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Oviposition selection by a rare grass skipper *Polites mardon* in montane habitats: Advancing ecological understanding to develop conservation strategies

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ABSTRACT

The Grass skipper subfamily (Hesperiinae) includes many at risk species across the globe. Conservation efforts for these skippers are hindered by insufficient information about their basic biology. Mardon skipper (*Polites mardon*) is declining throughout its range. We surveyed mardon oviposition across nine study meadows in the Gifford Pinchot National Forest of Washington State. We conducted habitat surveys with respect to oviposition ($n = 269$) and random ($n = 270$) locations, recording data on over 50 variables. Mardon oviposited on 23 different graminoid species, yet are selective for specific graminoids within meadows. Most frequent ovipositions across meadows occurred on *Festuca idahoensis* and *Poa pratensis* (accounting for 112 of 269 total oviposition observations). Discriminant Function Analyses revealed that mardon habitat was too variable to detect oviposition selection across study meadows, yet there was strong selection occurring within meadows (r^2 ranging from 0.82 to 0.99). Variables important to within meadow selection were graminoid cover, height, and community; oviposition plant structure (leaf density, height, area); insolation factors (tree abundance and canopy shading); and litter layer factors (cover and depth). With few exceptions the primary variables discriminating between oviposition and random locations were significantly different ($p < 0.001$). Conservation implications include maintaining native meadow ecosystems with sensitivity to local habitat preferences.

1. Introduction

Lepidoptera are one of the largest, most diverse, and most endangered taxonomic groups (Thomas et al., 1994; Smallidge and Leopold, 1997; Liu et al., 2006). Habitat loss and degradation has led to declines in butterfly populations across many parts of the world; including Europe, Africa, Asia, Australia, and North America (Thomas et al., 1994; Smallidge and Leopold, 1997; Bergman, 1999; Eastwood and Hughes, 2003; Fox et al., 2006; Freese et al., 2006; Liu et al., 2006; Albanese et al., 2007b; Edge et al., 2008). Successful recovery of at risk species largely depends on a sufficient understanding of their basic biology, yet this knowledge is often lacking for rare butterflies (Schultz and Crone, 2008).

Butterfly declines often signal the degradation of the habitats with which they are associated (Oostermeijer and van Swaay, 1998). Lepidoptera have a polymorphic life history, including a larval and pupal form in the juvenile state and a winged form in the adult state, making them dependent on a variety of resources within their environment. Adult life stages require sufficient food resources, most commonly nectar flowers, access to host plants, and large scale structural components; such as habitat connectivity, refuge from adverse weather, and adequate insolation (Dennis et al., 2006). Larval stages may require specific plant species for forage as well as particular microhabitat conditions (Grundel et al., 1998; Awmack and Leather, 2002; Albanese et al., 2007a). Resources for adults may be spatially segregated with adults requiring adequate daily access to multiple resources across an area. The dependence on so many habitat variables creates sensitivity to even small changes within the ecosystem, and many species are considered environmental indicators (Oostermeijer and van Swaay, 1998; Brown and Freitas, 2000; Eastwood and Hughes, 2003). Rare butterflies are especially useful for monitoring unique ecosystems and are often associated with other threatened fauna (Brown and Freitas, 2000).

An understanding of what factors determine essential habitat for rare butterflies is imperative to their conservation. Important habitat characteristics are commonly determined by investigating larval habitat use (Ellis, 2003; Anthes et al., 2008). The susceptibility of butterflies to environmental changes is pronounced in the larval state due to their limited mobility and restricted habitat requirements (Thomas et al., 2001; Anthes et al., 2003). Larval survivorship is significantly influenced by ovipositing females, as larvae generally do not travel far, if at all, from their natal locations (Awmack and Leather, 2002; Bergman 1999; Doak et al., 2006).

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Female butterflies are selective during oviposition, depositing eggs in locations that are favorable to larval development and survival will increase their fecundity (Awmack and Leather, 2002). Correspondingly, female butterflies may increase the number of eggs deposited in high quality habitats and host plants (Fownes and Roland, 2002; Chen et al., 2004; Mizumoto and Nakasuji, 2007). Habitat factors that a female butterfly may cue-in on when selecting a suitable oviposition location include host plant species (e.g. Apollo butterfly, *Parnassius apollo,* Fred et al., 2006), host plant nutritional and chemical content (e.g. cabbage white butterfly, *Pieris rapae*, Chen et al., 2004), host plant size and structure (e.g. marsh fritillary, *Euphydryas aurina*, Anthes et al., 2003), and oviposition location microclimate (e.g. Karner blue butterfly, *Lycaeides melissa samuelis*, Grundel et al., 1998; Grundel and Pavlovic, 2007).

