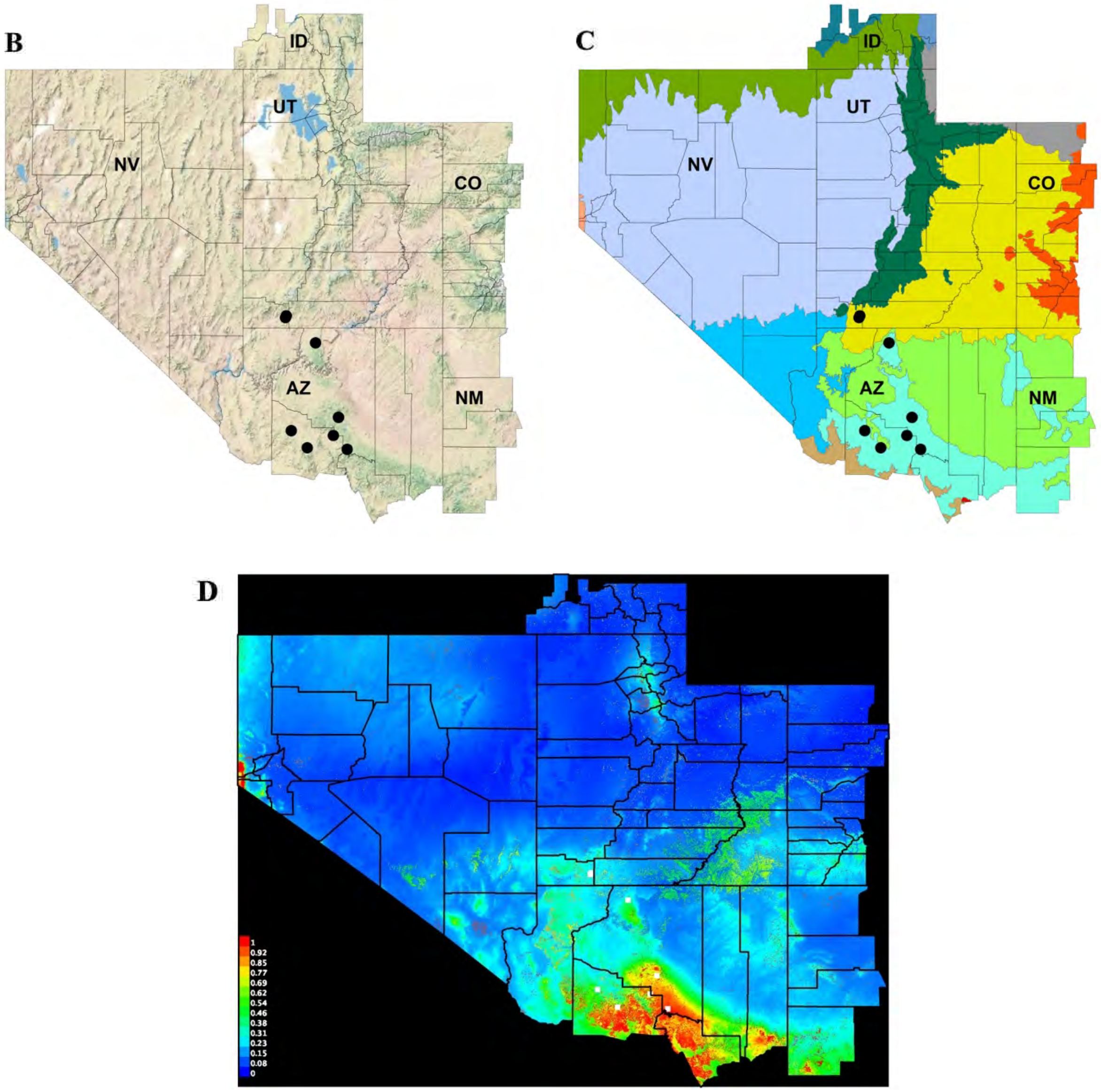


Figure 82. *Pseudohemihyalea edwardsii* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino and Yavapai; UTAH: Washington

Ecoregion Records: Arizona/ New Mexico Mountains and Colorado Plateaus

Years Collected: 1962 - 2012

Flight Season: 18 July - 15 October

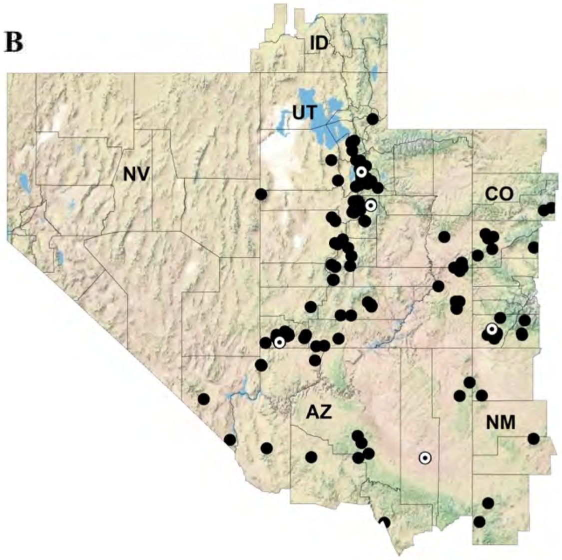
Elevation Range: 813 – 2408 m

Notes: The species in this genus are commonly known as glassy wing moths. They moth have tan forewings that generally lack scale and thoraxes that are tan while their abdomens are bright orange/red. This species is not very common in the Intermountain West and occurs in the south in Arizona. This species is also very difficult to distinguish from *Pseudohemihyalea labecula* and these two species are in need of taxonomic attention (Powell and Opler 2009).

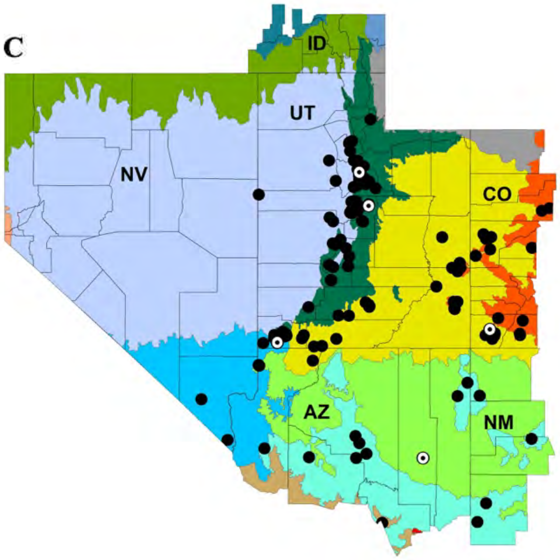
Pseudohemihyalea labecula (Grote, 1881)

A

B



C



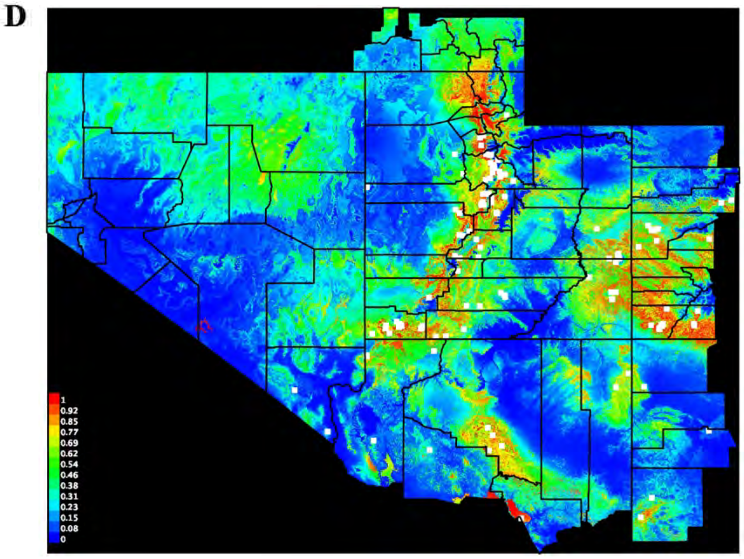


Figure 83. *Pseudohemihyalea labecula* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache, Coconino, Gila, Mohave, Navajo, and Yavapai; COLORADO: Delta Garafield, La Plata, Mesa, and Montezuma; NEVADA: Clark; NEW MEXICO: Catron and Cibola; UTAH: Garfield, Iron, Juab, Kane, Millard, Morgan, Piute, Salt Lake, San Juan, Sanpete, Sevier, Tooele, Utah, and Washington

Ecoregion Records: Arizona/ New Mexico, Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, and Southern Rockies, and Wasatch and Uinta Mountains

Years Collected: 1907 - 2018

Flight Season: 24 April - 30 October

Elevation Range: 689 – 3259 m

Notes: This species is much more common than *Pseudohemihyalea edwardsii* in the Intermountain West. This species is very difficult to distinguish from *Pseudohemihyalea edwardsii* and these two species are in need of taxonomic attention (Powell and Opler 2009).

Pygarctia murina (Stretch, 1885)

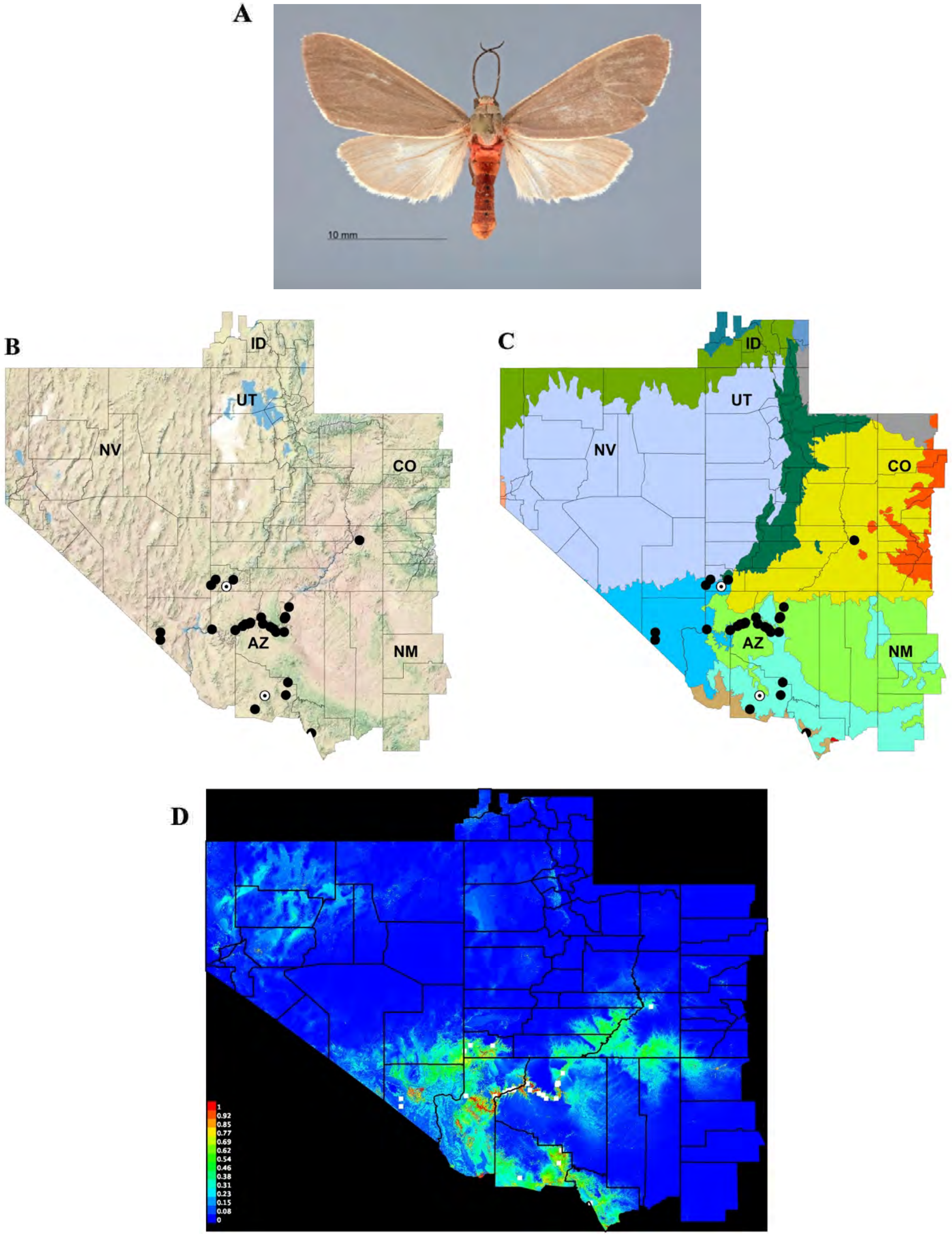


Figure 84. *Pygarctia murina* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino, Gila, Mohave, and Yavapai; NEVADA: Clark; UTAH: San Juan and Washington

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Colorado Plateaus, and Mojave Basin and Range

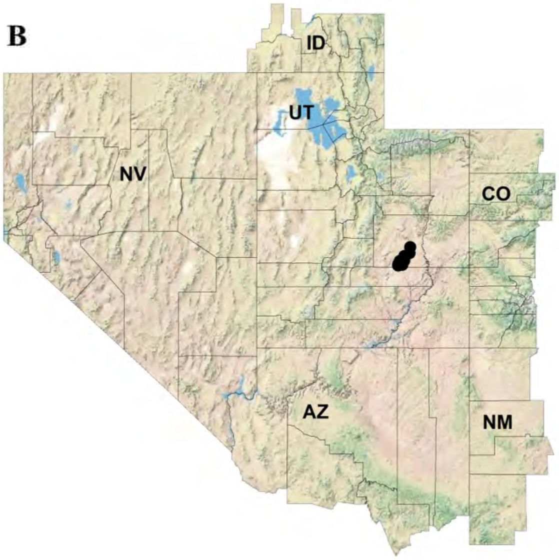
Years Collected: 1960 - 2012

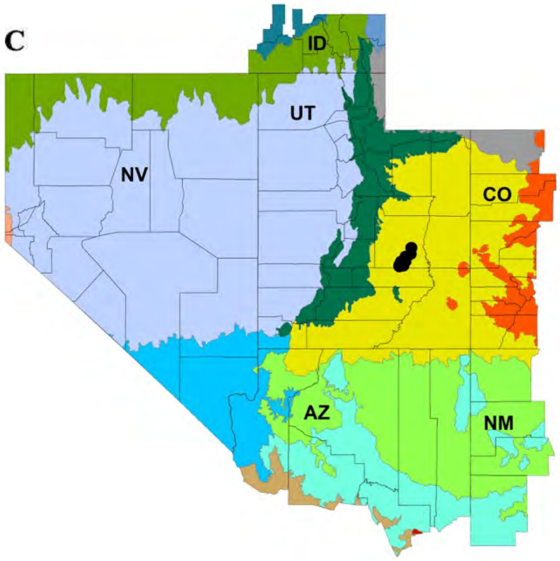
Flight Season: 10 April - 22 September

Elevation Range: 479 – 2499 m

Notes: A small gray and red moth that is primarily found in southern Utah and Arizona.

Pygarctia neomexicana (Barnes, 1904)





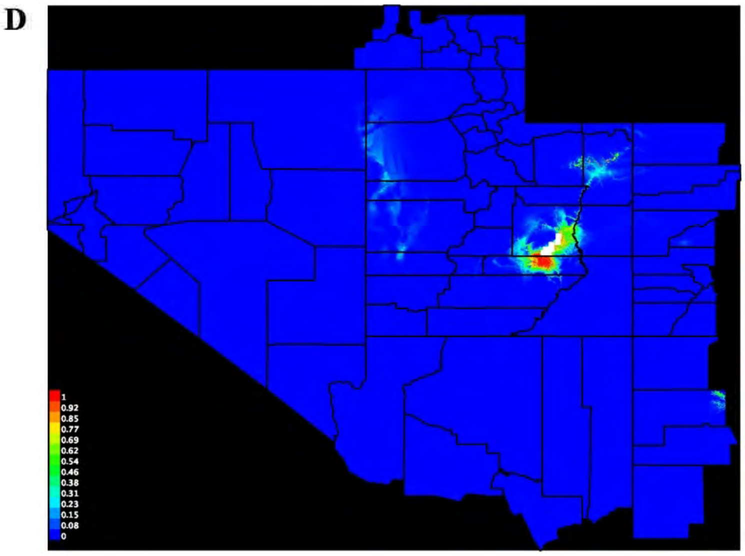


Figure 85. *Pygarctia neomexicana* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Emery

Ecoregion Records: Colorado Plateaus

Years Collected: 1998 - 2014

Flight Season: 9 May - 9 June

Elevation Range: 1499 – 2397 m

Notes: This species has been exclusively found in central Utah. It is similar to *P. murina*, but can be distinguished by having a pink on the inner margin of the hind wing (Moth Photographers Group 2018).

