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Observations on the Life History of the Sagebrush Sheep Moth, *Hemileuca hera hera* (Lepidoptera: Saturniidae)

Abstract

This study was conducted principally to investigate the suggestion that length of growing season influences the length of development time (i.e., a one year versus two year egg to adult period). Field-collected sagebrush sheep moth, *Hemileuca hera hera* (Harris), larvae were reared to obtain information on egg counts and length of life cycle. Field-collected larvae were reared in cages within the area from which the larvae had been collected in order to match closely the natural conditions. Results indicate that in south-central Washington, an area having a relatively long growing season, *H. hera hera* generally exhibits a one year cycle, with some individuals emerging in the second year. Egg counts revealed a mean total number of eggs per female of 125 (range 64-168) and a mean number of eggs per ring of 28 for reared females and 31 for egg rings observed in the field. Our study indicates that while an extended, milder climate is a significant factor in a single season development time, other factors that have longer term survival significance may also play roles.

Introduction

The life histories of several North American *Hemileuca* species were described by Ferguson (1971) and Tuskes et al. (1996). Species from California and Oregon were described by McFarland (1974), Stone et al. (1988), and Tuskes (1984). Information provided by Tuskes (1984) for the sagebrush sheep moth, *Hemileuca hera hera* (Harris), was based on studies of populations in California on the east side of the Sierra-Cascade ranges in high desert habitats. For these populations, Tuskes (1984) reported a two year life cycle with larval emergence in late April through May of year one and emergence from the puparium and a flight period of late June through mid-September of the second year. In this two-year cycle, eggs and pupae overwintered. Emergence during the same year as pupation was reported for other species of *Hemileuca* occurring in areas having longer growing seasons (Ferguson 1971 and Tuskes et al. 1996).

The present study was conducted to investigate the emergence patterns of *H. hera hera* in the mid-Columbia region of south-central Washington at elevations ranging from 120 to 500 m. The growing season in this region is longer than that in the Sierra-Cascade areas of California where previous studies were conducted (Tuskes 1984). The area is sagebrush-steppe habitat dominated by big sagebrush (*Artemisia tridentata* Nutt.), the primary food plant for larval *H. hera hera*. The present study provides insight into life cycle differences for *H. hera hera* between long and short developmental regions as suggested by Tuskes (1984) for other *Hemileuca* species, and by Stone et al. (1988) for *H. hera magnifica* (Rotger). During the course of the study information on egg counts was also obtained.

Material and Methods

Hemileuca hera hera was reared from eggs and larvae collected in the field from sagebrush-steppe habitat in the vicinity of Richland, Benton County, Washington. Eggs and larvae were placed in cages containing soil 5-20 cm deep. Fresh cut sagebrush sprigs were provided every three to four days. Rearing simulated natural conditions as closely as possible. Cages were kept outdoors in areas having sun for several hours per day, based on the need of the larvae for direct sunshine as suggested by Duke Downey and as reported by Ferguson (1971).

Following pupation, cages were left undisturbed to await emergence of the adults. The cages were inspected in the evening of each day and records were made of newly emerged adults. Once females

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were observed to have mated, they were allowed to lay eggs in individual cages supplied with small sagebrush stems with leaves, approximately 20 cm in length. Eggs were laid in rings on the twigs as described for various *Hemileuca* species by Tuskes (1984). The number of eggs in each ring was recorded, as was the total number of eggs laid by each female. Dead females were opened to determine the number of eggs remaining, which were added to the number of eggs laid to yield the total number of eggs produced.

After the emergence period ended the first year, all remaining pupae (157) were removed from the soil of the rearing cages and consolidated into three cages to await emergence of adults during the second year. Pupae were placed under 2-5 cm of soil in the emergence cages.

During the course of the study, frequent visits were made to local sagebrush-steppe locations from which the caged larvae had been collected. The progress of wild larvae and adults was observed for comparison with that of caged individuals to determine if the reared larvae were developing similarly to the wild larvae.

The number of eggs laid by females in the field was investigated by finding and counting rings of empty eggs in the spring, just after hatching. Egg rings were found by searching sagebrush plants for groups of the newly hatched gregarious larvae. The black larvae were easy to see on the light sagebrush plants. The plants were then searched for the rings of empty egg shells. Egg rings were found along small stems of the plant at all heights above the ground, although the most likely place was near the base on small dead branches. This search was successful for about half of the larval groups found.

