SUMMARY OF AN ONGOING POPULATION STUDY OF *PARNASSIUS CLODIUS* BUTTERFLIES

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✦ INTRODUCTION

Climate change presents unique challenges to high-altitude, high-latitude flying insects such as butterflies, bees, and flies. Models predict that climate change will cause general range shifts toward the poles and high elevations (Parmesan and Yohe 2003, Root et al. 2003) and empirical studies confirm that these range shifts are occurring (Parmesan et al. 1999, Kerr et al. 2015). As the earth warms, animals already living at high elevations and/or high latitudes may have nowhere to go. Furthermore, the body temperature of insects is dependent on ambient temperatures, and therefore many aspects of their ecology and general biology (development, growth, survival, dispersal, mating) may be stressed by or incompatible with a changing climate. Finally, animal flight at altitude involves substantial aerodynamic and physiological challenges, and significant reductions in air density and oxygen constrain flight at higher elevations (Dillon and Dudley 2015). Moving up in elevation therefore may not be an option for some high-altitude fliers.

The Greater Yellowstone Ecosystem (GYE) has served as a model worldwide for the preservation of a large-scale, relatively intact ecosystem. However even in the GYE there are numerous taxonomic groups for which biodiversity patterns are poorly understood. Invertebrates are particularly challenging because they can be difficult (and sometimes impossible) to identify in the field. Parnassius butterflies link the GYE to national parks and reserve areas worldwide. They have a Palearctic/ Nearctic distribution and are a high elevation and high latitude species, generally inhabiting unforested areas above latitudinal or elevational treeline. Both Parnassius butterflies and their habitats are exhibiting responses to climate change (Nakonieczny et al. 2007). In Europe *P. apollo* and *P. mnemosyne* are listed on the IUCN Red List as vulnerable species, while in Canada the range of *P. smintheus* is shrinking due to treeline encroachment (Roland and Matter 2007).

Our research group has been studying *Parnassius clodius* (Figure 1) in the GYE since 1992 and we have been collecting population data within the Pilgrim Creek region of Grand Teton National Park since 1998 (Auckland et al. 2004). Our recent surveys within Grand Teton National Park identified 32 locations where the species could be found. However, none of these supported large populations: 11 had medium-sized populations (~25 butterflies observed/survey) and 21 had small-sized populations (~3 butterflies observed/survey) (Szcodronski 2014). Furthermore, our previous research showed that during drought, butterflies associated with particular habitats in the GYE show declining trends (Debinski et al. 2013).

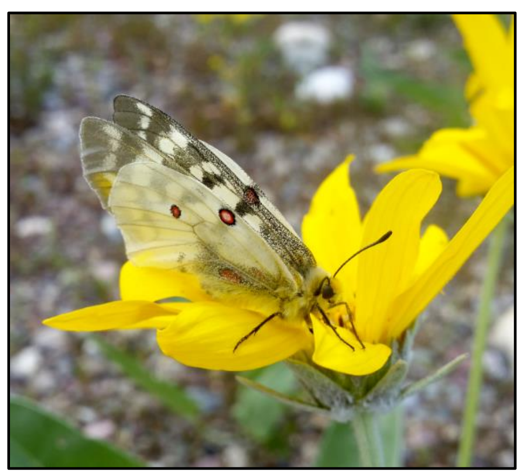

Figure 1. *Parnassius clodius* butterfly.

It is unclear whether the current population configuration in Grand Teton National Park is a stable one. Forest encroachment and shrinking meadow habitat related to climate change could threaten the viability of the *P. clodius* population. Recent studies of sister-species *P. smintheus* have been conducted in alpine meadows along the Rocky Mountain range of Alberta, Canada. Roland et al. (2000) found that treeline changes reduced the average meadow size by 78% from 1952 to 1993, interfering with habitat connectivity and reducing the number of *P. smintheus* moving between meadows by 41%. Butterflies in the Alberta system do not disperse among meadows if there is more than 1 km of forest separating the populations (Roland and Matter 2007).