Pygarctia spraguei (Grote, 1875)

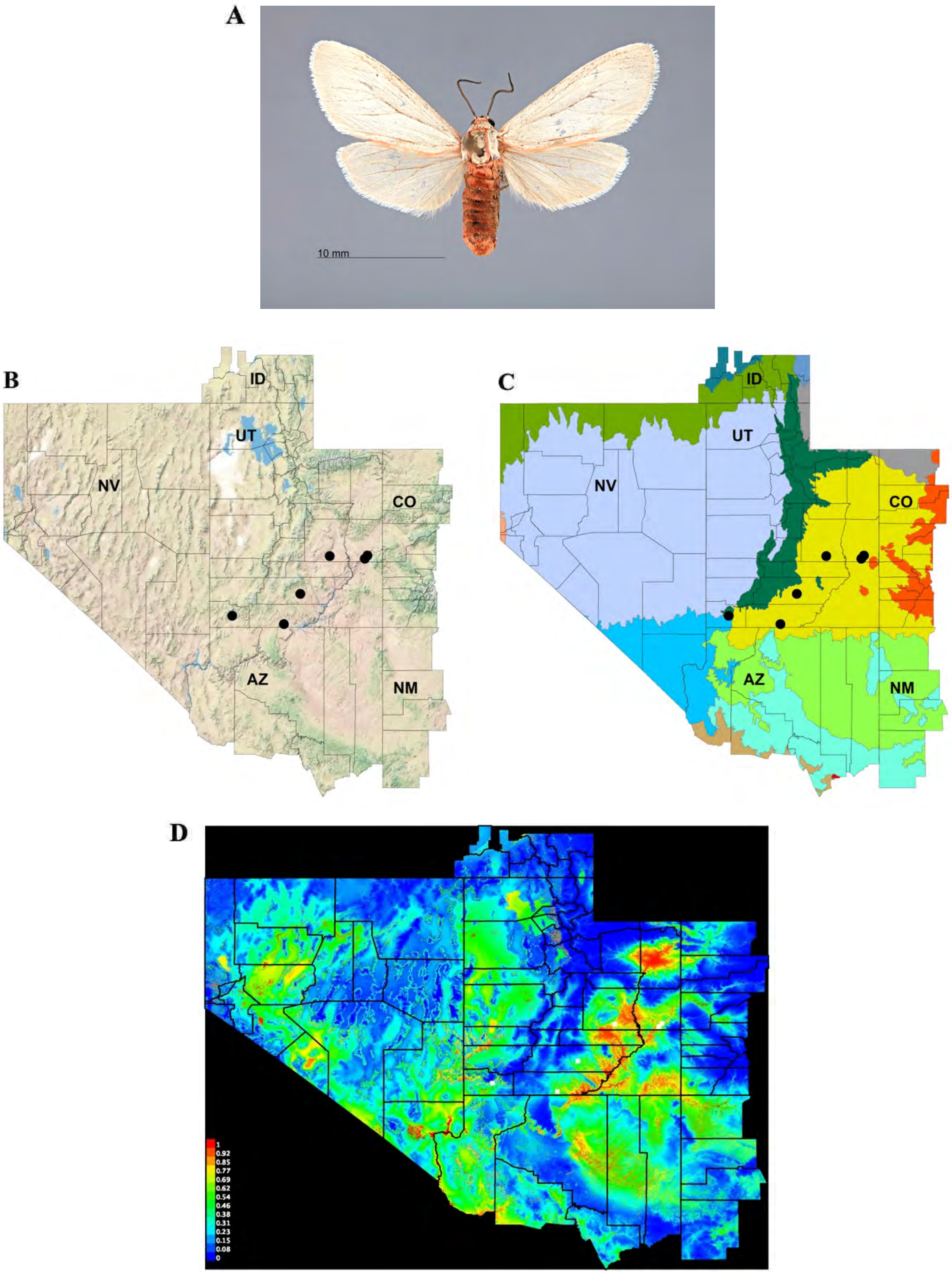


Figure 86. *Pygarctia spraguei* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: UTAH: Emery, Kane, Garfield, Grand, and Washington

Ecoregion Records: Colorado Plateaus and Wasatch and Uinta Mountains

Years Collected: 1992, 1994, 2003, and 2009

Flight Season: 10 June - 25 August

Elevation Range: 1226 – 2830 m

Notes: This species has been collected around central to southern Utah. It can be distinguished from other *Pygarctia spraguei* by having orange pink margins on the outer rims of its wings.

Pygoctenucha terminalis (Walker, 1854)

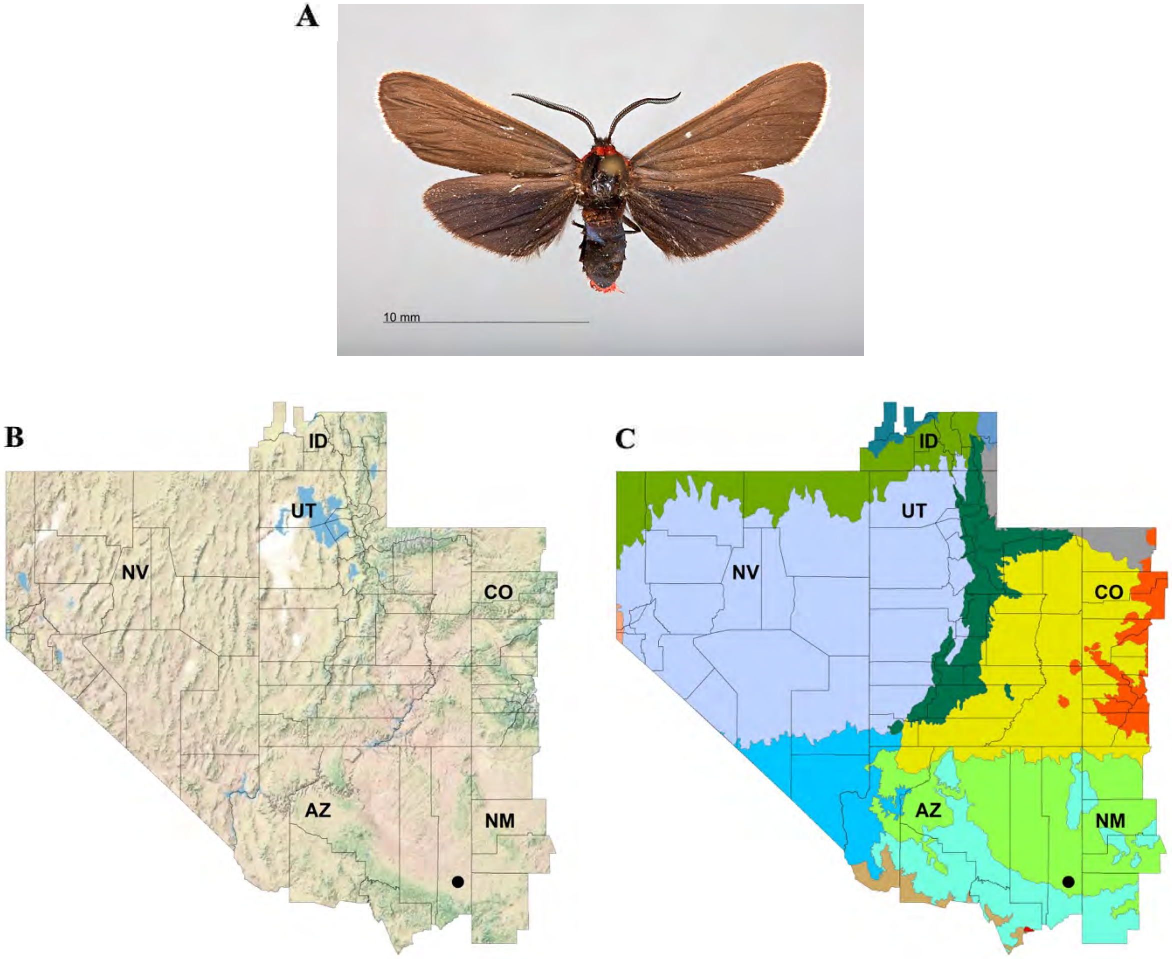


Figure 87. *Pygoctenucha terminalis* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: ARIZONA: Apache

Ecoregion Records: Arizona/ New Mexico Plateau

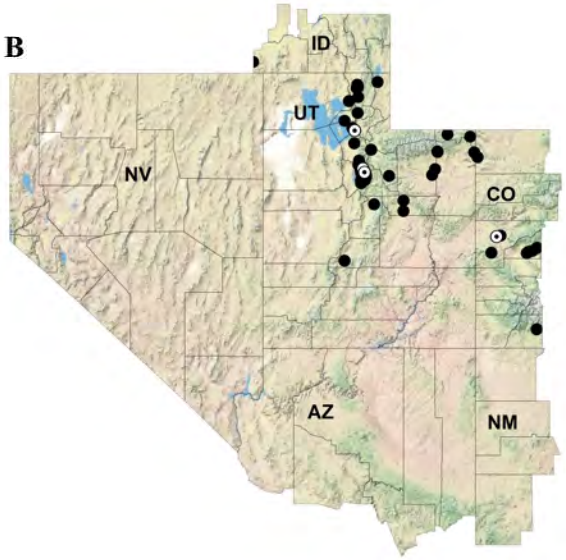
Years Collected: 1984

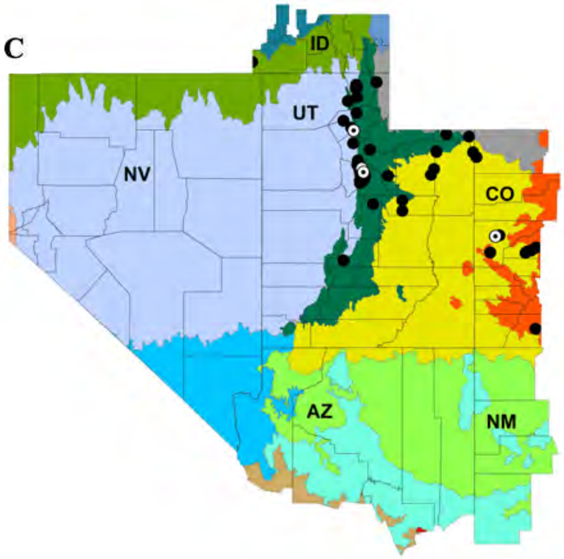
Flight Season: 4 August

Elevation Range: 1789 m

Notes: Limited with one record, we did not conduct an ENM analysis

Pyrrharctia isabella (Smith, 1797)





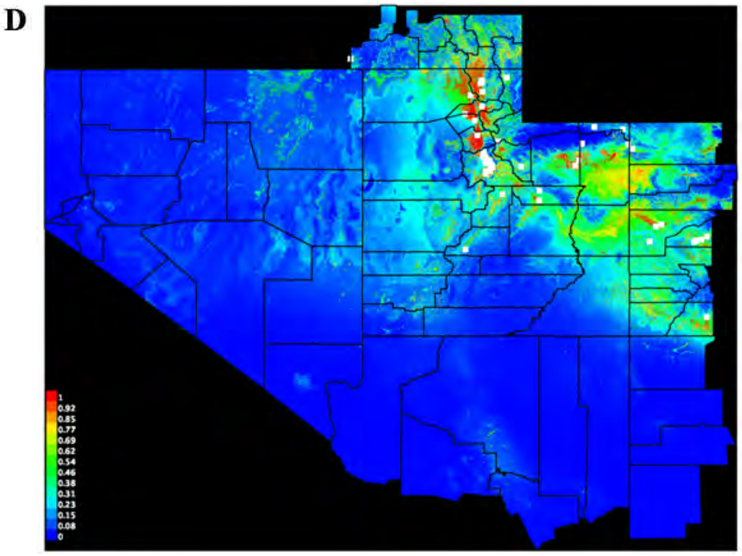


Figure 88. *Pyrrharctia isabella* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta, La Plata, Mesa, and Moffat; IDAHO: Cassia; UTAH: Box Elder, Cache, Carbon, Daggett, Davis, Duchesne, Rich, Salt Lake, Sanpete, Sevier, Uintah, Utah, and Weber

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1918 - 2009

Flight Season: 3 January, 19 April - 15 September

Elevation Range: 1281 – 2953 m

Notes: The species is a cream color with hindwings with a slight pink hue. The larvae are commonly known as the woolly bears and have a red orange center that is believed to predict the severity of the upcoming winter (Wagner 2009; Powell & Opler 2009).

Spilisoma latipennis (Stretch, 1872)

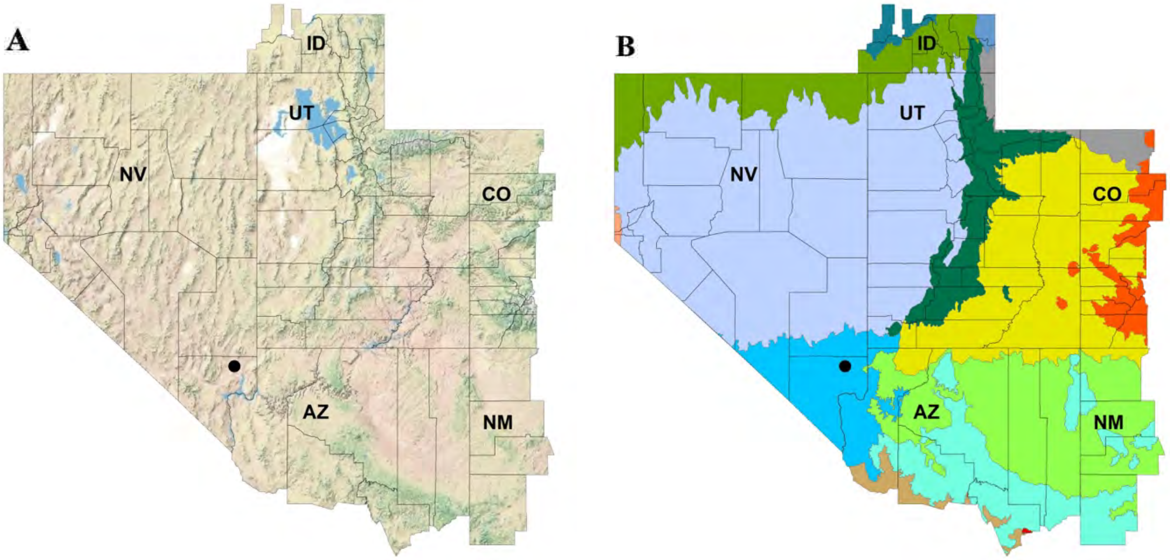


Figure 89. *Spilisoma latipennis* A: Topographic map of documented occurrences and B: Level III ecoregion map of documented occurrences

State and County Records: NEVADA: Clark

Ecoregion Records: Mojave Basin and Range

Years Collected: 1930

Flight Season: 1 August

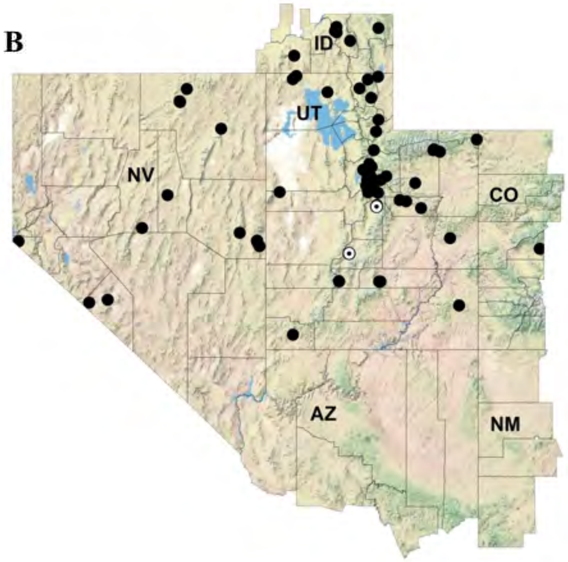
Elevation Range: 463 m

Notes: The species is similar to *Spilisoma virginica,* but instead of yellow forelegs, has pink/red forelegs and is not common in the Intermountain West. Limited with one record, we did not conduct an ENM analysis.

