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Authors: Wick, Ashley Anne, Pruss, Shelley, Spence, John, and Erbilgin, Nadir

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MICROHABITAT USE IN A NORTHERN PERIPHERAL POPULATION OF *APODEMIA MORMO*:
FACTORS BEYOND THE HOST PLANT

ASHLEY ANNE WICK^{1,2*}, SHELLEY PRUSS^{2,3}, JOHN SPENCE², NADIR ERBILGIN²

¹Current address: Conservation Stewardship Department, Kalamazoo Nature Center, 7000 North Westnedge Avenue,
Kalamazoo, Michigan 49009 United States

²Department of Renewable Resources, University of Alberta, Edmonton, Alberta T6G 2E3 Canada

³Parks Canada Agency, Western and Northern Service Centre, Calgary, Alberta T2P 3M3 Canada

*Corresponding Author: email: awick@naturecenter.org

ABSTRACT. The Mormon metalmark (*Apodemia mormo*) is widely distributed throughout western North America. The species exists in two peripheral populations in Canada and is listed as threatened in Saskatchewan and endangered in British Columbia. In Saskatchewan, this butterfly relies on *Eriogonum pauciflorum* for larval food and as its primary nectar source; however, presence of its host plant is insufficient to define habitats actually utilized by the butterfly. We investigated microhabitat characteristics that might explain habitat use of *A. mormo* adults using 102 host plant quadrats in which the butterfly was occupied (present) or unoccupied (absent) in Grasslands National Park and the Val Marie Community Pasture, Saskatchewan. Linear discriminant analysis demonstrated significant differences between occupied and unoccupied quadrats. *Apodemia mormo* was found disproportionately in quadrats with a combination of the following variables: higher percent bare ground and soil pH, steeper slope, southerly to south-westerly aspect, lower elevation, and lower soil nitrogen. Our results show that habitat use by *A. mormo* butterflies is correlated with environmental factors that define, either directly or indirectly, the local probability of association with host populations.

Additional key words: *Apodemia mormo*, conservation, *Eriogonum pauciflorum*, Grasslands National Park, habitat selection

Understanding relationships between species and their habitats is a central aspect of ecology (Grinnell 1917; Elton 1927), and has particular significance for species deemed at risk as well as for populations at the extreme periphery of their ranges (Fraser 2000). According to evolutionary theory, individuals and necessary resources are expected to be more concentrated at the center of a species' range than at the periphery; therefore, gradual declines in abundance are often observed toward range edges (Brown 1984). However, given that resource abundance and associated population sizes are dynamic, these patterns vary. As recent range shifts to higher latitudes in some species are associated with climate change (e.g., Parmesan & Yohe 2003, Battisti et al. 2005), peripheral populations presently existing at higher latitudes in North America will likely become increasingly important for the persistence of many animal and plant taxa.

There are other ecological and evolutionary reasons for interest in peripheral populations. Although they are thought to be genetically impoverished relative to central populations, peripheral populations may also be more genetically distinct and freer to evolve and change (Mayr 1940, Noss 1994). Environmental variation clearly affects distribution, phenology, abundance, and diversity of populations (Crick & Sparks 1999; Roy & Sparks 2000, Parmesan & Yohe 2003), and such relationships may be more easily discerned in

populations near species range limits. Indeed, Rosenzweig (1991) suggested that it is crucial to investigate microhabitat characteristics of populations at range peripheries, where natural selection likely drives individuals to select the most advantageous microhabitats. This could have interesting consequences for understanding insect-host plant relationships, as under more extreme conditions microhabitat characteristics may be important constraints on host use. In more benign environments such constraints may be more difficult to discover.

Lepidopterans have long been used as model species for studies in ecology and evolutionary biology, and many species discriminate among habitats based on environmental variables in addition to presence of their host plants (Papaj & Rausher 1987, Lastra et al. 2006, Ashton et al. 2009). For example, soil nutrients affect habitat preferences of some butterfly species (Ehrlich 1965, Ravenscroft 1994, Prudic et al. 2005). Likewise, physical characteristics of grasslands, such as slope and aspect, may affect exposure to solar radiation and create a variety in thermal microenvironments that can affect larval growth and development, as has been shown in studies of the bay checkerspot butterfly (Murphy & Weiss 1988).