The skipper butterfly family, Hesperiidae, harbors approximately 4000 species (Warren et al., 2008). There are at least 55 at risk skippers world wide, including a minimum of 35 grass skippers (subfamily Hesperiinae, Supplementary Data A). Mardon skipper (*Polites mardon*, US federal candidate, Washington State endangered) is a rare and declining butterfly endemic to the Pacific Northwest of the United States (Mattoon et al., 1998). The biology of this species is poorly understood (Potter et al., 2002; Black and Vaughan, 2005; Beyer and Black, 2006). In the US there are three federally listed skippers, including Carson wandering (*Pseudocopaeodes eunus obscurus*, endangered) Laguna Mountains (*Pyrgus ruralis lagunae*, endangered), and Pawnee montane (*Hesperia leonardus montana*, threatened). There are two US federal candidate species, Dakota skipper (*Hesperia dacotae*, Canada endangered) and mardon skipper (*P. mardon*, Washington State endangered), as well as several other state-listed skippers. To date, limited information on habitat requirements inhibits management efforts for these butterflies (US Fish and Wildlife Service, 1997, 1998, 2005; Potter et al., 2002; Beyer and Black, 2006; Warren et al., 2008). Grass-feeding butterflies, in general, have highly complex resource requirements and very little is known about how they utilize habitats. In 2006 we conducted an exploratory study of mardon skipper with the Xerces Society for Invertebrate Conservation. Eleven species of grasses and sedges were observed as oviposition plants (Beyer and Black, 2006). Formerly mardon were believed to deposit eggs only on *Festuca* species, however *Festuca* was absent in many of the sites. This result completely changed former perceptions about mardon habitat (Black and Vaughan, 2005), and further stimulated inquiry as to what makes this butterfly rare.

In this study we investigate mardon skipper site utilization to determine what aspects are critical to conservation. The primary goal of this study is to determine what influences mardon skipper oviposition location selection, thereby understanding larval habitat needs. We aim to determine (1) what graminoid species are utilized for oviposition, (2) what landscape and local factors influence oviposition selection, and (3) to what extent these factors vary between sites. This information is the first step in developing mardon skipper conservation plans and serves as baseline ecological information for future research. In addition, the information contributes to conservation of other rare skippers by advancing knowledge of this understudied family.

2. Methods

2.1. Study species and habitat

Mardon skipper belongs to the grass skipper subfamily, *Hesperiinae* and are dependent on meadow-grassland habitats. Female mardon drop eggs singly while perched; eggs do not affix to host plant. Distributions of extant mardon skipper populations are disjunct; ranging from the grasslands of northwest California to the Puget Trough including the Cascade Mountain Range in both Oregon and Washington State. All known mardon skipper sites are small; most support populations of less than 50 individuals and are isolated from neighboring populations (Potter et al., 2002; Black and Vaughan, 2005).

Existing mardon habitat has undergone major reductions and several populations have been extirpated (Black and Vaughan, 2005). Threats to its existing habitat are a consequence of urban development, resource management (logging, grazing, and fire suppression), and increased recreational use of public lands (Black and Vaughan, 2005). Montane meadow habitats have drastically declined (Coop and Givnish, 2007; Roland and Matter, 2007). Fire suppression has led to tree and shrub encroachment in forest meadows (Norman and Taylor, 2005). Grazing, recreation, increased logging roads, and agriculture have aided the spread of invasive weeds (Leung and Marion, 2000; Trombulak and Frissell, 2000). As a result, meadows and grasslands are disappearing (Griffiths et al., 2005) or undergoing drastic habitat changes (Crawford and Hall, 1997; Noss et al., 1995).

2.2. Meadows

Since 2000, 39 mardon skipper meadows have been documented in the Gifford Pinchot National Forest (Fig. 1). These meadows range from 800 to 1700 m in elevation, and have various management histories. This provided a great opportunity to study several distinct populations, each persisting within different habitat types, and allowing us to investigate the commonality between them. In 2007, 21 of the 39 documented mardon skipper meadows had historically recorded populations where counts exceeded 10 butterflies and were scouted as potential research sites. Of these 21 meadows, three were excluded because they were not logistically feasible, five of the populations never produced adults during our research season, and four were excluded due to small population sizes (under 15 individuals). The nine remaining meadows were included in this study (Fig. 1): Cave Creek, Peterson, Lost, Flog Salvage, Midway, Smith Butte, Muddy, 7A, and Grapefern.

Dominant vegetation at all study meadows consisted of a mix of grasses and sedges. Rushes were only noted present at Cave Creek, Muddy, and 7A meadows which are a mix of moist wetland and dry grassland. Cave Creek is particularly impacted by noxious weeds including houndstounge (*Cynoglossum officinale*) and Canada thistle (*Circium arvense*). Approximately 80% of the Cave Creek meadow has been fenced to reduce grazing and spread of invasive weeds. Historically, Peterson Prairie had heavy livestock grazing impacts. In recent years all grazing on Peterson Prairie has ceased. Flog Salvage was heavily logged, and reseeded with Lodgepole pine (*Pinus contorta*). Approximately 80% of the original meadow is now densely overgrown with saplings, and graminoid diversity there includes only a few species. Lost Meadow, bordered by an open second generation forest, is exposed to short periods of heavy grazing. Midway is an open meadow connected to other open areas of potential mardon habitat. The area surveyed was chosen based on *a priori* knowledge of high mardon use areas.

2.3. Oviposition surveys

Within each meadow we surveyed mardon skipper oviposition selectivity. Surveys were conducted on calm (<5 on Beauford wind scale), sunny days with temperatures above 15 °C. Oviposition observations began when any female was observed flying. A random point and direction within the meadow was located, using random number tables, from which a transect line (~10 m wide) was walked until a female was encountered. Observations were made with the aid of 8 × 42 binoculars. If the female was not indicating oviposition behavior after 10 min, the surveyor terminated