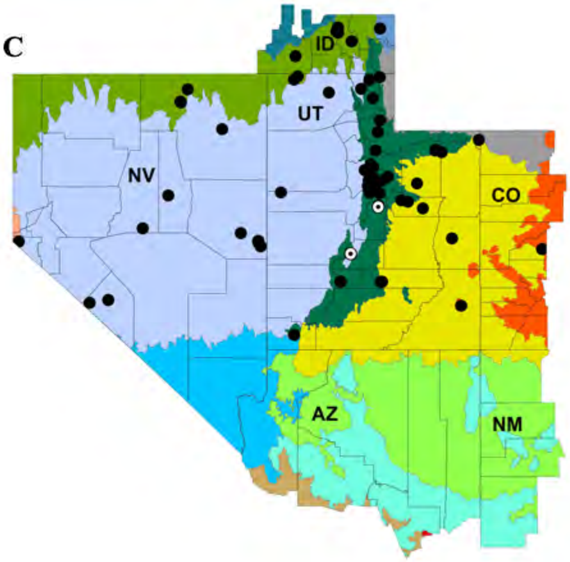
Spilisoma vagans (Boisduval, 1852)

A

B



C



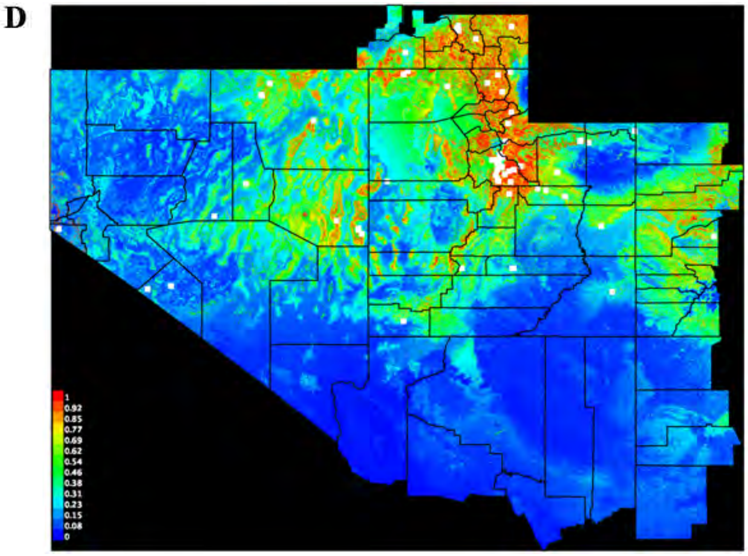


Figure 90. *Spilisoma vagans* A: Specimen images (various forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta; IDAHO: Bannock, Caribou, and Cassia; NEVADA: Douglas, Elko, Esmeralda, Lander, Nye, and White Pine; UTAH: Box Elder, Cache, Carbon, Daggett, Duchesne, Grand, Juab, Morgan Piute, Rich, San Juan, Sanpete, Summit, Uintah, Utah, Wasatch, Washington and Wayne.

Ecoregion Records: Central Basin and Range, Colorado Plateaus, and Middle Rockies, Northern Basin Range, Sierra Nevada, Southern Rockies, Wasatch and Uinta Mountains, and Wyoming Basin

Years Collected: 1925 - 2016

Flight Season: 9 May - 14 August

Elevation Range: 1211 – 3183 m

Notes: The species has variation, but are always some kind of tan. It is one of the few tiger moths that is not aposematically colored.

Spilosoma vestalis (Packard, 1864)

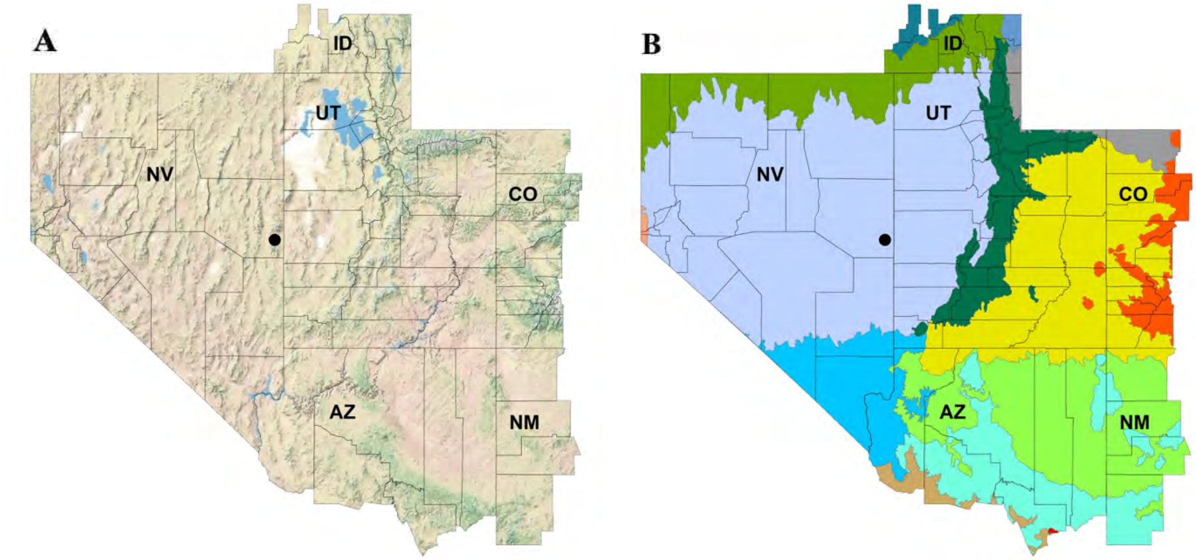


Figure 91. *Spilisoma vestalis* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: NEVADA: White Pine

Ecoregion Records: Central Basin and Range

Years Collected: 2000

Flight Season: 20 June

Elevation Range: 2316 m

Notes: This is not a common species in the Intermountain West. Limited with one record, we did not do an ENM analysis.

Spilisoma virginica (Fabricius, 1788)

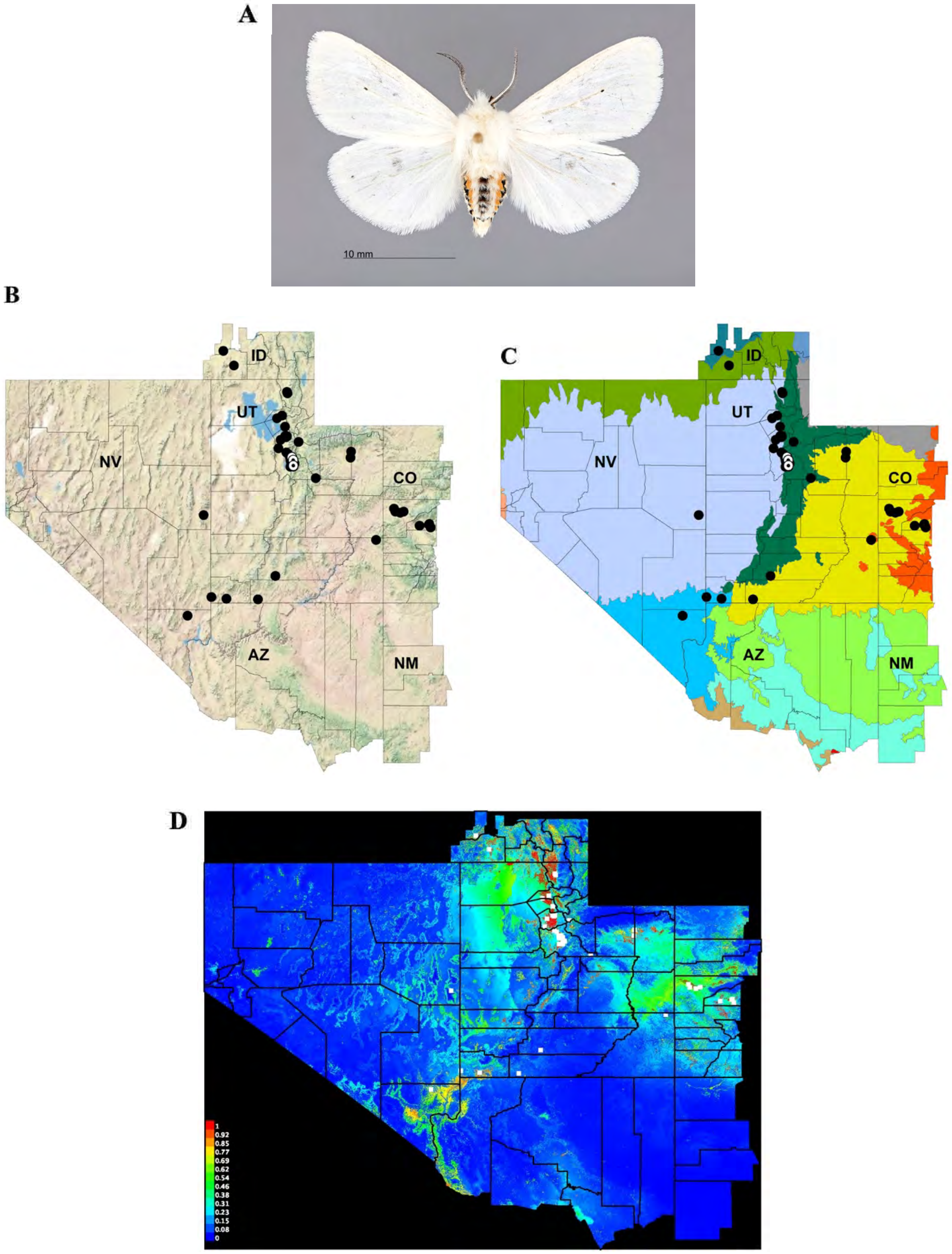


Figure 92. *Spilisoma virginica* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: COLORADO: Delta and Mesa; IDAHO: Cassia and Minidoka; NEVADA: Clark and White Pine; UTAH: Cache, Davis, Duchesne, Garfield, Grand, Kane, Salt Lake, Uintah, Utah, Washington, and Weber

Ecoregion Records: Central Basin and Range, Colorado Plateaus, Mojave Basin and Range, Northern Basin Range, Snake River Plain, Southern Rockies, and Wasatch and Uinta Mountains

Years Collected: 1906 - 2013

Flight Season: 20 January, 21 March - 8 October

Elevation Range: 843 – 3259 m

Notes: The species is similar to *Spilisoma latipennis,* but much more common. See 'Notes' of *S. latippennis* for more details on how to distinguish between the two. The species is also similar to *Hyphantria cunea* with white wings and yellow forelegs. This species can be distinguished by having sparse spots if present and a yellow and black pattern down the abdomen.

Virbia aurantiaca (Hübner 1831)

A

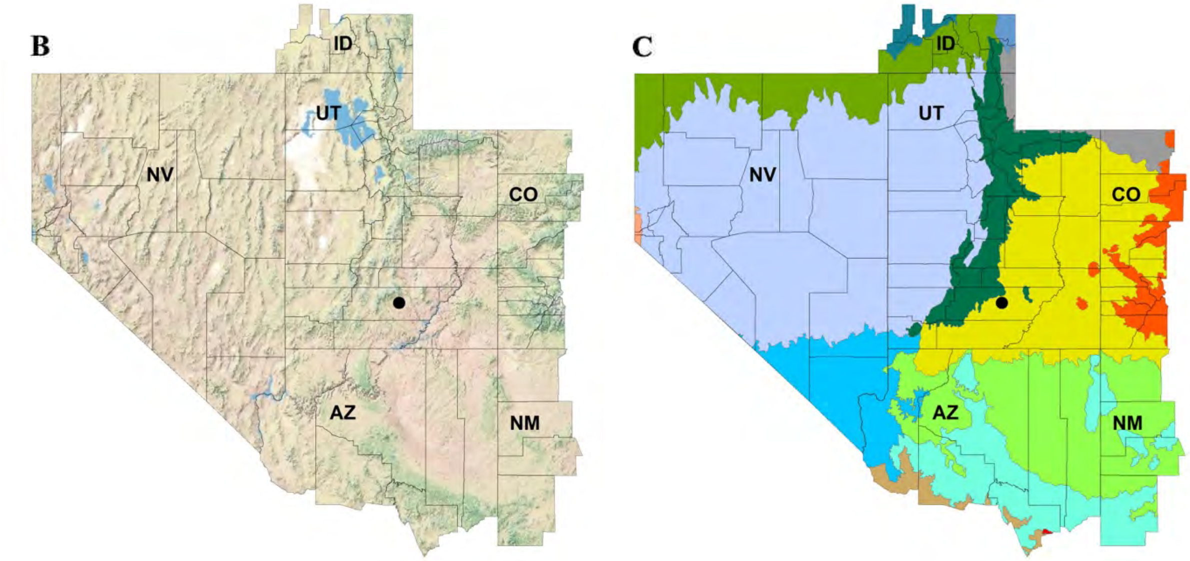


Figure 93. *Virbia aurantiaca* A: Specimen image, B: Topographic map of documented occurrences, and C: Level III ecoregion map of documented occurrences.

State and County Records: UTAH: Garfield

Ecoregion Records: Colorado Plateaus

Years Collected: 2000 - 2001

Flight Season: 23 June - 2 July

Elevation Range: 1580 - 1813m

Notes: The species is similar to *Virbia fragilis,* but is smaller and has subterminal markings on its hindwings (Zaspel et al. 2008). Limited with one record, we did not conduct an ENM analysis.

Virbia costata (Stretch, 1885)

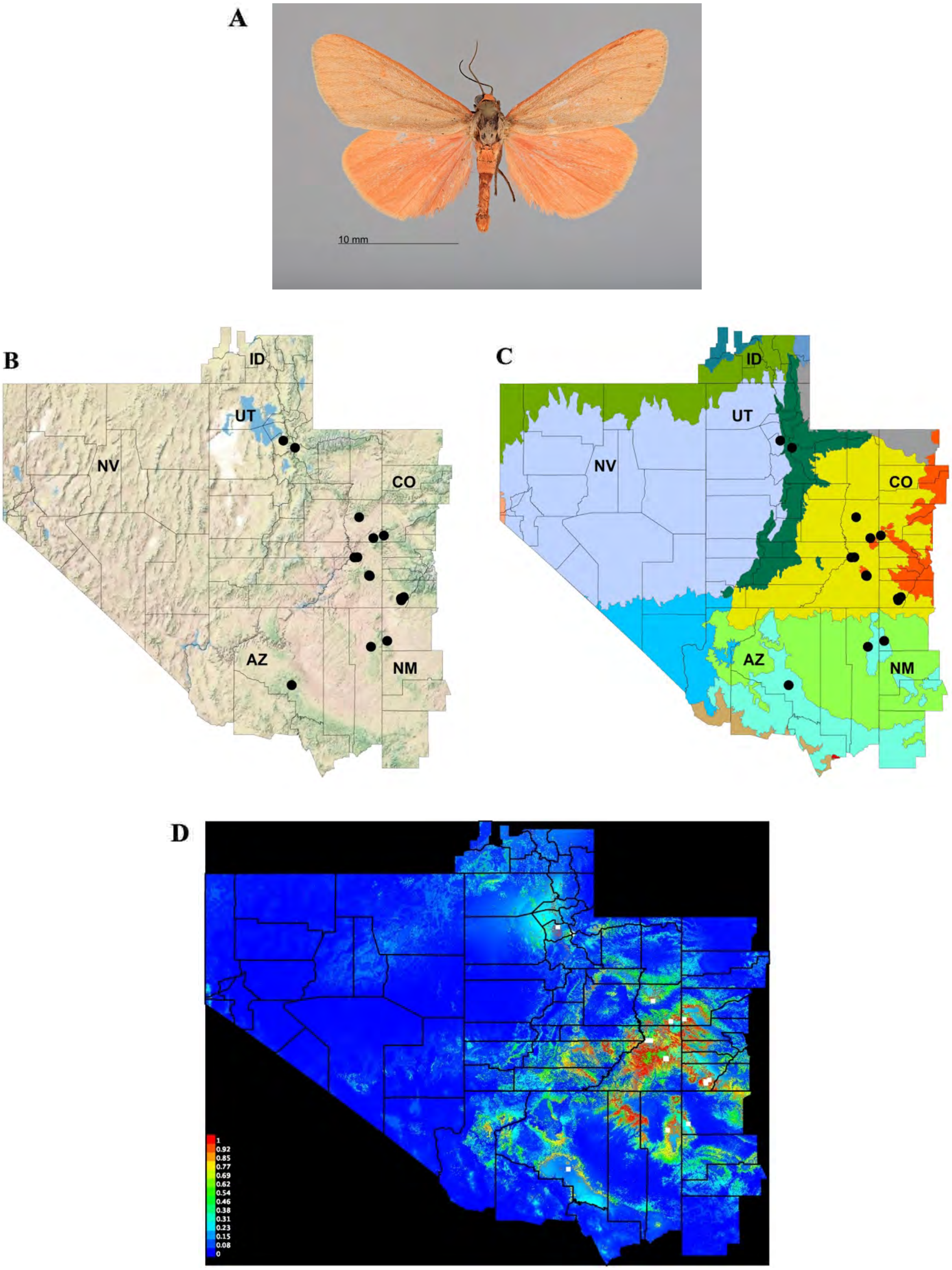


Figure 94. *Virbia costata* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Apache and Coconino; COLORADO: Mesa and Montezuma; NEW MEXICO: San Juan; UTAH: Grand, Salt Lake, San Juan, and Wasatch

Ecoregion Records: Arizona/ New Mexico Mountains, Arizona/ New Mexico Plateau, Colorado Plateaus, Southern Rockies,and Wasatch and Uinta Mountains

Years Collected: 1967 - 2017

Flight Season: 6 June - 28 August

Elevation Range: 1300 – 2497 m

Notes: The species occurs largely within the Colorado Plateau. It can generally be distinguished from the other *Virbia* species by its light orange hind with no design, but the sexes are dimorphic. As such, males can be sometimes confused with *Virbia fragilis* and to distinguish them one must look at genitalia characters (Zaspel et al. 2008). We did our best in these cases of specimen verification.