We investigated microhabitat characteristics for the disjunct northern peripheral prairie population of the Mormon metalmark (*Apodemia mormo* Felder &

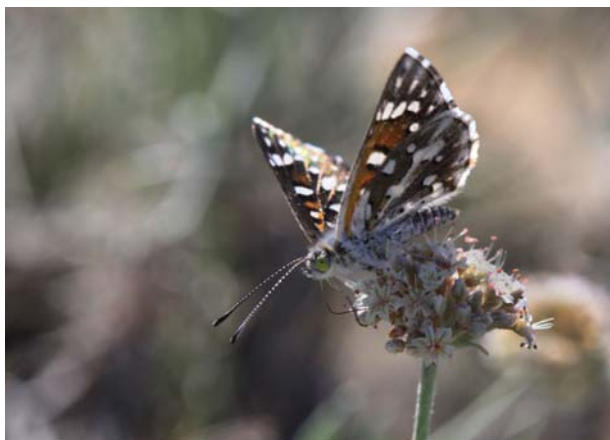


FIG. 1. *Apodemia mormo* on *Eriogonum pauciflorum* in Grasslands National Park, Saskatchewan. (Photo credit: Johane Janelle of Val Marie, SK)

Felder 1859, Riodinidae) in southern Saskatchewan, Canada. *Apodemia mormo* is the only riodinid in Canada, and this prairie population is listed as threatened (COSEWIC 2003, SARA Public Registry). Our objective was to better understand microhabitat use of butterflies by comparing soils, vegetation, and topography between colonies of host plant habitats where the butterfly is present (occupied habitat) and colonies where it is absent (unoccupied habitat). Such higher understanding of this species, in turn, should contribute to greater efficiency in prioritizing particular local areas for conservation action.

MATERIALS & METHODS

Study sites. Grasslands National Park (GNP; 49° 15' N, 107° 09' W) was established in 1984 in the mixed grass prairie ecoregion of southern Saskatchewan. With long, cold winters and short, hot summers, GNP comprises upland and lowland grasslands that are interspersed with sparsely vegetated badland habitat. Approximately half of the 52,700 ha GNP includes badlands, which are eroded landscapes with distinct plant communities characterized by sparse vegetation (Michalsky & Ellis 1994).

Grasslands National Park is apportioned into the East and West Blocks. These two blocks are separated by approximately 40 km of privately owned pasture and farmland. The East Block includes much of Rock Creek and is surrounded by the Wood Mountain plateau while the West Block surrounds the Frenchman River valley southeast of the village of Val Marie (Saskatchewan Institute of Pedology 1992). The West Block contains a herd of plains bison (*Bison bison*) that graze the area at a density of one bison per 55 ha (W. Olson pers. com. 2012).

In addition to GNP, we studied butterfly habitat in the Val Marie Community Pasture (VMCP; 49° 41' N, 107° 92' W), a 40,649 ha area located several kilometers northwest of the park. The VMCP is stocked at a density of one cow-calf pair per 35 ha, and cattle graze from April until the end of October (T. Dyck pers. com. 2012). The VMCP contains several *A. mormo* colonies as well as large areas of host plant habitat where repeated surveys have not uncovered presence of the butterfly.

***Apodemia mormo* and host plant.** *Apodemia mormo* is a small butterfly of the principally neotropical family Riodinidae (Fig. 1). As the most wide-ranging riodinid in North America, it occurs from Mexico to Canada, throughout the western United States. Only two populations of *A. mormo* are found in southern Canada (Scott 1986, Layberry et al. 1998): the “mountain population” in the Similkameen River Valley in British Columbia, and the “prairie population” in Saskatchewan, which is the subject of this study (COSEWIC 2003, Pruss et al. 2008).

While *A. mormo* populations in the southern part of the species range may have multiple flight periods, the prairie population is strictly univoltine with adults generally emerging at the beginning of August and waning towards the end of the month (Arnold 1980; Peterson et al. 2010). However, depending on weather, the flight period of *A. mormo* can vary from mid-July into September (Henderson et al. 2008).

Branched umbrella plants (*Eriogonum pauciflorum* Polygonaceae) are the sole larval host plant and primary nectar source for *A. mormo* (Figure 1) and rabbitbrush (*Ericamerica nauseosa* Asteraceae) is a secondary nectar source. Females of the *A. mormo* prairie population have been recorded ovipositing in small crevices in the soil and on rocks near *E. pauciflorum*, on lichen growing on bare soil, and on the dead material at the base of *E. pauciflorum* (Wick et al. 2012).