The rearing and emergence study extended from March of 1991 through October of 1992. The remaining uneclosed pupae from 1992 were observed through October of 1993 but no additional adults emerged. In October of 1993, the remaining pupae were uncovered and found to be dead as determined by the light weight of the pupa or obvious physical damage. All egg rings deposited by captive females were returned to the site from which larvae had been collected.

Results and Discussion

Egg Counts

Egg counts were obtained from 21 females during the study. The total number of eggs deposited per individual ranged from 64 to 168 (x=125, SD = 31, N = 21). The number of eggs per ring by caged females (n=21) ranged from 5 to 59 (x=28, SD = 12, N = 54). Eggs per ring as counted in the field ranged from 19 to 45 (x=31, SD = 9, N = 15). Egg counts for *H. hera hera* were reported by McFarland (1974) to range from 20 to 80 eggs per ring. Also, Stone et al. (1988) reported that for the closely related *H. hera magnifica*, the first egg ring laid generally contained between 50 and 75 eggs and subsequent egg rings contain from 30 to 35 eggs. These numbers are in general agreement with the observations of this study. The small egg counts we observed with caged females were likely the last ring laid by the female when she emptied herself of eggs. This is based on observations from three females in which egg counts were recorded in the order of being laid. For each of these three females the last ring was the smallest, including the minimum observed for the study (5). For these three females, the first ring did not contain a larger number of eggs than the following rings, in contrast to the observation of Stone et al. (1988) for *H. hera magnifica*. The field observations (for all studies) could be slightly biased toward larger egg counts because the larger groups of eggs and larvae are easier to find; finding small numbers of larvae in the field is difficult.

Larvae and Pupae

Newly hatched first instar larvae were found during the first three weeks of March. Additionally, second, third and fourth instar larvae were collected during April and May. Although the groups of black larvae were easy to detect on the light-colored sagebrush, the presence of a black fuzzy gall on the sagebrush made detection of groups of small larvae more difficult. The larvae may derive a degree of protection from predators because of the apparent mimicry association with the galls. Based on information provided by Gagné (1989), the galls appeared to be a response on the part of the plant to attack by a midge in the genus *Rhopalomyia* (Cecidomyiidae).

During late April four wild fourth instar larvae were each observed to have a small egg attached to their dorsal surface, a condition indicative of attack by parasitic tachinid flies. Two reared caterpillars that appeared to be dying were opened and found to each contain one fly maggot. The maggots were allowed to mature, and the adult flies obtained were identified as *Chetogena* sp.

(Diptera:Tachinidae). This observation is consistent with the report by Stone et al. (1988) who found *H. hera magnifica* larvae to be parasitized.

Ultimate instar larvae were observed in the field until mid-June. The reared larvae had completed pupation by the end of June. At total of 228 pupae were reared during the first year of the study.

Emergence during the first year (year of pupation) began on 23 August and ended on 3 October. The mean emergence date for first year pupae was 13 September for males (SD=10), and 10 September for females (SD=10), with a combined mean of 11 September (SD=9). A total of 43 males and 28 females emerged the first year. During the second year, emergence began on 6 August and ended on 28 September with a mean emergence date of 24 August for both males (SD=8) and females (SD=13, combined SD = 11). A total of 23 males and 17 females emerged during the second year. The total number of adults emerging was 111 of the 228 pupae obtained from larval rearing. Tuskes et al. (1996) commented on the difficulty of rearing *H. hera hera* because of factors including disease and parasitism.

These results demonstrate that at our study site, *H. hera hera* emerge during both the first and second year after pupation. Tuskes (1984) suggested that this difference reflects the longer growing season in lower elevation areas such as our Richland, Washington sites. Table 1 presents climate data (WRCC 1999) from the study area and from several locations in the east Sierra-Cascade habitat of *H. hera hera* of California. The table presents two parameters related to climate. First, the median length of the freeze-free period is given as a general measure of the growing period for each location. This period always includes 1 August. Also presented is the total number of days per year which the minimum temperature is 0°C or lower (average number of days with frost per year). These show that the area in our study has a significantly longer growing season and fewer days with freezing temperatures than do the California sites. This gives the first-year individuals more time to develop to the adult stage in our Richland, Washington locations.