Montane meadow butterflies such as Parnassius that are constrained to isolated, shrinking habitats and that avoid forest edges are highly vulnerable to genetic isolation, and could be under an increased extinction threat (Keyghobadi et al. 1999, Roland et al. 2000, Keyghobadi et al. 2005, Roland and Matter 2007, Dirnbock et al. 2011). Between 1975 and 1999, *P. apollo* went extinct in 10% of its range, and is in decline in 43% of its range. Populations are known to be stable in only 18% of its territory. Major factors causing the decline of the species include extreme weather variability, shrinking population sizes leading to reduced genetic diversity, and shrinking habitat due to forest encroachment (Nakonieczny et al. 2007).

This study, begun in 2009, was established to provide more information about the population dynamics of one of the largest populations of *Parnassius clodius* in Grand Teton National Park. We collected data using mark-recapture techniques to assess population parameters such as emergence date, population size, and sex ratio. Here we compile information obtained from population studies and observations of *P. clodius* from 2009 through 2015.

✦ METHODS

Study organisms

Parnassius clodius are moderately large (5 to 7 cm wingspan), predominantly white butterflies found in western Canada and the western United States. Highest densities of *P. clodius* are typically found in dry, gravelly sagebrush meadows (Auckland et al. 2004). *P. clodius* males emerge several days before the females in June-July and adults fly for 3-4 weeks. Adult females oviposit on vegetation near the host plant species, *Dicentra uniflora*, a spring ephemeral that grows near the edges of snowmelt. *P. clodius* larvae feed on the host plant throughout the spring until pupation.

Study sites

We conducted our mark-recapture-release (MRR) surveys in a dry sagebrush meadow with a relatively homogeneous topography at an elevation of ~2100 meters in Grand Teton National Park, WY. The meadow is approximately 2 km x 0.5 km in size (Auckland et al. 2004) and located along Pilgrim Creek Road, just south of the University of Wyoming-National Park Service Research Station. The Pilgrim Creek population is one of the larger populations of *P. clodius* within the Greater Yellowstone Ecosystem (Szcodronski 2014).

Mark-recapture-release (MRR) study

We investigated adult population parameters during the flight period in 2015. We initiated MRR studies immediately after adult emergence and terminated surveys when less than 10 butterflies were seen summed across all of the plots, signaling population decline. Daily surveys were limited to the hours between 10:00 and 17:00, when the temperature was above 21° C, wind was less than 16km/h, and the sun was not obscured by clouds.

Using MRR technique, two investigators walked within 50 x 50 meter plots (located approximately 200 meters apart) for 20 minutes and captured any *P. clodius* individual within the boundary of the plot using a butterfly net. Individuals were then placed in glassine envelopes and held by the investigator in a small box attached to a belt until the end of the survey. We marked all captured individuals with unique numbers on the ventral side of each hindwing using a felt-tip permanent marker. We identified males and females based on external morphological differences. Female mating status was determined by the presence or absence of sphragus (a waxy structure deposited by the male during mating that prevents future matings). Wing wear (an indicator of age) and behavior at the time of capture were also recorded.

✦ RESULTS

Field work

Parnassius clodius butterflies emerged at the Pilgrim Creek site on June 7, 2015. We began field surveys on June 9th, and continued surveys through July 4th. Over the course of the flight season we conducted a total of 76 surveys and marked a total of

621 butterflies in 664 capture events. Captures and recaptures are listed in Table 1.

Table 1: *Parnassius clodius* butterflies captured in 76 surveys during the 2015 flight season

Number of captures	1	2	3
Males	357	29	3
Females	225	6	1
Total	582	35	4

Data analysis

Population size and capture probability from raw MRR data can be estimated using methods developed by Craig (1953) and refined by Matter and Roland (2004).

✦ DISCUSSION

Six years of mark-recapture-release studies on the Pilgrim Creek population of *Parnassius clodius* butterflies indicate that the size of this population is highly variable. Future work should examine environmental conditions that might be responsible for the fluctuations in the population sizes. This population is also demonstrating a trend toward earlier emergence and longer flight periods. Possible asynchrony between the flight season and the flowering season of its primary nectar sources (e.g., *Eriogonum umbellatum*) should be the topic of future analyses. Increased asynchrony may lead to a higher percentage of unmated females stranded at the end of the flight season (Calabrese et al. 2008). Increasing asynchrony in this population may make it more likely to suffer from the Allee effect, in which population growth rate decreases at low population densities. Finally, an investigation into the phenology of the larval stage of the butterfly could provide insights into causal mechanisms driving earlier adult emergence dates.

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