Study design. Historically, presence of *A. mormo* in Saskatchewan has been documented through field surveys by Parks Canada, the Government of Saskatchewan, the University of Alberta, and Rev. R. Hooper. Locations of *E. pauciflorum* habitat without the butterfly have also been recorded (Parks Canada, unpublished data 2011). Using this historical information about presence of both imagos and larvae, we established 102 quadrats (5 m × 5 m) in areas where *E. pauciflorum* is present in the badlands of GNP and the VMCP in 2011. Roughly half (n=50) of these quadrats were in areas where *A. mormo* had previously been documented, or occupied habitat, with 33 in the West Block, 11 in the East Block and 5 in the VMCP. The remaining quadrats of unoccupied habitat were

randomly selected from *E. pauciflorum* locations where *A. mormo* had never been recorded, with 30 in the West Block, 9 in the East Block and 14 in the VMCP. Quadrats were visited from May to July of 2011 and a series of measurements were taken in each quadrat to characterize microhabitat.

Each quadrat was characterized with respect to several variables. Elevation, slope, and aspect were taken at the center of each quadrat, and one soil data based on one core taken from the center of each quadrat. The soil samples were dried and analyzed for total nitrogen content (TKN, mg/L; an indicator of soil fertility status), acidity (pH), and soil electrical conductivity (EC; a measurement of soil salinity) at the University of Alberta. We also measured soil penetrability on site using a penetrometer (g/cm; E280 Dayton Pocket Penetrometer). We characterized the biotic community in each quadrat by estimating percent bare ground, percent host plant cover, and percent cover of all vascular plant species. Grasses and sedges were difficult to reliably identify to species within the time-span of this study, so we estimated abundance of sedges and grasses as total grass cover.

Data Analysis. In order to discriminate between characteristics of occupied and unoccupied habitats, we ran a linear discriminant analysis (LDA) in the R package MASS (Venables & Ripley 2002, R Development Core Team 2009). Linear discriminant analysis is a classic parametric method of classification used with a categorical response variable. LDA aims to minimize variance within groups. It explains the variance between groups using a set of predictor variables and maximizes the ratio of between-class variance to within-class variance by defining the linear transformation, or discriminant function, that best fits the data. This method does not rely on the significance of any single predictor variable, but combines them to create a new linear transformation. In our study LDA models the data as two distributions: one each for occupied and unoccupied habitat. We used a Welch two sample t-test to test whether these two linear transformations (occupied vs. unoccupied) differed statistically from one another.

RESULTS

The average measurements of potential habitat predictors for quadrats occupied or unoccupied by *Apodemia mormo* are summarized in Tables 1 and 2. Table 1 shows that occupied sites had lower soil penetrability, lower available nitrogen, higher acidity, higher salinity, slightly higher bare ground, lower elevation, a more southerly or southwesterly aspect, and a steeper slope than unoccupied habitats. In particular,

on average, occupied habitats were more than 5 degrees steeper and 10 meters lower in elevation than unoccupied habitats.

The vegetation composition surveys were done from May to July, and therefore, there was high variability in which herbaceous flowering plants were present or in identifiable stages. Some of these plant species had a narrow phenological window and were absent from plots in one part of the sampling season, making the data of their presence or absence unreliable; such species were excluded from analyses. However, in addition to the host plant and *E. nauseosa*, creeping juniper, yellow umbrella plant, saltbush, prickly pear cactus, Colorado rubberweed, yellow sweet clover, wild rose and sage were all present throughout the summer and were included in candidate models used for selection of variables. In occupied habitats there was an average of 5.5% more host plant cover, 2% less grass/sedge cover, and 0.5% less yellow sweet clover cover.

The LDA results suggest that distributions of microhabitat traits differed between occupied and unoccupied habitats (Table 3; Figure 2). Table 3 shows the directionality of relationships with presence of the butterfly; for instance, there is a negative relationship with elevation, as more easily visualized in Figure 2. A Welch Two Sample T-test showed a significant difference (df: 122, $t=2.4$, $p=0.02$) between the distributions, indicating that *E. pauciflorum* habitat used by *A. mormo* adults differs from unoccupied habitat. Butterflies were more likely to be found in host plant habitat with lower elevation, a southerly to southwesterly aspect, lower available soil nitrogen, a steeper slope, higher % bare ground, and higher soil pH than those habitats without *A. mormo*.