Of the pupae removed from the cages and consolidated after the first year, 107 appeared still to be viable. If so, the mortality rate during the first year was 22% (50 of 228 appeared non-viable) after the first year and the emergence rate was 31% (71 adults emerged from 228 pupae). For the second year, based on the remaining 107 presumed live pupae, the emergence rate was 40% and the mortality rate was 60%. Conclusions regarding specific rates of emergence and mortality of wild specimens cannot be made from this study.

Even though we believe that the high mortality rate seen in our studies is probably attribut-

TABLE 1. Comparison of climate data for the study area and the East Sierra-Cascades of California.

	Location Data			Climate Data	
Weather Station	Elevation (ft)	Latitude	Longitude	Median Freeze-Free Period (days)	Average Frost days per year
Study Area (Washington)					
Richland	370	N 46° 19'	W 119° 16'	192	89
East Sierra-Cascades (California)					
Adin RS	4190	N 41° 12'	W 120° 57'	88	171
Alturas RS	4400	N 41° 30'	W 120° 33'	71	203
Bowman Dam	5390	N 39° 27'	W 120° 39'	139	136
Bridgeport	6470	N 38° 15'	W 119° 14'	35	258
Cedarville	4670	N 41° 32'	W 120° 10'	127	153
Doyle 4SSE	4390	N 39° 58'	W 120° 05'	121	153
Fort Bidwell	4500	N 41° 51'	W 120° 08'	111	163
Mono Lake	6450	N 38° 00'	W 119° 09'	125	177
Portola	4850	N 39° 48'	W 120° 28'	47	219
Sierraville RS	4970	N 39° 35'	W 120° 22'	58	199
Susanville	4150	N 40° 23'	W 120° 34'	118	159
Truckee	6020	N 39° 20'	W 120° 11'	46	235
White Mountain 2	12470	N 37° 35'	W 118° 14'	33	289
Woodfords	5650	N 38° 47'	W 119° 48'	119	149

able to natural factors such as disease it may, in part, be due to handling of the pupae between the first and second years. Tuskes (1984) reported that *Hemileuca* pupae are formed in a fragile cell and merely picking them up can result in their destruction. We detected no obvious damage from handling the pupae but it is possible that the removal of the pupae from the rearing cages and placing them under soil in the emergence cages was responsible for some mortality during the second year. Also, the 2-5 cm of soil placed over the pupae may not have provided sufficient thermal protection for them.

The emergence dates indicate that first-year adults emerged about 18 days later than second-year adults. This difference is statistically significant at the 99.95% confidence level using the t-test for comparison of means of distributions (Neter and Wasserman 1974). This difference in emergence time may be because the first year pupae require time to develop before emergence, while the second year pupae are fully developed and ready to emerge when conditions are right.

While these data show that there is adequate developmental time during a single season in the Columbia Basin of central Washington, they also show that a significant portion of the population of *H. hera hera* emerges during the second year. Perhaps, the minimum developmental time period may be reached under certain conditions in the Basin but not all individuals are exposed to conditions needed to complete development that season. There also may be survival benefits to populations that have both one and two year cycles. Climate in the Columbia Basin of central Washington is best characterized as semiarid with hot and dry summers and cold winters (ERDA 1975). Precipitation in the study area ranges from 30-35 cm to less than 12 cm. Temperatures range from an average of 3°C in January to 33°C in July; temperatures of 32°C or above occur an average of 56 days per year (ERDA 1975). These extremes may stress the immature stages of the moth, and slight variations in temperature and precipitation may be detrimental if all individuals were programmed to emerge in a single season (see discussion of desert-inhabiting insects in Tauber et al. 1986). For example, if fall and winter rains would fail to materialize, sagebrush growth during the following spring may not be adequate to support larval sheep moth development. Additionally, *H. hera hera* is prone to disease and parasite attack which may place added stress on the species during any given single season. Dual developmental periods are common in insects and may be a valuable survival strategy (see discussion of bet-hedging devices in Tauber et al. 1986).

Acknowledgements

DLS expresses gratitude and appreciation to the late Dr. Richard E. Fitzner for his guidance and counseling during this study. His frequent encouragement to "write everything down" was found to be valuable advice as this paper was being prepared nearly seven years after completion of the field study. We also thank Dr. Paul Eslinger of the Pacific Northwest National Laboratory for assistance with the statistical analysis of data and Dr. N. E. Woodley of the Systematic Entomology Laboratory, U.S. Department of Agriculture for identification of the parasitic fly specimens.

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Received 3 February 2000
Accepted 24 October 2000

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