Virbia fragilis (Strecker, 1878)

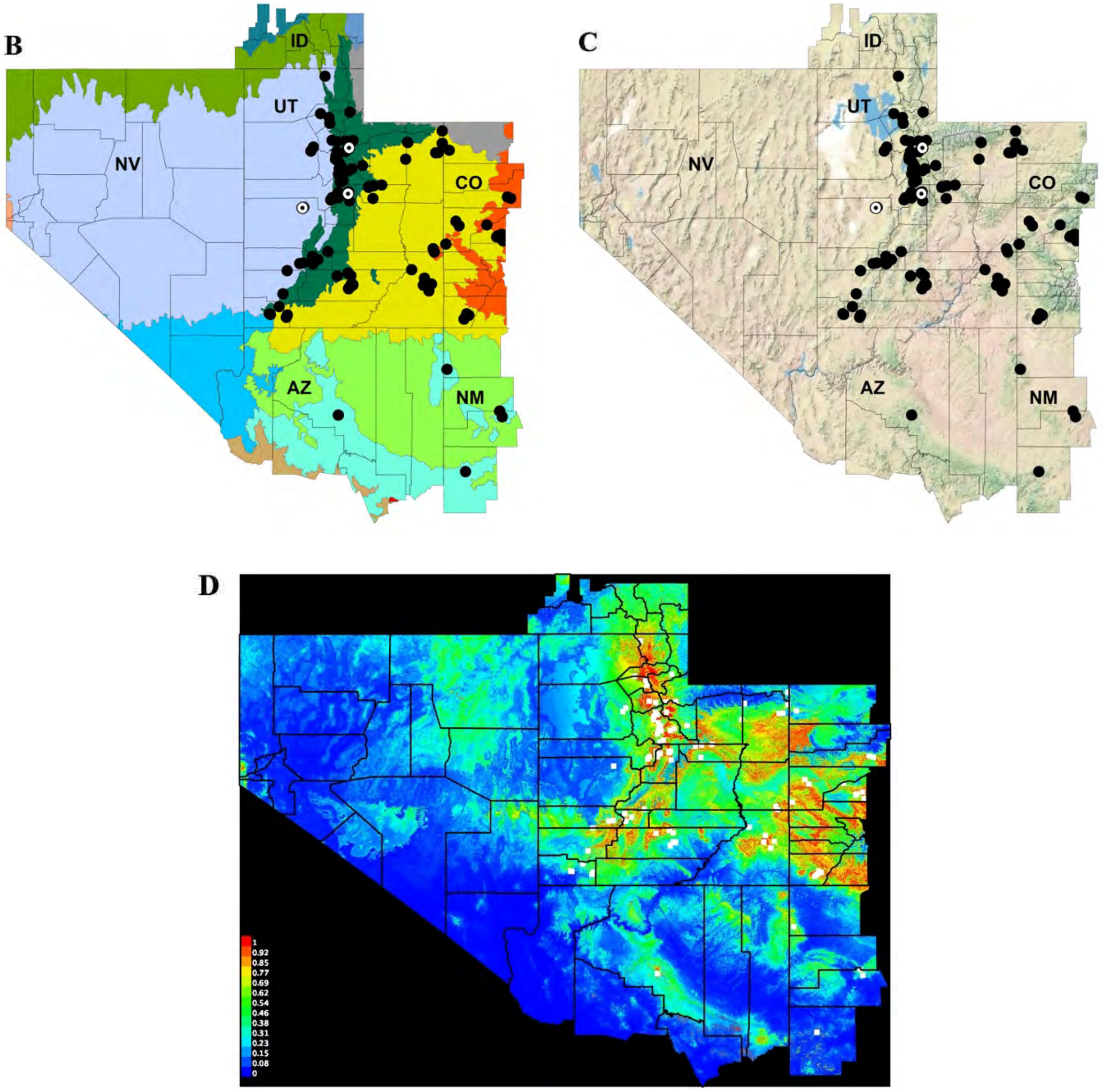


Figure 95. *Virbia fragilis* A: Specimen images (marked and pale forms), B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino; COLORADO: Delta, Garfield, Gunnison, Mesa, Moffat, and Montezuma; NEW MEXICO: Catron, Cibola, and San Juan; UTAH: Beaver, Cache, Carbon, Daggett, Davis, Duchesne, Garfield, Grand, Iron, Juab, Millard, Morgan, Piute, Salt Lake, San Juan, Sanpete, Sevier, Summit, Tooele, Uintah, Utah, Wasatch, Washington, and Weber

Ecoregion Records: Arizona/ New Mexico Mountains, Central Basin and Range, Colorado Plateau, Southern Rockies, and Wasatch and Uinta Mountains

Years Collected: 1918 - 2018

Flight Season: 7 May - 3 September

Elevation Range: 1218 – 3380 m

Notes: The species has been collected across our region, but hasn't been documented in Nevada. This could be due to a lack of undersampling for the state as a section of the state is marked with moderate probability from our model to be present. The species can resemble *Virbia aurantica* and male *Virbia costata*, see their respective 'Notes' for more details on how to distinguish the species.

Virbia ostenta (Edwards, 1881)

A

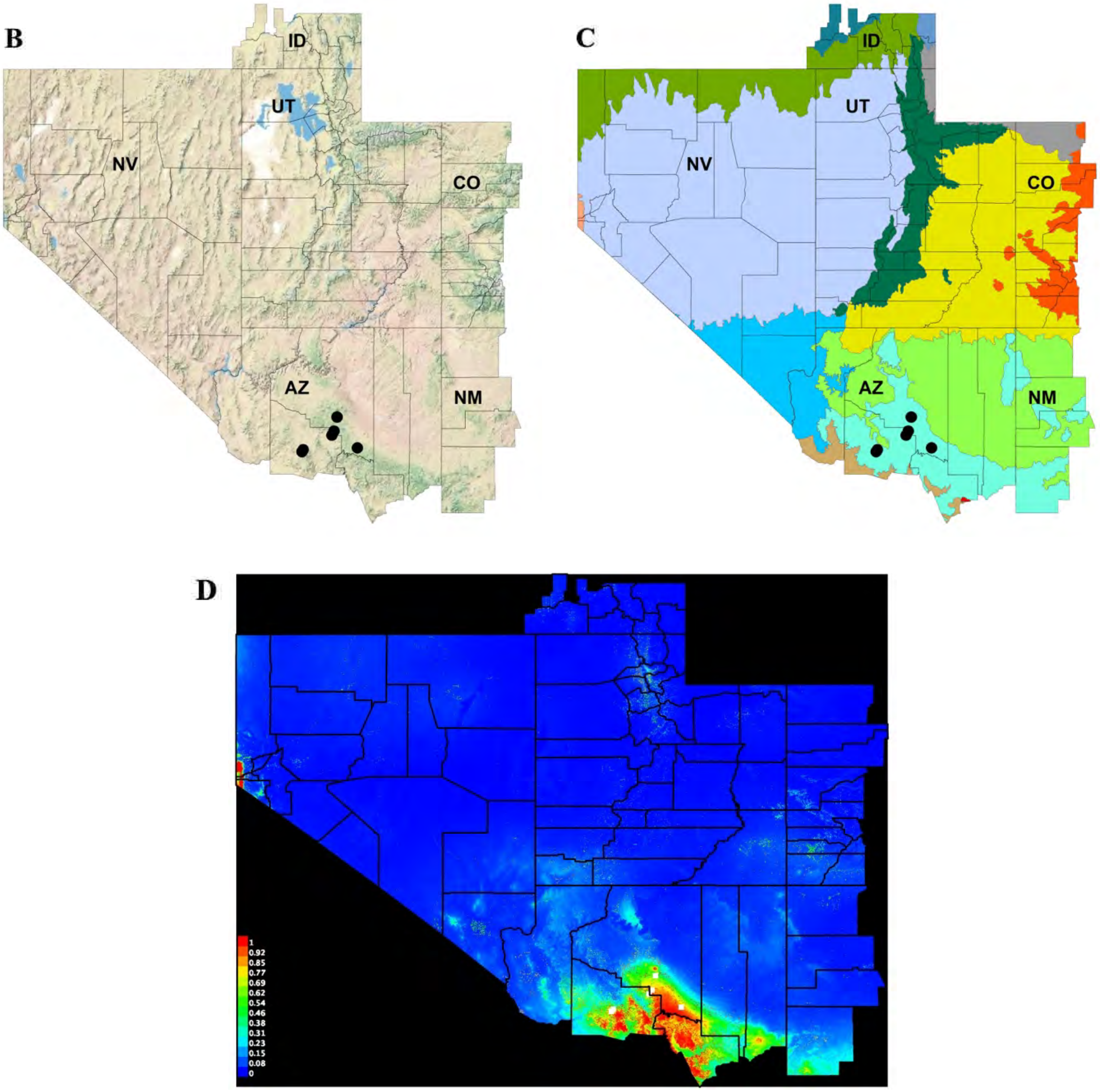


Figure 96. *Virbia ostenta* A: Specimen image, B: Topographic map of documented occurrences, C: Level III ecoregion map of documented occurrences, and D: Predicted ENM map with documented occurrences and estimated range.

State and County Records: ARIZONA: Coconino and Yavapai

Ecoregion Records: Arizona/ New Mexico Mountains

Years Collected: 1967 - 2006

Flight Season: 11 July - 21 August

Elevation Range: 1395 – 2104 m

Notes: As the largest *Virbia*, this species ranges from Arizona to New Mexico (Zaspel et al. 2008; Powell & Opler 2009). The species also has the most southern distribution out of the *Virbia* species we evaluated.

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Chapter 3. Pick your poison: the decision of what's for dinner for the lichen feeding caterpillars of *Cisthene angelus* (Lepidoptera: Erebidae: Arctiinae)

Introduction

Optimal larval performance for many holometabolous insects correlates with locating appropriate food sources (Marazzi & Städler 2005; Thompson & Pellmyr 1991; Singer et al. 1988; Gripenberg et al. 2010). For many Lepidoptera, the adult female finds appropriate hosts on which she lays her eggs (Singer 1984; Ramaswamy et al. 1987; Thompson & Pellmyr 1991; Renwick & Chew 1994; Thompson 1988). However, in Arctiinae (Lepidoptera: Erebidae), commonly known as the tiger moths, some caterpillars are principally responsible for finding appropriate food sources for their survival (Dethier 1988; Castrejon 2006).

Arctiinae caterpillar host selections have received considerable attention as many are pharmacophagous, meaning they feed on noxious plants for chemicals rather than nutrients. (Boppré 1984; Boppré 1990). The best understood of these chemicals are pyrrolizidine alkaloids (PAs) (Bowers 2009; Boppré 1990; Conner & Weller 2004; Hartman 2009). PAs give the moths their distasteful properties (Conner 2009; Hristov & Conner 2005) and are involved in the morphogenesis of male pheromone structures called coremata (Schneider et al 1982; Boppré & Schneider 1985; Davenport & Conner 2003; Jordan et al. 2007), and the production of PA laced spermatophores (Dussourd et al. 1991; LaMunyon 1997; Dussourd et al. 1988; Iyengar 1999). With these enhancements to survival and reproduction, PAs greatly influence host selection and PA-specialist caterpillars select foliage and seed pods with the highest levels of PAs (Hartmann 2009; Hartmann & Witte 1995).

In contrast to their phytophagous counterparts, less is known about what influences host selection within Lithosiini. Lichens are resistant to herbivory due to flat, inaccessible growth forms and an array of secondary chemistry. Indeed, lichenivory among invertebrates is uncommon (Pöykkö et al. 2005; Zukal 1895; Rundel 1978; Solhaug & Gauslaa 2012; Lawrey 1986; Molnár & Farkas 2010). However, Lithossini, a large tribe of 3,000 species (Common 1990; Holloway 2002), are recorded to feed on lichens (meaning both the fungal: mycobiont and algal: photobiont components), algae, mosses, and/or liverworts (Lafontaine et al. 1982; Wagner et al. 2008; Moskowitz & Westphal 2002; Rawlins 1984). Despite such a large lineage having this unique feeding behavior, actual host records are scarce (J. Zaspel pers. com.; Moskowitz & Westphal 2002; Anderson et al. 2017). Those that do exist are also generalizations, rarely identifying host specifics and come from assumptions from where caterpillars were found, not necessarily what they were eating (Moskowitz & Westphal 2002). This has left our understanding of the Lithosiini caterpillar-host interaction rudimentary at best.

Debate exists if Lithosiini caterpillars are true lichen feeders, meaning they consume the mycobiont components of lichen (Rawlins 1984), or if they avoid the lichenized fungus in a search for lichen-associated algae (Hesbacher et al. 1995; Wagner et al. 2008; Scott et al. 2014). *Hypoprepia fucosa* was found in its natural habitat feeding on free living algae by scraping it from substrates (Moskowitz & Westphal 2002). When given lichen in captivity the caterpillars fed by scraping to peel off the lichen cortex with algae, not going into the medullary layer comprised primarily of fungal hyphae (Moskowitz & Westphal 2002). In another case, *Clemensia albata* rejected lichens and solely fed on algae in captivity (McCabe 1981). This has led some researchers to propose lithosiines as primarily algal feeders and feeding on lichens, mosses, or other substrates as merely incidental as caterpillars search for algal meals (Rawlins 1984; Moskowitz & Westphal 2002). Subsequently, many species have successfully been reared exclusively on algae, although the majority of these are not published (Moskowitz & Westphal 2002; Wagner 2008).

Only a few lithosiine species have been reared on lichens. Wagner et al. reared multiple caterpillars from a couple species they found in their last instars on various lichens (2008); and Anderson et al. (2017) reared *Crambidia cephalica* from eggs using *Physcia* lichens. Nevertheless, despite the lack of observed feeding on the mycobiont, many lithosiine caterpillars have been found to still have an important relationship with the lichenized fungus. Several studies have identified sequestered lichen mycobiont metabolites within lithosiines (Hesbacher et al. 1995; Scott et al. 2014; Anderson et al. 2017) Furthermore, Chialvo et al. (2018) found that sequestration from a single lichen chemical pathway may represent an early synapomorphy for the group followed later by the ability to sequester phenolics produced by multiple pathways.

Several factors likely influence host selection, but secondary chemistry is likely one of them. Chialvo et al. (2018) reported that phenolic sequestration patterns were more similar within lithosiine species than among congeners. Similar to phytophagous arctiines, the advantages gained by host secondary chemistry may induce host preferences (Chialvo et al. 2018). Lichen photobionts may be the primary nutrient source, but caterpillars may selectively choose to feed on lichens with desirable mycobiont metabolites (Chialvo et al. 2018). Lichen-feeding behavior is believed to make the moths less palatable to bats and birds (Hristov & Connor 2005; Acharya & Fenton 1992; Dowdy & Conner 2016). However, in preference tests with *Eilema* spp. larvae were also seen to avoid lichens rich in polyphenolics, e.g., like usnic and vulpinic acid (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005). In preference tests, caterpillars ate minor portions of such lichens, but when exclusively fed them, caterpillars quickly died (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005). The two *Eilema* spp. studies are the only studies that have empirically investigated factors that influence host preferences within lithosiine larvae and demonstrate that preferences may not be as clear cut as we initially suspected.

Our study further explores the potential impacts of host chemistry in lithosiine caterpillar host preferences in *Cisthene angelus*, common moths in the arid Intermountain West (Fig. 1). Wagner et al. (2008) reported rearing these on algae, but lichens are likely more suitable hosts in their natural environment where free-living algae are scarce and lichens are abundant. Other congeners, *C. martini* and *C. tenuifascia*, have also been documented to incorporate phenolics from lichen feeding behavior (Scott et al. 2014) and *C. angelus* is likely to follows suit. We verified the lichen feeding behavior of the putatively lichenivorous *C. angelus* and conducted caterpillar host preference tests. Potential lichen hosts within the moth's environment vary in chemical profiles and we performed these preference tests to see how these chemical differences influence host selection. We specifically tested how *C. angelus* caterpillars interact with host secondary chemical usnic acid that deter *Eilema* spp., other lithosiines (Pöykkö et al. 2005). We hypothesized *C. angelus* caterpillars to similarly avoid lichens from their habitat that contained usnic acid.