DISCUSSION

Probability of finding *A. mormo* in quadrats with *E. pauciflorum* was affected by a combination of physical and biotic variables. Although host plant presence is a necessary predictor of butterfly presence, it is insufficient to fully characterize habitats occupied by *A. mormo*. In fact, the coefficients from the LDA show that, when factored in, several other variables were critical in distinguishing occupied and unoccupied habitats. *Apodemia mormo* was found disproportionately in *E. pauciflorum* habitat in low-lying areas, with steep slope, a southerly to southwesterly aspect, lower soil nitrogen, higher pH, and higher % bare ground.

Extent of local *E. pauciflorum* cover increased the probability of *A. mormo* presence. In fact, no other plant variables were identified as significant predictors

TABLE 1. Summary statistics averages (standard error of the mean) of habitat predictors at 102 microhabitat quadrats representing occupied (N=50) and unoccupied (N=52) sites by *Apodemia mormo* in southern Saskatchewan, Canada.

Variable	Unoccupied	Occupied	Difference in Means
Penetrability ^a	3.23 (0.199)	0.295 (0.188)	0.28
TKN mgL ^b	2.58 (0.248)	2.36 (0.136)	0.22
Soil acidity (pH)	5.86 (0.207)	5.96 (0.191)	-0.1
Soil salinity (EC) ^c	1055.3 (168.61)	1159.0 (198.08)	-103.7
Bare ground %	51.0 (3.02)	51.3 (3.10)	-0.3
Elevation (metres)	841.1 (5.91)	831.5 (6.34)	9.6
Aspect [°]	171.6 (13.62)	201.0 (15.12)	-29.4
Slope [°]	12.6 (1.22)	17.8 (1.75)	-5.2

^a Penetrability is a measure of the penetrability of the soil, a higher value implies a higher penetrability.

^b TKN is available soil nitrogen, an indicator of soil fertility status.

^c Soil electrical conductivity (EC) is a measurement of soil salinity.

[°] Compass degrees

TABLE 2. Plant survey in *Apodemia mormo* habitat results expressed as the average % cover for each species in occupied and unoccupied sites, in southern Saskatchewan, Canada.

Latin name	Common Name	Occupied %	Unoccupied %	Difference in %
<i>Eriogonum pauciflorum</i>	Branched umbrella plant	21.5	16.0	5.5
<i>Ericamerica nauseosa</i>	Rabbitbrush	6.4	5.1	1.3
<i>Juniperus horizontalis</i>	Creeping juniper	3.7	2.8	0.9
<i>Opuntia polyacantha</i>	Prickly pear cactus	0.5	0.9	-0.4
<i>Poaceae</i> & <i>Cyperaceae</i>	Grasses and sedges	5.4	7.4	-2.0
<i>Hymenoxys richardsonii</i>	Colorado rubberweed	0.1	1.1	-1.0
<i>Eriogonum flavum</i>	Yellow umbrella plant	0.7	0.6	0.1
<i>Artemisia sp.</i>	Sage	4.5	5.0	-0.5
<i>Atriplex nuttallii</i>	Saltbush	2.3	0.9	1.4
<i>Melilotus officinalis</i>	Yellow sweet clover ¹	0.1	0.6	-0.5
<i>Rosa sp.</i>	Wild rose	1.6	2.6	-1.0

¹ *M. officinalis* is an invasive species

of habitats occupied by *A. mormo*, including presence of the secondary nectar source, *E. nauseosa*. High host plant densities are likely crucial for developing larvae as they undertake several short distance migrations from one host plant to another during their late instar development (Peterson et al. 2010, Wick et al. 2012). Host plant density is also critical for other insect-plant systems. For example, density of host plant flowerheads, influenced the presence and abundance of the endangered large blue butterfly, *Maculinea teleius* in Europe (Batary et al. 2007).

Many other studies have also shown that microhabitat factors, in addition to host plant presence, affect habitat selection by insects. For example Thomas et al. (1986) demonstrated that the ideal habitat for the British silver spotted skipper (*Hesperia comma*) consisted of broken south-facing terrain with 45% host plant cover and 40% bare ground. In fact, the butterfly had apparently disappeared from sites after these habitat characteristics had been disturbed, suggesting strong ties between microhabitat characteristics and butterfly presence. Bonebrake et al. (2010) found that the relationship between oviposition behavior and offspring performance was context dependent, and that habitat heterogeneity was likely an important factor.

In a study on the Quino checkerspot butterfly (*Euphydryas editha quino*), presence was positively associated with microhabitat features such as vegetation composition and high solar insolation, in addition to presence of the host plant (Osborne & Redak 2000). Although in the current study we did not investigate how the microhabitat characteristics affect butterfly

TABLE 3. Coefficients of linear discriminants (Scores) included in the model explain the relationship of each variable with *Apodemia mormo* presence in host plant habitat.