Materials and Methods

We chose to investigate *Cisthene angelus* (Fig. 1) because of their ease of identification, abundance, and female attraction to light that made it easy to obtain eggs. We collected 44 gravid female *C. angelus* moths and transferred them into 50 ml vials to lay eggs (Fig. 2) on 30-31 August 2017. Our study site was in Leeds Canyon, Utah (Fig. 3) and we attracted moths using ultraviolet (UV) light traps (BioQuip 2851 bucket set with 12 watt UV bulb) and mercury vapor lights (Regent Model H38100MDX). The study site was located at 37.270174° N,113.378406°

W at an elevation of 1280 meters in an arid region with much red rock in a rich shrub transition zone.

At the same time and site, we chose three abundant lichens to keep as constant food options for the caterpillars to choose from during preference tests: the crater lichen (mycobiont =*Diploschistes scruposus*), the bright cobblestone lichen (mycobiont =*Acarospora socialis*) and green rock shield lichens (mycobiont =*Xanthoparmelia coloradonensis* and *Xanthoparmelia cumberlandia*) (Fig. 4). Throughout the remainder of our report, lichens will be referred to using the name of their respective dominant mycobiont partner. Lichens were collected from local red sandstone substrates by wetting them lightly and removing them using a knife. We collected and sorted lichens into clean brown paper bags for transportation. Once back at the laboratory, lichens were air dried for several days in preparation for offering them to caterpillars (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005).

The sampled lichens varied in growth form with *D. scruposus* and *A. socialis* being crustose and the *Xanthoparmelia* spp. being foliose. These lichens also differed in secondary chemistry in ways that would highlight any preferences rooted in lichen metabolites (Consortium of North American Lichen Herberia 2018). *Diploschistes scruposus* produces lecanoric acid (major), orsellinic acid (minor), and may contain diploschistesic acid. *Acarospora socialis* produces rhizocarpic acid and can have epanorin in trace amounts. Both *X. coloradonensis* and *X. cumberlandia* produce usnic and norstictic acids. *X. coloradoensis* also produces salazinic and consalzinic acids. *X. cumberlandia* also produces stictic acid, minor amounts of constitic acid, and trace amounts of connorstictic, cryptostictic, and peristictic acids. We did not differentiate between the morphologically cryptic *Xanthoparmelia* species as both were certain to have the chemical of interest, usnic acid, with its antiherbivore properties (Ingolfsdottir 2002). Since usnic acid deterred other lithosiines, *Eilema* spp. (Pöykkö et al. 2005) the *Xanthoparmelia* spp. is what we expected to be the least preferred.

To test caterpillar host preference, we conducted cafeteria style host preference tests similarly designed to those used to test *Eilema* caterpillar preferences (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005). We used 12 independent caterpillar clutches comprised of 5-21 caterpillars. We randomly assigned each to a 14 cm diameter petri dish (with lid) that contained the three lichens. Each lichen was an equal distance of about 9 cm from one another, at the points of an equilateral triangle, on 12.5 cm diameter Fisher brand filter paper (Fig. 4). When the majority of each clutch had hatched, we placed the caterpillars and any of its unhatched eggs into the center of their dish approximately 4 cm away from each lichen (Table 1). As the caterpillars would have to travel to lichen food sources, we lightly dropped caterpillars into each dish randomizing their primary direction to avoid any biases from initial travel directions. We allowed about a minute to pass from caterpillar placement and then lightly misted the dish. We stored the dishes at slightly above room temperature, 29° C and matched outside conditions with a 12:12 light-dark cycle.

We observed caterpillars for 30 days after which they were reared to maturity on Pin-Cushion Sunburst Lichen: *Xanthomendoza montana,* a common, local lichen we could use to match their large appetites. During the 30 days of the preference test, we counted caterpillars on each lichen in each dish eight times 2, 3, 5, 10, 15, 20, 25, and 30 days after initial caterpillar placement. The lichens morphological differences may have impacted the caterpillars ability to consume them so we opted to evaluate the time caterpillars spent on each rather than the amount they consumed as done with *Eilema* spp. (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005). We spread out counting times like this to observe initial lichen selection as well as preference over the longer period of 30 days. We counted a caterpillar on a lichen if it was in direct contact with it. Because caterpillars moved during the night, but stood still during the day (personal observation), we counted caterpillars during the afternoon expecting them to be in direct contact with lichens they had most previously interacted with. Because of this caterpillar wandering behavior, they were occasionally found on the filter paper or dish, not in contact with any lichen. To account for these we included a fourth “Off Lichen” category in which these caterpillars were assigned. The four categories caterpillars were counted into were: *D. scruposus*, *Xanthoparmelia* spp., *A. socialis* and Off Lichen.

In evaluating *C. angelus* host selection, we took into consideration the wandering behavior of the caterpillars (Dethier 1988; Castrejon 2006; David Wagner and Timothy Anderson personal communications). We noted if significant host switching occurred and if preferences were detected during the beginning, middle, or end of the experiment. To do this we used a mixed model approach in version 13 of JMP (JMP®, Version *13*. SAS Institute Inc., Cary, NC, 1989-2007). We selected a mixed model approach so results from the experiment could be inferred to the larger insect and lichen populations our subjects were extracted from. We ran two models that included Dish and Observation as random variables to account for variation between dishes and observations and Day and Lichen as fixed variables to evaluate *C. angelus* caterpillar host selection. Two dishes midway through the experiment were compromised, being dropped and spilled. The dishes were reset and the caterpillars were continued in the same fashion as the others, but were not included in either model. Nevertheless, we still had a large enough sample size to test for significant differences in the caterpillar’s host selection over time. Therefore, Dish represented the 10 dishes used and Observation was a discrete, nonrepeating category for each time a dish’s caterpillars were counted. Caterpillars were counted into one of the four Lichen variable categories and the variable was crossed with the Observation and Dish random variables (Appendix 2: Table1). Instead of using raw caterpillar counts as the dependent variable we used percentages We did this to standardize results and to account for any caterpillar deaths, although they rarely occurred. The Day variable was a repeating representation of the 30 days for each dish and was either continuous or categorical depending on the model. It was continuous in the model used to inspect if *C. angelus* caterpillars switch hosts as they grow and categorical in the model used to pinpoint significant preferences throughout time. In the continuous model we used the eight counting periods to approximate uninterrupted time throughout the 30 days. In the categorical model, Day was broken into three, ten-day intervals aptly labeled beginning, middle, and end. We accompanied this with Student's t tests for all possible lichen pairings within each ten day period with a pseudobonferroni corrected p value of 0.01 (Table 2).

For future metabolomic work, we fed other caterpillars collected at the same time solely one of the three lichens from the preference tests over a 45 day period. At the conclusion of the 45 days before freezing caterpillars in preparation for metabolomic analyses, we measured the largest width of the head capsule from the dorsal view of each caterpillar. This was done with an Olympus MVX microscope with an Olympus DP74 camera attached (Table 3). Here we mention these as preliminary results to aid in the discussion of what influences host selection, but the majority of details from this work and our findings from this companion experiment will be published in a future publication.

Results

We found that moths readily laid eggs in the 50 ml vials. At the site, we collected 44 gravid females with 42 that laid eggs with clutches that varied from 4 to 29 eggs. We had 12 clutches that hatched 5 or more caterpillars and were the ones used in the described experiment

(Table 1). Our data represents the behavior of the caterpillars we initially placed within the dishes as only one of the unhatched eggs we placed with them hatched shortly after. We observed caterpillars quickly wandering from the center to select and use lichen hosts once they were misted. Some caterpillars continued to wander periodically throughout the experiment, even after spending time grazing on an initial host. Caterpillars exhibited true lichenivory by grazing through the upper cortex and algal layers of the lichens, though they did not feed into the medullary layer or lower cortex of any lichen. This left behind white skeletonized lichen bodies (Fig. 5). In each dish we observed grazing damage on all three lichens and frass clustered around each lichen group throughout the experiment. After the 30 day trial, caterpillars were successfully reared to maturity on a diet mostly consisting of *X. montana,* growing to adulthood on a completely lichen based diet.

Throughout the experiment only 7 out of the 140 caterpillars died, providing us adequate data for the statistical analyses of the *C. angelus* caterpillars host selections. A very few times we were not able to locate a particular caterpillar at the measured time due to its small size. However, our team was able to locate and count caterpillars the vast majority of the time, 347 out of the 352 times we counted caterpillars on lichens providing the substantial data for the statistical analyses (Appendix 2: Table 1). The mixed model results are as follows: the random variable interactions accounted for the variation within our dishes and observations. The Dish*Lichen interaction accounted for 28.12 percent and the Observation*Lichen interaction accounted for the remaining 71.88 percent. Significant lichen switching was done by the caterpillars with the fixed effect Lichen and the Lichen*Day interaction with p values <0.001. In reference to the Off Lichen category, caterpillars migrated off the *D. scruposus* and onto the *Xanthoparmelia* spp and *A. socialis.* Over the 30 days the *D. scruposus* lost an estimated 14.33

percent of caterpillars while the *Xanthoparmelia* gained and estimated 20.57 percent, and the *A. socialis* gained an estimated 10 percent. Caterpillars also exhibited a significant initial preference for *D. scruposus* with all pairwise comparisons involving it with other lichens within the first 10 days having p values <0.01 (Table 2). This preference was lost after the first 10 days with no other lichen to lichen pairs being significant throughout the test. Caterpillars were afterwards more homogeneously distributed among the three lichens, but the subtle shift of caterpillars from *D. scruposus* to the *Xanthoparmelia* spp. was visible. The middle *D. scruposus*/Off Lichen, middle *Xanthoparmelia* spp./Off Lichen, and end *Xanthoparmelia* spp./Off Lichen pairs were significant with p values <0.01.

In our observations of caterpillars prepared for future metabolomic analyses, all three lichens maintained live caterpillars which actively fed for the 45 days. Some deaths occurred, but we had more than enough for the desired 3 replicate level for metabolomic analyses. Though caterpillars grew similarly in the beginning, after the 45 days, caterpillars on *D. scruposus* were stunted compared to caterpillars fed on *Xanthoparmelia* spp. and *A. socialis* (Table 3). *D. scruposus* caterpillars had the smallest head capsules with an average size of 1.09 mm. *Xanthoparmelia* spp. caterpillars had an average head capsule size of 1.19 mm. *A. socialis* caterpillars were the largest with an average head capsule size of 1.23 mm.

Discussion

In the beginning, *C. angelus* caterpillars moved within seconds to feed on lichens once the lichens were misted and brought into full metabolic activity. The caterpillars grazed lichens similar to *H. fucosa* caterpillars, scrapping the upper cortex and algal layers (Fig. 5) of each lichen (Moskowitz & Westphal 2002) suggesting the caterpillars target nutrient algae, but also consume the upper cortex with its chemistry. The success in rearing caterpillars to maturity completely on lichen more fully confirms some kind of whole lichen-based diet for *C. angelus*.

The cafeteria style preference test and caterpillar counting (Appendix 2: Table 1) proved to be effective with low caterpillar mortality providing adequate data to informed us of what that diet may look like. The caterpillar's initial preference for *D. scruposus* which was lost after the first 10 days (Fig. 6; Table 2), differs from the *Eilema* species that exhibited clear long-term preferences (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005). There are a few potential reasons for the initial preference and its loss; host mycobiont chemistry, the lichens differing growth forms, and differences in available nutrients are all plausible suspects.

Host secondary chemistry was one of the main influences in host selection for *Eilema* (Pöykkö & Hyvärinen 2003; Pöykkö et al. 2005). The *Eilema* caterpillars avoided lichens rich in antiherbivory chemistry, especially usnic acid, only briefly feeding on them briefly during preference tests and quickly dying when solely fed them. Our results differ in that secondary chemistry was not the main influence in host selection of *C. angelus* caterpillars in the milieu of the three lichens we offered them. Despite their initial preference, *C. angelus* caterpillars were consistently found on each of the lichens regardless of their chemistry throughout the 30 days (Fig. 6). Also surprising was that as the initial preference dissipated, caterpillars shifted to the usnic acid containing *Xanthoparmelia* spp. twice as much as they migrated to *A. socialis* (Fig. 6). Furthermore when *C. angelus* caterpillars were solely fed one of the three lichens, consistent feeding occurred with only minor die off on each. We are currently investigating the sequestration patterns by caterpillars with such a broad acceptance of lichen chemistry in our future metabolomic companion paper. *Cisthene* and *Eilema* belong to sister subtribes (Scott et al.

2013), and the differences in chemical acceptance and sequestration should be evaluated in a phylogenetic framework to provide insights into the evolution of their unique life histories.

Since differences in host chemistry did not explain the preference of early instars or subsequent general feeding by later instars, perhaps other host characteristics should be explored. Differences in lichen growth form and (micro)topography confounded our ability to determine the relative influence of growth form vs. secondary chemistry in larval host selection. However by including various lichen growth forms we were able to observe *C. angelus* caterpillars feeding under more natural conditions and see them scrape like other lithosiine caterpillars (Moskowitz & Westphal 2002). Though the lichens had multiple differences, the caterpillars overall generalist behavior was apparent (Fig. 6; Table 2) allowing us to still evaluate those differences and consider their influence on the caterpillars host selection.

In phytophagous insects, host toughness, i.e. structural complexity, has been shown to influence host selection (Clissold 2007; Sanson 2006; Takagi & Miyashita 2008). Here, we correlate this to the differing crustose and foliose lichen growth forms (Fig. 3). The two different growth forms may require different biomechanical adaptions for them to be used as food. Foliose growth forms with their ridges and bumps may be harder to graze for younger caterpillars than the flat surface of the crustose growth form. As caterpillars grew, the complex foliose cortex could have become more accessible as larger mandibles could have made it easier to feed on the *Xanthoparmelia* spp..

Comparably, differences in lichen growth form could have also influenced where we found caterpillars by influencing other things such as hiding space. Crustose lichens are cemented tightly to their substrate with no lower cortex and a medulla that seeps directly into the rock substrate making it impossible to dissociate them from it. *Acarospora socialis* tended to crumble rather easily while *D. scruposus* generally came off in larger pieces, but both crustose lichens came with considerable amounts of their red rock substrate. In contrast, foliose lichens do have a lower cortex and attach to substrates more loosely with rizhines or holdfasts. *Xanthoparmelia* spp. were easily removed with no substrate, leaving a substantial amount of space available underneath (Fig. 4). The larger space under the *Xanothoparmelia* spp. may have attracted growing caterpillars that hide during the day and in need of more space as they got larger.

The lichen morphological differences involving both caterpillar feeding and hiding could explain the shift over time from the crustose *D. scruposus* to the foliose *Xanthoparmelia* spp., but do not account for the near constant caterpillar numbers and slight increase on the crustose *A. socialis* (Fig. 6). These factors may contribute to why more caterpillars went to the *Xanthoparmelia* spp. over the *A. socialis* when leaving the *D. scruposus*, but a contrast of crustose and foliose growth forms is insufficient to describe the early instars preference or quick shift to generalist lichen feeding.

Eilema caterpillars selected lichens with lower amounts of polyphenolics, but also balanced selections by choosing those with higher nutritional content (Pöykkö & Hyvärinen 2003). Furthermore, when polyphenolics were removed from otherwise avoided lichens, they became suitable food options, opening the way for other factors such as nutritional value to potentially drive lichen selection (Pöykkö et al. 2005). *Cisthene angelus* caterpillars were neither deterred by any of the secondary chemistry presented nor strongly influenced by differences in lichen morphology. This opens the way for other factors like the caterpillars nutritional needs to govern feeding behavior. From our data (Fig. 6; Table 2; Table 3; Appendix 2: Table 1) we propose that the caterpillars' nutritional needs are the major driving force in host selection and subsequent loss of the early instar preference in *C. angelus*.

We did not directly measure nutrients, but did observe differing growth rates among the different caterpillar-lichen groups we prepared for chemical analysis (Table 3). Early in the 45 days, caterpillars grew similarly on each lichen, but in the end, caterpillars fed *D. scruposus* were stunted in body and head capsule size compared to those on *A socialis* and the *Xanthoparmelia* spp.. Initially *D. scruposus* may have become metabolically active quicker than the other lichens or it may offer young caterpillars a beneficial metabolite or nutrient explaining their early affinity to it, but it does not appear to have all the necessary nutrients for caterpillars to successfully mature. This would lead to the succeeding polyphagous instars to supplement diets with the other lichens, just like what we observed in our preference tests. Future work should include host nutritional content and how it relates to caterpillar growth and host preference.

In our study, we evaluated preferences with three lichens selected from the caterpillar's environment. There may exist stronger preferences with a lichen we did not include, although, our data supports the conclusion that *C. angelus* caterpillars are largely generalist lichen feeders. Such behavior is likely advantageous considering how the caterpillar's natural environment is structured. Within the caterpillar's habitat many different lichens coexist within small regions, often growing closely together and at times are largely intermixed (Fig. 7). The caterpillars wander, but are limited in how far they can travel due to their small size. Caterpillars with the ability to feed on differing metabolite profiles and growth forms increase their access to lichenized algal nutrients in their arid environment where free living algae are difficult to come by. Our upcoming metabolomic work will further illuminate the function of hosts and targeted mycobiont metabolites by such generalist caterpillars. Our results help clarify points of Lithosiini caterpillar feeding behavior and present novel findings as a foundation for future research. We look forward to enhancing our understanding of broader scale interactions between Lithosiini and lichens.

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Chapter 3 Tables

Table 1. The raw size, eggs + caterpillars, and amount of hatched caterpillars from the 12 clutches we used in preference tests.

Clutch	Eggs in clutch	Hatched Caterpillars
1	9	5
2	23	18
3	22	21
4	19	16
5	17	15
6	11	11
7	12	11
8	9	8
9	7	7
10	7	7
11	8	7
12	14	14

Table 2. Pairwise comparison p values of the preference counting groups in the Beginning (first 10 days), Middle (next 10 days), and End (last 10 days) of trial. Those indicated with a *, are significant with a pseudobonferroni corrected p value of 0.01.

Lichen Group	*D. scrubosus*	*Xanthoparmelia* spp.	*A. socialis*
Beginning			
Xanthoparmelia spp.	0.0089*		
A. socialis	0.0009*	0.4190	
Off lichen	<.0001*	0.052	0.2458
Middle			
Xanthoparmelia spp.	0.8565		
A. socialis	0.2386	0.1747	
Off lichen	0.0008*	0.0005*	0.0260
End			
Xanthoparmelia spp.	0.4155		
A. socialis	0.5142	0.1441	
Off lichen	0.0411	0.0048*	0.1604

Table 3. Dorsal head capsule measurements for caterpillars of *Cisthene angelus* fed 45 days solely on *D. scruposus* (n=5), *Xanthoparmelia* spp. (n=4), or *A. socialis* (n=7). The overall means and standard deviations of each group. Caterpillars perfomed the best on *A. socialis* while they were stunted when only fed *D. scuposus*.

Lichen	*D. scruposus*	*Xanthoparmelia* spp.	*A. socialis*
Head Capsule Size	1.12 mm	1.27 mm	1.18 mm
	1.19 mm	1.24 mm	1.22 mm
	1.12 mm	1.16 mm	1.28 mm
	1.06 mm	1.08 mm	1.30 mm
	0.94 mm		1.23 mm
			1.18 mm
			1.24 mm
Mean	1.09 mm	1.19 mm	1.23 mm
Standard Deviation	0.093701654	0.08	0.043089055

Chapter 3 Figures

Figure 1. *Cisthene angelus* on a sheet with a mercury vapor light. Leeds Canyon, Utah collected on 7 June 2017.

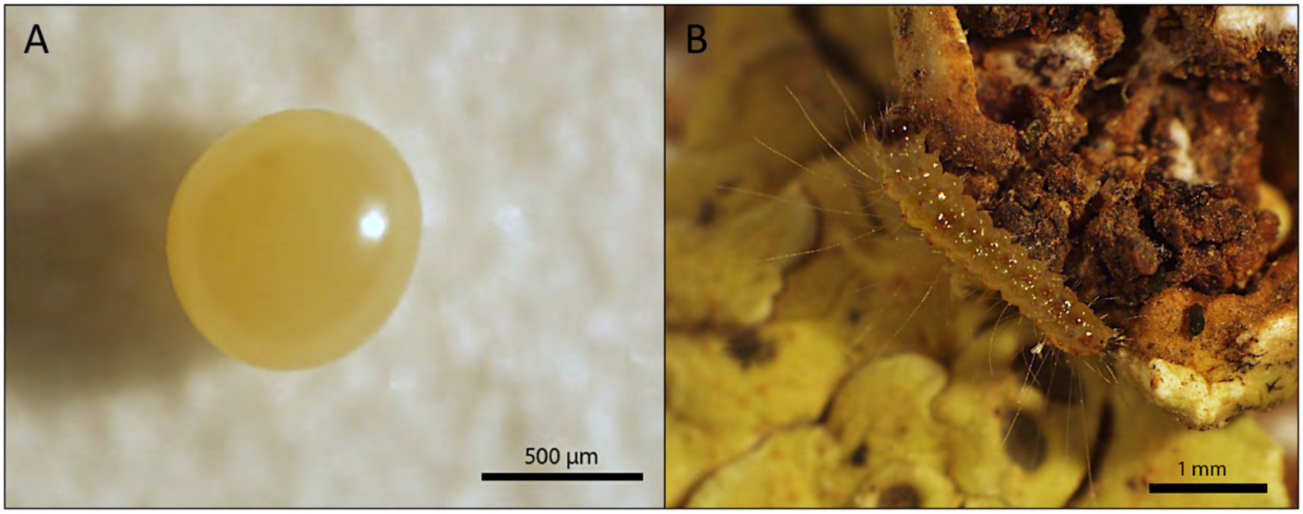

Figure 2. A: Egg from gravid *C. angelus* female collected at an attracting sheet of mercury vapor lamp trap at Leeds Canyon, Utah on 7 June 2017. B: Subsequent early instar caterpillar.

Figure 3. Leeds Canyon habitat, Utah semiarid, red rock environment on 16 June 201

Figure 4. Preference test design with A: *Diploschistes scruposus*, B: *Xanthoparmelia* spp., and C: *Acarospora socialis* lichen options.

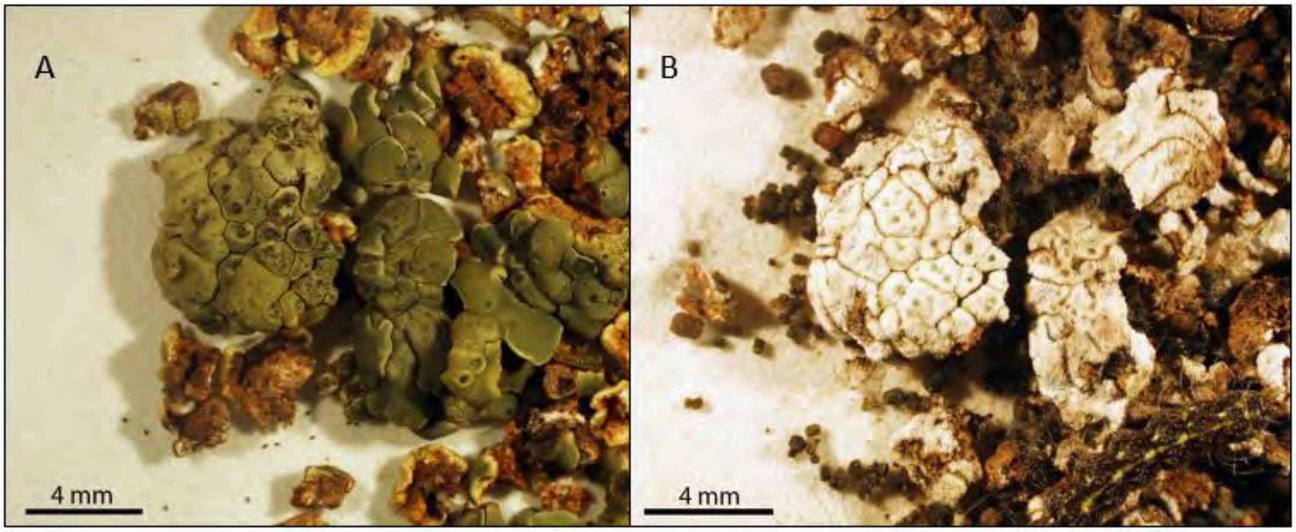

Figure 5. *A. socialis* A: before and B: after *C. angelus* caterpillar feeding. Note the white skeletonized lichen body as a result of the caterpillars scraping off the top mycobiont and photobiont layers.

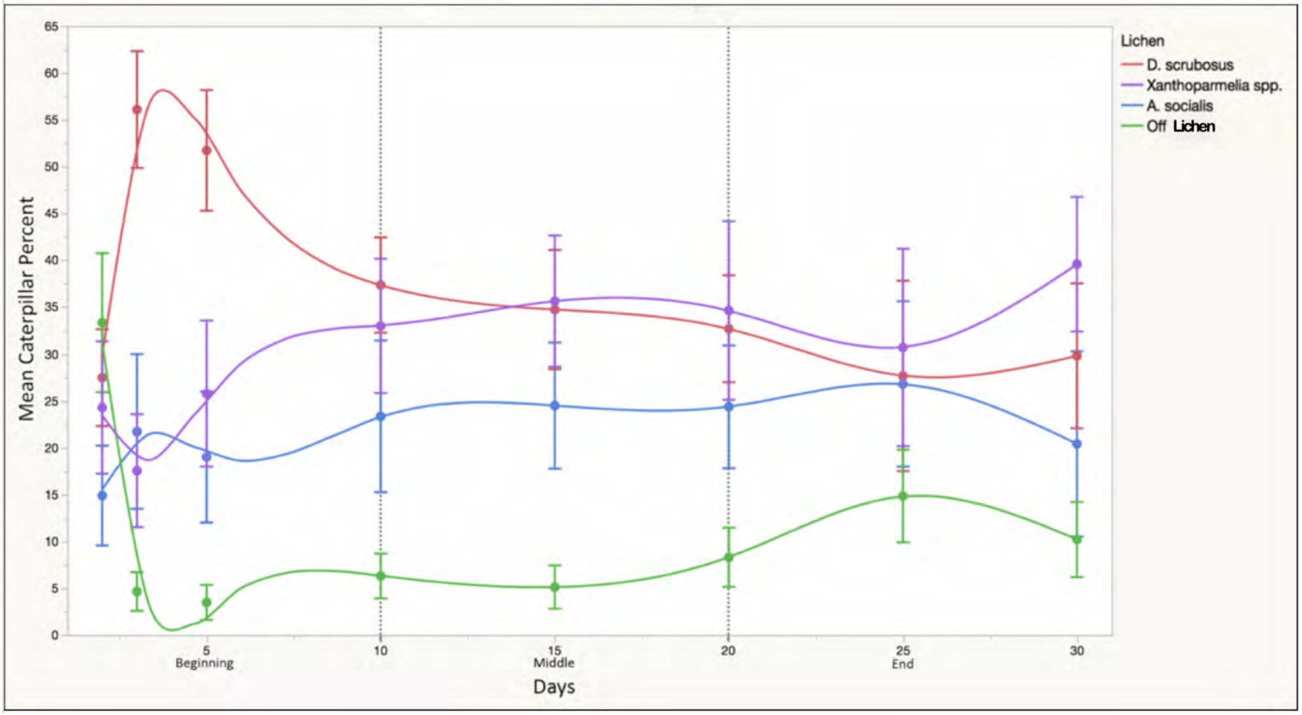

Figure 6. Lichen host use by *Cisthene angelus*. Mean caterpillar percent on each counting group: *D. scruposus*, *Xanthoparmelia* spp*., A. socialis* and the Off Lichen category. Actual count averages for 2, 3, 5, 10, 15, 20, 25, 30 days into the experiment are plotted with standard error bars. The overall 30 days are divided into 3, 10 day intervals: Beginning, Middle, and End, to display the initial *D. scruposus* preference and subsequent generalist feeding behavior after the first 10 days.

Figure 7. Gray *D. scruposus* on its red rock substrate, intermixed with various other lichens, in Leeds Canyon, Utah.

Appendix 1

Table 1. Bioclim variables from Worldclim that were kept for use in Maxent after reducing groups whose correlation was high (Pearson Product-Moment correlations > r = 0.80).

Bio 2	Mean Diurnal Range
Bio 7	Temperature of Coldest Month
Bio 8	Mean Temperature of Wettest Quarter
Bio 9	Mean Temperature of Driest Quarter
Bio 12	Annual Precipitation
Bio 14	Precipitation of Wettest Month
Bio 15	Precipitation of Seasonality
Vegetation Type	North American Vegetation Type 2014
Elevation	North American Elevation 2010

Table 2. Training AUC score and percent contribution for each of the nine environmental variables we included in our ENM Maxent analyses for each species we investigated.

Genus species	Training AUC Score	Bio 2	Bio 7	Bio 8	Bio 9	Bio 12	Bio 14	Bio 15	Vegetation Type	Elevation
Estigmene acrea	0.988	1.1	0	0	32.5	32.3	0.9	1.6	31.6	0
Estigmene albida	0.949	0	1.9	0	0	0	0	0	86.1	11.9
Pseudohemihyalea ambigua	0.956	0.5	1.9	5.1	19.3	0.3	0.3	8.4	36.2	28.1
Cisthene angelus	0.97	9.1	1.5	9.2	3.8	0.5	4.7	22.2	13.6	35.4
Euchaetes antica	1	3.6	0	45.1	6.5	0	0	2.1	41.5	1.1
Lophocampa argentata	0.908	2.3	1	3.9	2.3	1.4	10.4	4.5	70.4	3.7
Eudesmia arida	1	0.1	0	48.5	5.7	6.3	0	1	38.4	0
Apantesis arizoniensis	0.998	19.4	0	0	0	0	0	0	80.6	0
Cisthene barnesii	0.913	2.5	19.2	3.2	6.4	2.5	12.8	3.6	49.1	0.7
Apantesis bowmani	0.999	9.7	0	5.1	53.8	0.4	0	8	23	0
Apantesis brillians	0.928	0	0	27.7	0	0	0	0	71.1	1.2
Hypoprepia cadaverosa	0.969	0.3	3.4	16.9	12.4	5	1	1.8	59.3	0
Arctia caja	0.932	0.5	2	1.4	6	0.6	43.1	9.5	35.3	1.5
Leptarctia californiae	0.901	9.6	0.6	15.2	1.9	15.8	2.1	5.1	49.3	0.4
Crambidia casta	0.976	0.1	21.5	4.3	0	1.4	0	3.6	69.2	0
Crambidia cephalica	0.897	2.3	20.8	6.9	4.5	8.7	0.4	8.5	42.4	5.6
Arachnis citra	0.904	6.8	21.1	11	4.2	4.5	1.8	12.8	37.5	0.4
Ectypia clio	0.886	0.6	0.1	10.6	1	6.9	0	2	69.8	9
Virbia costata	0.984	21.1	0.7	6	5.1	4	2	2.2	58.9	0