Variable	Scores
Elevation	-0.0165
Aspect	0.0032
Available soil nitrogen	-6.7855
Slope	0.0823
% Bare ground	0.0043
pH	0.2059

biology, Osborne & Redak (2000) showed that high shade was associated with delayed emergence from diapause whereas low shade was associated with early emergence and accelerated development. Likewise, both Dobkin et al. (1987) and Weiss et al. (1988) reported that topographic heterogeneity, with respect to slope exposure in serpentine grasslands, contributed to the long-term persistence of populations of *E. editha*. This is likely because microclimate, which largely depends on microtopography, affects the phenology of larval host plants and adult nectar sources (Weiss et al. 1988). Microhabitat features of sites can also influence site preferences of insects by affecting microclimate, influencing lepidopteran thermoregulation and providing protection from predators (Quirt et al. 2006). Such results suggest that microtopography and microclimate effects on *A. mormo* could be further investigated to understand patterns of habitat use observed in the present study.

Presence of exotic plants influences habitat use in many butterfly species, mainly through competitive exclusion of host plants (Proctor & Woodwell 1975, Murphy & Ehrlich 1988, Murphy & Weiss 1988, Mattoni et al. 1997, Osborne & Redak 2000). In the current study, the only exotic species noted in *E. pauciflorum* habitat was *Melilotus officinalis* ((L.) Lam., Fabaceae). The occurrence of this species in host plant habitat was very low at an average of 0.1% cover in occupied vs. 0.6% cover in unoccupied habitats. We suspect two potential adverse effects of *M. officinalis* in *A. mormo* biology. Presence and abundance of this species may limit movement between host plants during larval dispersal and influence host plant selection during adult *A. mormo* dispersal, as there are large tracts of land that have been densely occupied by this exotic

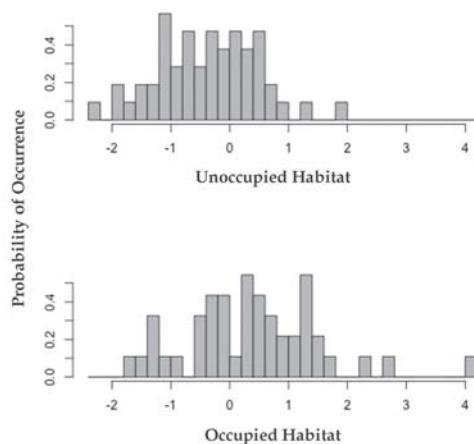


FIG. 2. Linear discriminant analysis shows the distribution “discriminants” of the two distributions, the first of which is “unoccupied” habitat and the second, which is “occupied”.

plant, some of them bordering small areas of *E. pauciflorum* habitat. Additional studies are needed to better understand the potential role of exotic plants during habitat selection by *A. mormo*.

The effects of grazing, either by bison or cattle, were not included in the final analyses used in this paper. Spatial autocorrelation among sites could not be separated from grazing categories, because grazing types and intensity were separated by several dozen kilometers. Continuing work may provide the opportunity to investigate the effects of grazing on *A. mormo* habitat choice and usage.

While the present study is specific to the Saskatchewan prairie population of *A. mormo*, new information presented may apply to the southern mountain population in British Columbia, as well as those in the northern portion of the species range in the United States. While the southern mountain population differs from the prairie population in climate and host plant (*Eriogonum niveum*), it is likely that this population may be under similar pressures and further work may reveal similar trends.

Conservation implications. In the face of global warming and other major environmental and land use changes, northern peripheral populations, such as those of *A. mormo* in southern Canada, will likely be important for the long-term persistence of many species (Hunter 1991, Fraser 2000). It is thus vital to understand the ecology and habitat requirements of these populations in order to effectively manage habitats to ensure that their survival is not negatively impacted by anthropogenic disturbance. The distribution of *A. mormo* in the prairie population is restricted in two ways: butterflies only occur in badland habitat and, in proximity of the larval host plant, *E. pauciflorum*. In addition, we have shown that other environmental characteristics influence butterfly occupancy in *E. pauciflorum* habitat. These additional factors should be considered in managing the occupied habitats in both GNP and VCMP. We suggest the following criteria be used to refine habitat designations for *A. mormo*: *E. pauciflorum* growing on soils with higher pH and low available nitrogen, on steep slopes that are south-west to south facing at lower than average elevation, in badland habitat with bare ground cover.

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