Ctenucha cressonana	0.995	0	0.8	2.6	0	18.4	0	11.6	46.7	19.9
Hyphantrea cunea	0.936	3.6	10.3	0.2	6.4	1	17.3	0.4	57.1	3.8
Gnophaela discreta	0.993	0	3.4	4.9	8.4	47.2	5.2	20.4	10.5	0
Pseudohemihyalea edwardsii	0.989	0	8	0	0	16.9	15	0	60.1	0
Apantesis f-pallida	0.958	3.7	0.2	11.2	2	14.7	4.8	11.5	51.2	0.6
Virbia fragilis	0.906	0.4	3	5	2.6	10.1	34.4	3.9	38.7	1.9
Lycomorpha fulgens	0.977	3.6	0	35.4	0	0	6.3	5.9	43.1	5.7
Cisseps fulvicollis	0.932	2.3	12.3	3.8	9.6	0	21.1	0.3	50.6	0
Kodiosoma fulvum	0.983	0.7	0.7	2.8	0	3.5	0.5	3.6	50.3	38
Lycomorpha grotei	0.882	1.6	2.1	2.6	7.5	5.2	14.1	9.9	55.5	1.4
Bruceia hubbardi	0.921	4.2	2	0	10.3	4.8	2	15.9	60.7	0
Crambidia impura	0.975	0.4	0.3	32.4	0	29.3	0	22.6	15	0
Apantesis incorrupta	0.919	6	1.9	18.5	3.5	3.9	10.8	9.7	42.2	3.5
Hyoprepia inculta	0.926	3.4	6.2	1.2	7.1	3.2	19.4	9.1	49.4	1
Lophocampa ingens	0.979	1.3	0.9	4.7	30.9	0.3	3.3	5.5	42	11.2
Pyrrharctia isabella	0.975	2.0	10.5	0.3	1	1.2	25.1	0.4	57.1	2.5
Cisthene juanita	0.976	0	0	0	0	0	0	0	100	0
Pseudohemihyalea labecula	0.907	2.6	1.4	7.4	9.4	26.4	5.4	6	39.4	1.9
Arctia lapponica	1	26	1.8	0	0	0	33.7	0	38.4	0
Haploa lecontei	0.993	22.8	42.6	5.4	0	0	0	8	21.2	0
Lophocampa maculata	0.919	0.7	2	1.6	5.2	3.7	56	2.6	27.1	1
Pygarctia murina	0.978	0.4	0.5	32.6	4.1	0.1	4.2	14.6	23.2	20.2
Pygarctia neomexicana	0.999	0	23.8	9.1	34.7	3.3	0	3	26.1	0
Apantesis nevadensis	0.893	1.7	6.8	2.1	10.5	4.5	16.2	16.2	40.6	1.3
Apantesis obliterata	0.992	0	10.6	12.2	41	1	1.5	0	33.7	0
Cycnia tenera	0.997	0	0.3	0	16.3	24.7	2.9	0.4	54.5	1
Apantesis ornata	0.961	13.2	0	1.1	8	0.3	39.2	0	37.1	0.9
Virbia ostenta	0.994	0	7.7	2.7	0	36	14.5	5.2	34	0
Apantesis parthenice	0.968	0.1	2.3	0.2	18.4	4.9	37.1	0.6	36.2	0.1
Arctia parthenos	0.947	0	0	0	0	0	0	60.8	39.2	0
Hypercompe permaculata	0.877	0.1	1.3	3.3	12.9	1.1	21.4	4.2	50.3	5.5
Arachnis picta	0.879	1.9	8.6	9.6	8.3	14.8	1.2	0.8	47.2	7.7
Arctia plantaginis	0.958	8.2	3.9	4.2	3	35.5	27.2	0.1	17.7	0.1
Apantesis proxima	0.948	0.8	2.5	4.3	25	4	0.6	2.2	56.4	4.3

Bruceia pulverina	0.893	0.2	5.7	7.7	0.4	0.9	18.4	1.6	64.9	0.3
Lycomorpha regulus	0.999	0	6.3	0	0	1.6	0	0.6	91.5	0
Lophocampa significans	0.979	0	0	16.3	0	18.2	0	0	56.5	9
Apantesis speciosa	0.984	0	1.1	0.6	0	0	4.7	10	83.7	0
Lycomorpha splendens	0.929	6.7	2.5	7.8	1.1	6.7	5.6	16.3	35.7	17.5
Pygarctia spraguei	0.985	0	15.1	4.4	0	0	26.4	0.1	51.4	2.6
Cycnia oregonensis	0.996	8.7	0	0	0	0	0	26.8	57	7.4
Cisthene tenuifascia	0.992	2.4	0	45.1	0.7	9.3	0.3	6.9	35.5	0
Bertholdia trigona	0.958	0	9.6	14.7	17.2	1.8	4.1	0.3	52.2	0.2
Spilisoma vagans	0.902	0.3	3.4	3.3	2.9	1.0	59.0	0.3	29.5	0.3
Ctenucha venosa	0.999	0	0	0	2.8	8.2	0	0	85.5	3.4
Gnophaela vermiculata	0.948	1	4.3	2.5	4	10.4	52.8	1.3	23.3	0.3
Arctia virginalis	0.957	0.2	0.2	11.6	20.6	10.8	24.9	4.2	25	2.6
Spilisoma virginica	0.977	1.3	0.9	0.6	19.2	1	7.7	0.4	67.2	1.6
Apantesis virgo	0.999	1.3	2.8	0.5	43.9	8.4	10.1	0.3	32.2	0.4
Apantesis virguncula	0.996	0	0.1	0	0	0	0	5.2	94.6	0
Apantesis williamsii	0.892	0.2	2.1	1.9	5.9	0.7	57.6	8.2	22.5	1
Arctia yarrowii	0.998	2.8	0	39.6	0	0	56.1	0	1.4	0.1
Echaetes zella	0.985	0	0	3	0	0	27.7	3.2	66.1	0

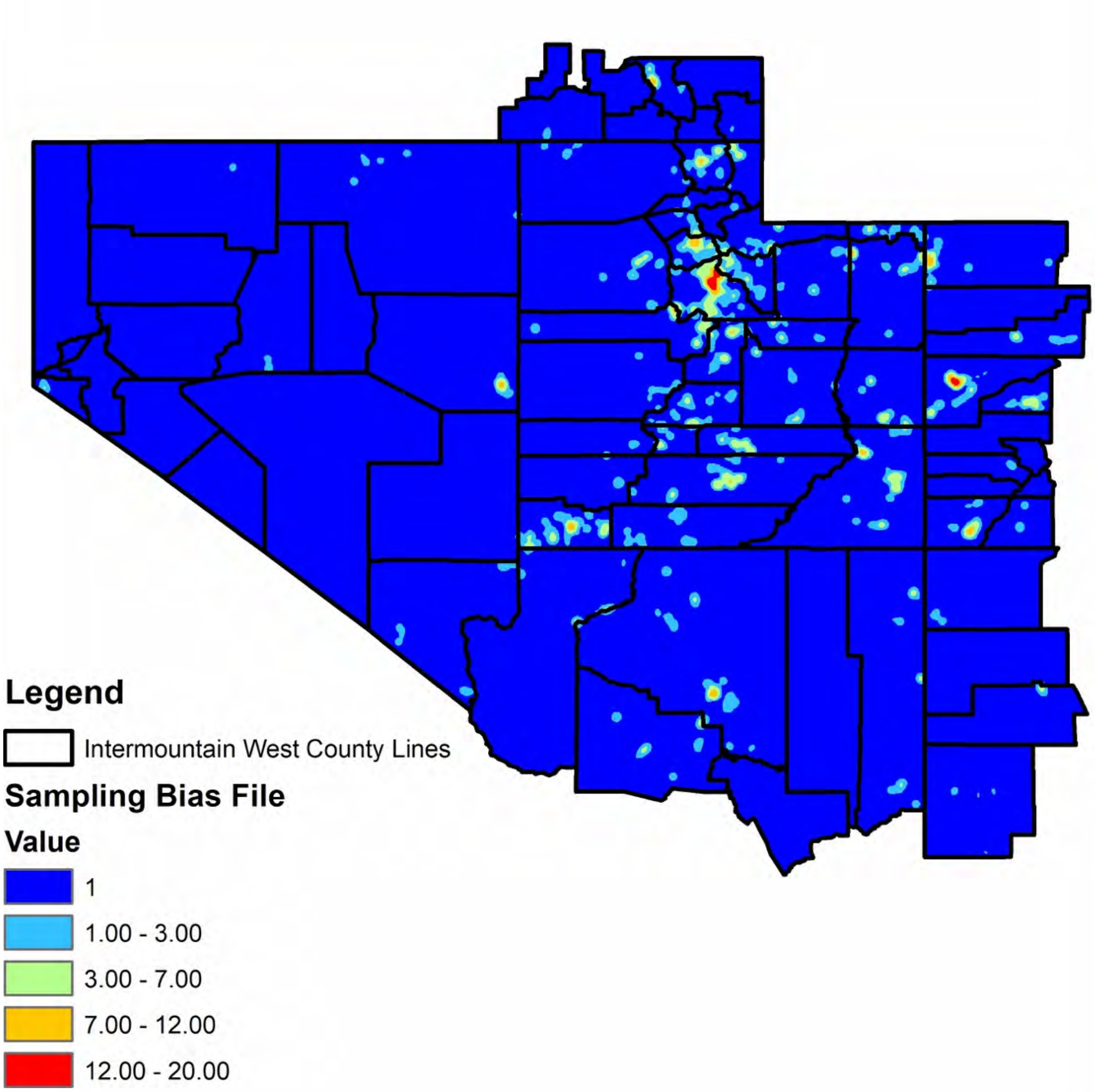

Figure 1. Sampling bias file for Maxent for ecological niche modeling of Intermountain West tiger moth species. The file was built from the records we gathered from collections using the "Gaussian kernel density of sampling localities" tool in the SDMtoolbox (Brown 2014).

Appendix 2

Table 1. Caterpillar counts and percentages per lichen category for the 12 dishes each time their caterpillars were observed. Dishes 2 and 3, indicated with an *, were compromised after day 10 and excluded from further caterpillar counting and statistical analyses. Caterpillars in the remaining dishes were counted 8 times: 2, 3, 5, 10, 15, 20, 25, 30 days into the experiment and each time was considered as a new observation.

Dish	**Date**	**Day**	**Lichen Category**	**Count**	**Caterpillar %**	**Observation**
1	18-Sep-17	2	*D. scruposus*	3	60	1
1	18-Sep-17	2	*Xanthoparmelia* spp.	1	20	1
1	18-Sep-17	2	*A. socialis*	0	0	1
1	18-Sep-17	2	Off lichen	1	20	1
1	19-Sep-17	3	*D. scruposus*	4	80	2
1	19-Sep-17	3	*Xanthoparmelia* spp.	1	20	2
1	19-Sep-17	3	*A. socialis*	0	0	2
1	19-Sep-17	3	Off lichen	0	0	2
1	21-Sep-17	5	*D. scruposus*	3	60	3
1	21-Sep-17	5	*Xanthoparmelia* spp.	2	40	3
1	21-Sep-17	5	*A. socialis*	0	0	3
1	21-Sep-17	5	Off lichen	0	0	3
1	26-Sep-17	10	*D. scruposus*	2	40	4
1	26-Sep-17	10	*Xanthoparmelia* spp.	3	60	4
1	26-Sep-17	10	*A. socialis*	0	0	4
1	26-Sep-17	10	Off lichen	0	0	4
1	1-Oct-17	15	*D. scruposus*	2	40	5
1	1-Oct-17	15	*Xanthoparmelia* spp.	3	60	5
1	1-Oct-17	15	*A. socialis*	0	0	5
1	1-Oct-17	15	Off lichen	0	0	5
1	6-Oct-17	20	*D. scruposus*	2	40	6
1	6-Oct-17	20	*Xanthoparmelia* spp.	1	20	6
1	6-Oct-17	20	*A. socialis*	2	40	6
1	6-Oct-17	20	Off lichen	0	0	6
1	11-Oct-17	25	*D. scruposus*	0	0	7
1	11-Oct-17	25	*Xanthoparmelia* spp.	2	40	7
1	11-Oct-17	25	*A. socialis*	1	20	7
1	11-Oct-17	25	Off lichen	2	40	7
1	16-Oct-17	30	*D. scruposus*	3	60	8
1	16-Oct-17	30	*Xanthoparmelia* spp.	2	40	8
1	16-Oct-17	30	*A. socialis*	0	0	8
1	16-Oct-17	30	Off lichen	0	0	8
*2	18-Sep-17	2	*D. scruposus*	2	11.11	9

*2	18-Sep-17	2	*Xanthoparmelia* spp.	6	33.33	9
*2	18-Sep-17	2	*A. socialis*	2	11.11	9
*2	18-Sep-17	2	Off lichen	8	44.44	9
*2	19-Sep-17	3	*D. scruposus*	1	5.88	10
*2	19-Sep-17	3	*Xanthoparmelia* spp.	3	17.65	10
*2	19-Sep-17	3	*A. socialis*	12	70.59	10
*2	19-Sep-17	3	Off lichen	1	5.88	10
*2	21-Sep-17	5	*D. scruposus*	3	17.65	11
*2	21-Sep-17	5	*Xanthoparmelia* spp.	8	47.06	11
*2	21-Sep-17	5	*A. socialis*	4	23.53	11
*2	21-Sep-17	5	Off lichen	2	11.76	11
*2	26-Sep-17	10	*D. scruposus*	2	11.76	12
*2	26-Sep-17	10	*Xanthoparmelia* spp.	5	29.41	12
*2	26-Sep-17	10	*A. socialis*	8	47.06	12
*2	26-Sep-17	10	Off lichen	2	11.76	12
*3	18-Sep-17	2	*D. scruposus*	0	0	17
*3	18-Sep-17	2	*Xanthoparmelia* spp.	2	9.52	17
*3	18-Sep-17	2	*A. socialis*	19	90.48	17
*3	18-Sep-17	2	Off lichen	0	0	17
*3	19-Sep-17	3	*D. scruposus*	1	4.76	18
*3	19-Sep-17	3	*Xanthoparmelia* spp.	1	4.76	18
*3	19-Sep-17	3	*A. socialis*	17	80.95	18
*3	19-Sep-17	3	Off lichen	2	9.52	18
*3	21-Sep-17	5	*D. scruposus*	4	20	19
*3	21-Sep-17	5	*Xanthoparmelia* spp.	5	25	19
*3	21-Sep-17	5	*A. socialis*	11	55	19
*3	21-Sep-17	5	Off lichen	0	0	19
*3	26-Sep-17	10	*D. scruposus*	2	11.76	20
*3	26-Sep-17	10	*Xanthoparmelia* spp.	2	11.76	20
*3	26-Sep-17	10	*A. socialis*	10	58.82	20
*3	26-Sep-17	10	Off lichen	3	17.65	20
4	18-Sep-17	2	*D. scruposus*	5	38.46	25
4	18-Sep-17	2	*Xanthoparmelia* spp.	1	7.69	25
4	18-Sep-17	2	*A. socialis*	2	15.38	25
4	18-Sep-17	2	Off lichen	5	38.46	25
4	19-Sep-17	3	*D. scruposus*	5	45.45	26
4	19-Sep-17	3	*Xanthoparmelia* spp.	0	0	26
4	19-Sep-17	3	*A. socialis*	6	54.55	26
4	19-Sep-17	3	Off lichen	0	0	26
4	21-Sep-17	5	*D. scruposus*	4	40	27

4	21-Sep-17	5	*Xanthoparmelia* spp.	0	0	27
4	21-Sep-17	5	*A. socialis*	6	60	27
4	21-Sep-17	5	Off lichen	0	0	27
4	26-Sep-17	10	*D. scruposus*	3	27.27	28
4	26-Sep-17	10	*Xanthoparmelia* spp.	1	9.09	28
4	26-Sep-17	10	*A. socialis*	7	63.64	28
4	26-Sep-17	10	Off lichen	0	0	28
4	1-Oct-17	15	*D. scruposus*	6	54.55	29
4	1-Oct-17	15	*Xanthoparmelia* spp.	1	9.09	29
4	1-Oct-17	15	*A. socialis*	4	36.36	29
4	1-Oct-17	15	Off lichen	0	0	29
4	6-Oct-17	20	*D. scruposus*	7	63.64	30
4	6-Oct-17	20	*Xanthoparmelia* spp.	0	0	30
4	6-Oct-17	20	*A. socialis*	4	36.36	30
4	6-Oct-17	20	Off lichen	0	0	30
4	11-Oct-17	25	*D. scruposus*	11	91.67	31
4	11-Oct-17	25	*Xanthoparmelia* spp.	0	0	31
4	11-Oct-17	25	*A. socialis*	0	0	31
4	11-Oct-17	25	Off lichen	1	8.33	31
4	16-Oct-17	30	*D. scruposus*	6	54.55	32
4	16-Oct-17	30	*Xanthoparmelia* spp.	5	45.45	32
4	16-Oct-17	30	*A. socialis*	0	0	32
4	16-Oct-17	30	Off lichen	0	0	32
5	18-Sep-17	2	*D. scruposus*	1	6.67	33
5	18-Sep-17	2	*Xanthoparmelia* spp.	0	0	33
5	18-Sep-17	2	*A. socialis*	8	53.33	33
5	18-Sep-17	2	Off lichen	6	40	33
5	19-Sep-17	3	*D. scruposus*	3	20	34
5	19-Sep-17	3	*Xanthoparmelia* spp.	1	6.67	34
5	19-Sep-17	3	*A. socialis*	11	73.33	34
5	19-Sep-17	3	Off lichen	0	0	34
5	21-Sep-17	5	*D. scruposus*	9	60	35
5	21-Sep-17	5	*Xanthoparmelia* spp.	2	13.33	35
5	21-Sep-17	5	*A. socialis*	2	13.33	35
5	21-Sep-17	5	Off lichen	2	13.33	35
5	26-Sep-17	10	*D. scruposus*	3	20	36
5	26-Sep-17	10	*Xanthoparmelia* spp.	1	6.67	36
5	26-Sep-17	10	*A. socialis*	10	66.67	36
5	26-Sep-17	10	Off lichen	1	6.67	36
5	1-Oct-17	15	*D. scruposus*	3	21.43	37

5	1-Oct-17	15	*Xanthoparmelia* spp.	1	7.14	37
5	1-Oct-17	15	*A. socialis*	9	64.29	37
5	1-Oct-17	15	Off lichen	1	7.14	37
5	6-Oct-17	20	*D. scruposus*	5	35.71	38
5	6-Oct-17	20	*Xanthoparmelia* spp.	1	7.14	38
5	6-Oct-17	20	*A. socialis*	6	42.86	38
5	6-Oct-17	20	Off lichen	2	14.29	38
5	11-Oct-17	25	*D. scruposus*	2	14.29	39
5	11-Oct-17	25	*Xanthoparmelia* spp.	0	0	39
5	11-Oct-17	25	*A. socialis*	7	50	39
5	11-Oct-17	25	Off lichen	5	35.71	39
5	16-Oct-17	30	*D. scruposus*	5	35.71	40
5	16-Oct-17	30	*Xanthoparmelia* spp.	4	28.57	40
5	16-Oct-17	30	*A. socialis*	3	21.43	40
5	16-Oct-17	30	Off lichen	2	14.29	40
6	18-Sep-17	2	*D. scruposus*	2	18.18	41
6	18-Sep-17	2	*Xanthoparmelia* spp.	6	54.55	41
6	18-Sep-17	2	*A. socialis*	1	9.09	41
6	18-Sep-17	2	Off lichen	2	18.18	41
6	19-Sep-17	3	*D. scruposus*	8	72.73	42
6	19-Sep-17	3	*Xanthoparmelia* spp.	3	27.27	42
6	19-Sep-17	3	*A. socialis*	0	0	42
6	19-Sep-17	3	Off lichen	0	0	42
6	21-Sep-17	5	*D. scruposus*	8	72.73	43
6	21-Sep-17	5	*Xanthoparmelia* spp.	3	27.27	43
6	21-Sep-17	5	*A. socialis*	0	0	43
6	21-Sep-17	5	Off lichen	0	0	43
6	26-Sep-17	10	*D. scruposus*	5	45.45	44
6	26-Sep-17	10	*Xanthoparmelia* spp.	2	18.18	44
6	26-Sep-17	10	*A. socialis*	4	36.36	44
6	26-Sep-17	10	Off lichen	0	0	44
6	1-Oct-17	15	*D. scruposus*	4	36.36	45
6	1-Oct-17	15	*Xanthoparmelia* spp.	5	45.45	45
6	1-Oct-17	15	*A. socialis*	1	9.09	45
6	1-Oct-17	15	Off lichen	1	9.09	45
6	6-Oct-17	20	*D. scruposus*	4	36.36	46
6	6-Oct-17	20	*Xanthoparmelia* spp.	5	45.45	46
6	6-Oct-17	20	*A. socialis*	2	18.18	46
6	6-Oct-17	20	Off lichen	0	0	46
6	11-Oct-17	25	*D. scruposus*	8	72.73	47

6	11-Oct-17	25	*Xanthoparmelia* spp.	2	18.18	47
6	11-Oct-17	25	*A. socialis*	1	9.09	47
6	11-Oct-17	25	Off lichen	0	0	47
6	16-Oct-17	30	*D. scruposus*	5	45.45	48
6	16-Oct-17	30	*Xanthoparmelia* spp.	6	54.55	48
6	16-Oct-17	30	*A. socialis*	0	0	48
6	16-Oct-17	30	Off lichen	0	0	48
7	18-Sep-17	2	*D. scruposus*	2	18.18	49
7	18-Sep-17	2	*Xanthoparmelia* spp.	3	27.27	49
7	18-Sep-17	2	*A. socialis*	1	9.09	49
7	18-Sep-17	2	Off lichen	5	45.45	49
7	19-Sep-17	3	*D. scruposus*	10	83.33	50
7	19-Sep-17	3	*Xanthoparmelia* spp.	0	0	50
7	19-Sep-17	3	*A. socialis*	1	8.33	50
7	19-Sep-17	3	Off lichen	1	8.33	50
7	21-Sep-17	5	*D. scruposus*	9	81.82	51
7	21-Sep-17	5	*Xanthoparmelia* spp.	0	0	51
7	21-Sep-17	5	*A. socialis*	2	18.18	51
7	21-Sep-17	5	Off lichen	0	0	51
7	26-Sep-17	10	*D. scruposus*	7	63.64	52
7	26-Sep-17	10	*Xanthoparmelia* spp.	2	18.18	52
7	26-Sep-17	10	*A. socialis*	2	18.18	52
7	26-Sep-17	10	Off lichen	0	0	52
7	1-Oct-17	15	*D. scruposus*	4	36.36	53
7	1-Oct-17	15	*Xanthoparmelia* spp.	1	9.09	53
7	1-Oct-17	15	*A. socialis*	4	36.36	53
7	1-Oct-17	15	Off lichen	2	18.18	53
7	6-Oct-17	20	*D. scruposus*	2	18.18	54
7	6-Oct-17	20	*Xanthoparmelia* spp.	1	9.09	54
7	6-Oct-17	20	*A. socialis*	7	63.64	54
7	6-Oct-17	20	Off lichen	1	9.09	54
7	11-Oct-17	25	*D. scruposus*	2	18.18	55
7	11-Oct-17	25	*Xanthoparmelia spp.*	0	0	55
7	11-Oct-17	25	*A. socialis*	9	81.82	55
7	11-Oct-17	25	Off lichen	0	0	55
7	16-Oct-17	30	*D. scruposus*	0	0	56
7	16-Oct-17	30	*Xanthoparmelia* spp.	0	0	56
7	16-Oct-17	30	*A. socialis*	10	90.91	56
7	16-Oct-17	30	Off lichen	1	9.09	56
8	18-Sep-17	2	*D. scruposus*	2	33.33	57

8	18-Sep-17	2	*Xanthoparmelia* spp.	2	33.33	57
8	18-Sep-17	2	*A. socialis*	2	33.33	57
8	18-Sep-17	2	Off lichen	0	0	57
8	19-Sep-17	3	*D. scruposus*	3	50	58
8	19-Sep-17	3	*Xanthoparmelia* spp.	0	0	58
8	19-Sep-17	3	*A. socialis*	2	33.33	58
8	19-Sep-17	3	Off lichen	1	16.67	58
8	21-Sep-17	5	*D. scruposus*	3	42.86	59
8	21-Sep-17	5	*Xanthoparmelia* spp.	0	0	59
8	21-Sep-17	5	*A. socialis*	4	57.14	59
8	21-Sep-17	5	Off lichen	0	0	59
8	26-Sep-17	10	*D. scruposus*	1	14.29	60
8	26-Sep-17	10	*Xanthoparmelia* spp.	3	42.86	60
8	26-Sep-17	10	*A. socialis*	2	28.57	60
8	26-Sep-17	10	Off lichen	1	14.29	60
8	1-Oct-17	15	*D. scruposus*	0	0	61
8	1-Oct-17	15	*Xanthoparmelia* spp.	4	57.14	61
8	1-Oct-17	15	*A. socialis*	3	42.86	61
8	1-Oct-17	15	Off lichen	0	0	61
8	6-Oct-17	20	*D. scruposus*	4	57.14	62
8	6-Oct-17	20	*Xanthoparmelia* spp.	0	0	62
8	6-Oct-17	20	*A. socialis*	1	14.29	62
8	6-Oct-17	20	Off lichen	2	28.57	62
8	11-Oct-17	25	*D. scruposus*	2	28.57	63
8	11-Oct-17	25	*Xanthoparmelia* spp.	4	57.14	63
8	11-Oct-17	25	*A. socialis*	0	0	63
8	11-Oct-17	25	Off lichen	1	14.29	63
8	16-Oct-17	30	*D. scruposus*	4	57.14	64
8	16-Oct-17	30	*Xanthoparmelia* spp.	1	14.29	64
8	16-Oct-17	30	*A. socialis*	0	0	64
8	16-Oct-17	30	Off lichen	2	28.57	64
9	18-Sep-17	2	*D. scruposus*	1	14.29	65
9	18-Sep-17	2	*Xanthoparmelia* spp.	0	0	65
9	18-Sep-17	2	*A. socialis*	0	0	65
9	18-Sep-17	2	Off lichen	6	85.71	65
9	19-Sep-17	3	*D. scruposus*	4	57.14	66
9	19-Sep-17	3	*Xanthoparmelia* spp.	2	28.57	66
9	19-Sep-17	3	*A. socialis*	1	14.29	66
9	19-Sep-17	3	Off lichen	0	0	66
9	21-Sep-17	5	*D. scruposus*	4	57.14	67

9	21-Sep-17	5	*Xanthoparmelia* spp.	2	28.57	67
9	21-Sep-17	5	*A. socialis*	0	0	67
9	21-Sep-17	5	Off lichen	1	14.29	67
9	26-Sep-17	10	*D. scruposus*	4	57.14	68
9	26-Sep-17	10	*Xanthoparmelia* spp.	2	28.57	68
9	26-Sep-17	10	*A. socialis*	0	0	68
9	26-Sep-17	10	Off lichen	1	14.29	68
9	1-Oct-17	15	*D. scruposus*	4	57.14	69
9	1-Oct-17	15	*Xanthoparmelia* spp.	2	28.57	69
9	1-Oct-17	15	*A. socialis*	1	14.29	69
9	1-Oct-17	15	Off lichen	0	0	69
9	6-Oct-17	20	*D. scruposus*	1	14.29	70
9	6-Oct-17	20	*Xanthoparmelia* spp.	5	71.43	70
9	6-Oct-17	20	*A. socialis*	0	0	70
9	6-Oct-17	20	Off lichen	1	14.29	70
9	11-Oct-17	25	*D. scruposus*	3	42.86	71
9	11-Oct-17	25	*Xanthoparmelia* spp.	0	0	71
9	11-Oct-17	25	*A. socialis*	4	57.14	71
9	11-Oct-17	25	Off lichen	0	0	71
9	16-Oct-17	30	*D. scruposus*	2	28.57	72
9	16-Oct-17	30	*Xanthoparmelia* spp.	5	71.43	72
9	16-Oct-17	30	*A. socialis*	0	0	72
9	16-Oct-17	30	Off lichen	0	0	72
10	18-Sep-17	2	*D. scruposus*	3	42.86	73
10	18-Sep-17	2	*Xanthoparmelia* spp.	0	0	73
10	18-Sep-17	2	*A. socialis*	1	14.29	73
10	18-Sep-17	2	Off lichen	3	42.86	73
10	19-Sep-17	3	*D. scruposus*	4	66.67	74
10	19-Sep-17	3	*Xanthoparmelia* spp.	0	0	74
10	19-Sep-17	3	*A. socialis*	2	33.33	74
10	19-Sep-17	3	Off lichen	0	0	74
10	21-Sep-17	5	*D. scruposus*	3	60	75
10	21-Sep-17	5	*Xanthoparmelia* spp.	1	20	75
10	21-Sep-17	5	*A. socialis*	1	20	75
10	21-Sep-17	5	Off lichen	0	0	75
10	26-Sep-17	10	*D. scruposus*	2	40	76
10	26-Sep-17	10	*Xanthoparmelia* spp.	1	20	76
10	26-Sep-17	10	*A. socialis*	1	20	76
10	26-Sep-17	10	Off lichen	1	20	76
10	1-Oct-17	15	*D. scruposus*	3	60	77

10	1-Oct-17	15	*Xanthoparmelia* spp.	2	40	77
10	1-Oct-17	15	*A. socialis*	0	0	77
10	1-Oct-17	15	Off lichen	0	0	77
10	6-Oct-17	20	*D. scruposus*	1	20	78
10	6-Oct-17	20	*Xanthoparmelia* spp.	3	60	78
10	6-Oct-17	20	*A. socialis*	1	20	78
10	6-Oct-17	20	Off lichen	0	0	78
10	11-Oct-17	25	*D. scruposus*	0	0	79
10	11-Oct-17	25	*Xanthoparmelia* spp.	2	50	79
10	11-Oct-17	25	*A. socialis*	1	25	79
10	11-Oct-17	25	Off lichen	1	25	79
10	16-Oct-17	30	*D. scruposus*	0	0	80
10	16-Oct-17	30	*Xanthoparmelia* spp.	2	50	80
10	16-Oct-17	30	*A. socialis*	2	50	80
10	16-Oct-17	30	Off lichen	0	0	80
11	18-Sep-17	2	*D. scruposus*	2	28.57	81
11	18-Sep-17	2	*Xanthoparmelia* spp.	3	42.86	81
11	18-Sep-17	2	*A. socialis*	1	14.29	81
11	18-Sep-17	2	Off lichen	1	14.29	81
11	19-Sep-17	3	*D. scruposus*	3	42.86	82
11	19-Sep-17	3	*Xanthoparmelia* spp.	3	42.86	82
11	19-Sep-17	3	*A. socialis*	0	0	82
11	19-Sep-17	3	Off lichen	1	14.29	82
11	21-Sep-17	5	*D. scruposus*	2	28.57	83
11	21-Sep-17	5	*Xanthoparmelia* spp.	4	57.14	83
11	21-Sep-17	5	*A. socialis*	1	14.29	83
11	21-Sep-17	5	Off lichen	0	0	83
11	26-Sep-17	10	*D. scruposus*	3	42.86	84
11	26-Sep-17	10	*Xanthoparmelia* spp.	4	57.14	84
11	26-Sep-17	10	*A. socialis*	0	0	84
11	26-Sep-17	10	Off lichen	0	0	84
11	1-Oct-17	15	*D. scruposus*	2	33.33	85
11	1-Oct-17	15	*Xanthoparmelia* spp.	2	33.33	85
11	1-Oct-17	15	*A. socialis*	2	33.33	85
11	1-Oct-17	15	Off lichen	0	0	85
11	6-Oct-17	20	*D. scruposus*	2	33.33	86
11	6-Oct-17	20	*Xanthoparmelia* spp.	4	66.67	86
11	6-Oct-17	20	*A. socialis*	0	0	86
11	6-Oct-17	20	Off lichen	0	0	86
11	11-Oct-17	25	*D. scruposus*	0	0	87

11	11-Oct-17	25	*Xanthoparmelia* spp.	7	100	87
11	11-Oct-17	25	*A. socialis*	0	0	87
11	11-Oct-17	25	Off lichen	0	0	87
11	16-Oct-17	30	*D. scruposus*	1	16.67	88
11	16-Oct-17	30	*Xanthoparmelia* spp.	4	66.67	88
11	16-Oct-17	30	*A. socialis*	0	0	88
11	16-Oct-17	30	Off lichen	1	16.67	88
12	18-Sep-17	2	*D. scruposus*	2	14.29	89
12	18-Sep-17	2	*Xanthoparmelia* spp.	8	57.14	89
12	18-Sep-17	2	*A. socialis*	0	0	89
12	18-Sep-17	2	Off lichen	4	28.57	89
12	19-Sep-17	3	*D. scruposus*	6	42.86	90
12	19-Sep-17	3	*Xanthoparmelia* spp.	7	50	90
12	19-Sep-17	3	*A. socialis*	0	0	90
12	19-Sep-17	3	Off lichen	1	7.14	90
12	21-Sep-17	5	*D. scruposus*	2	14.29	91
12	21-Sep-17	5	*Xanthoparmelia* spp.	10	71.43	91
12	21-Sep-17	5	*A. socialis*	1	7.14	91
12	21-Sep-17	5	Off lichen	1	7.14	91
12	26-Sep-17	10	*D. scruposus*	3	23.08	92
12	26-Sep-17	10	*Xanthoparmelia* spp.	9	69.23	92
12	26-Sep-17	10	*A. socialis*	0	0	92
12	26-Sep-17	10	Off lichen	1	7.69	92
12	1-Oct-17	15	*D. scruposus*	1	8.33	93
12	1-Oct-17	15	*Xanthoparmelia* spp.	8	66.67	93
12	1-Oct-17	15	*A. socialis*	1	8.33	93
12	1-Oct-17	15	Off lichen	2	16.67	93
12	6-Oct-17	20	*D. scruposus*	1	8.33	94
12	6-Oct-17	20	*Xanthoparmelia* spp.	8	66.67	94
12	6-Oct-17	20	*A. socialis*	1	8.33	94
12	6-Oct-17	20	Off lichen	2	16.67	94
12	11-Oct-17	25	*D. scruposus*	1	8.33	95
12	11-Oct-17	25	*Xanthoparmelia* spp.	5	41.67	95
12	11-Oct-17	25	*A. socialis*	3	25	95
12	11-Oct-17	25	Off lichen	3	25	95
12	16-Oct-17	30	*D. scruposus*	0	0	96
12	16-Oct-17	30	*Xanthoparmelia* spp.	3	25	96
12	16-Oct-17	30	*A. socialis*	5	41.67	96
12	16-Oct-17	30	Off lichen	4	33.33	96