IV.6 *Melanoplus sanguinipes* Phenology North–South Across the Western United States

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Distribution and abundance of an insect species are affected by its habitat requirements, such as food and/or climatic resources. As requirements become more specific, distribution and abundance become more limited. For instance, *Melanoplus bowditchi*, a grasshopper found in many Western States, is limited to the range of its primary host plants, silver sagebrush and sand sagebrush (Pfadt 1994). In fact, the relative abundance of these plants will determine if you can even find *M. bowditchi*. Distribution of the bigheaded grasshopper, *Aulocara elliotti*, appears to be limited by climatic conditions. It feeds mainly on grasses and sedges but is restricted to States west of longitude 95° W, where it is particularly abundant in the more arid areas (Pfadt 1994). But *M. femurrubrum*, a general feeder (polyphagous), is distributed throughout North America from coast to coast and from northern British Columbia to northern Guatemala (Pfadt 1994).

Melanoplus sanguinipes, the lesser migratory grasshopper, is polyphagous and distributed in North America from Alaska to Mexico and from coast to coast (Pfadt 1994). It is the most economically important species on Western U.S. rangeland and was partially responsible for the grasshopper "plagues" of the 1930's. Given the territory covered by *M. sanguinipes,* it appears that this species has a remarkable ability to adapt to a multitude of environmental and climatic conditions.

Egg Development and Hatch

All North American grasshoppers of economic importance lay eggs in the soil in pods in the late summer and fall (see Pfadt 1994 for more details). Egg development is important because the timing of hatch in the spring affects the timing of all subsequent stages of grasshopper growth. Hatch can be delayed by diapause, by temperatures below 50 °F (10 °C)—the threshold of developmental activity for most pest grasshoppers, by lack of soil moisture, and by placement of the egg pod in the soil; placement affects temperature and moisture. Likewise, hatch can be accelerated by temperatures above 50 °F and by soil moisture.

For instance, in southwestern Montana, embryos of *M. sanguinipes* develop faster at all temperatures above 50 °F than embryos of *A. elliotti* (see IV. 2). Yet

A. elliotti hatchlings typically appear earlier in the spring than *M. sanguinipes* hatchlings (Kemp and Sanchez 1987), mainly because the pods of *A. elliotti* are nearer the surface of the soil and are generally laid in areas devoid of vegetation. Heat reaches the *A. elliotti* eggs earlier in the spring, and thus they begin to develop earlier than *M. sanguinipes* eggs, which are placed 0.4 inch (1 cm) deeper in the soil and among grass clumps (in areas cooler than bare areas) (Fisher 1993, Kemp and Sanchez 1987).

M. sanguinipes and most other economically important grasshopper species on rangeland have an embryonic diapause. Diapause can be defined as a genetically controlled physiological state of suspended animation that will revert to normal working physiological processes and growth only after occurrence of a specific event or a specific sequence of events. There are two major types of diapause: obligatory (occurs in every individual in a population at the same stage regardless of prevailing conditions) and facultative (not always occurring in every individual in a population and usually dependent upon specific environmental conditions).

In *M. sanguinipes,* the embryonic diapause is facultative. It often occurs when the embryo is about 80 percent developed. Diapause may last for several weeks or several months. With *M. sanguinipes,* we have found that less than 50 percent of any given population (group from a specific place) appears to exhibit long-term diapause (where, at room temperature [about 72 °F or 22 °C], hatch does not occur for at least 2 months). However, for nearly all populations we have studied, the minimum time for eggs to hatch when incubated at 86 °F (30 °C) has been 4 weeks. This 4-week minimum may indicate a very short diapause because embryos from a lab-reared nondiapause strain take only 18–21 days from laying to hatch at 86 °F. We do know that with all natural populations that we have tested, exposure of eggs to cool temperature, particularly 40–52 °F (4–12 °C), for at least 15 days has decreased the subsequent time needed at 86 °F for an embryo to hatch.

Phenological Studies of *M. sanguinipes*

During the spring through summer of 1992 and 1993, we studied the phenology (seasonal growth and development

as it relates to climate) of *M. sanguinipes* at selected sites in Arizona, Utah, and Montana. Each week, we took samples at each site and determined the life stages of *M. sanguinipes*. The results are illustrated in figure IV. 6–1. This research revealed that the progression of growth by *M. sanguinipes* is a similar function of temperature at Bonita, AZ, and at Augusta, MT. The major difference is the calendar time when comparable events occur. Thus, it may be, at least in terms of what controls development in relation to temperature, that the genetic makeup of *M. sanguinipes* does not differ across its range.

Traveling north–south through the Western States, particularly during March, it is easy to notice phenological differences in plant maturity. In Montana, Idaho, Wyoming, and northern Utah, there will be snow on the ground, often freezing nighttime temperatures, and little or no green vegetation. As one moves south from about Salt Lake City, UT (40° N.), some greening is found west of the mountains in Utah and Nevada, and dramatic changes can be found south from Cedar City, UT (about 38° N.), where it is often cool and frosty, to the border of Arizona and Mexico (near 31° N.), where cacti are blooming and cotton has already been planted.

The first hatchlings at 32° N. (Bonita, AZ) were found in early to mid-March, whereas, the same event at New Harmony, UT (near 37° N.), did not occur until early to mid-May. Near 48° N. (Augusta, MT), hatchlings were not found until the first of June. Adults appear to live longer at the more southern sites—as much as 5 months at Bonita, AZ, compared to 3 months at Three Forks, MT.

The effects that accompany latitudinal differences in climate appear to have a greater overall effect on grasshopper growth and development than altitude. However, the sites that are illustrated here vary from about 3,800 ft (1,160 m) to 6,000 ft (1,830 m) in altitude. Two other sites that have been examined over the past 2 years have been Rubys Inn, UT, at more than 7,600 ft (2,316 m) and Pinedale, WY, at more than 7,200 ft (2,200 m). Over the 2 years of these studies at the two high altitude sites, we never collected enough *M. sanguinipes* to derive phenological diagrams. Phenology at high altitudes (> 6,000 ft [1,830 m]) within the same latitude may be different. For instance, Rubys Inn, UT, is at the same latitude as New Harmony, UT. But when hatchlings were showing in
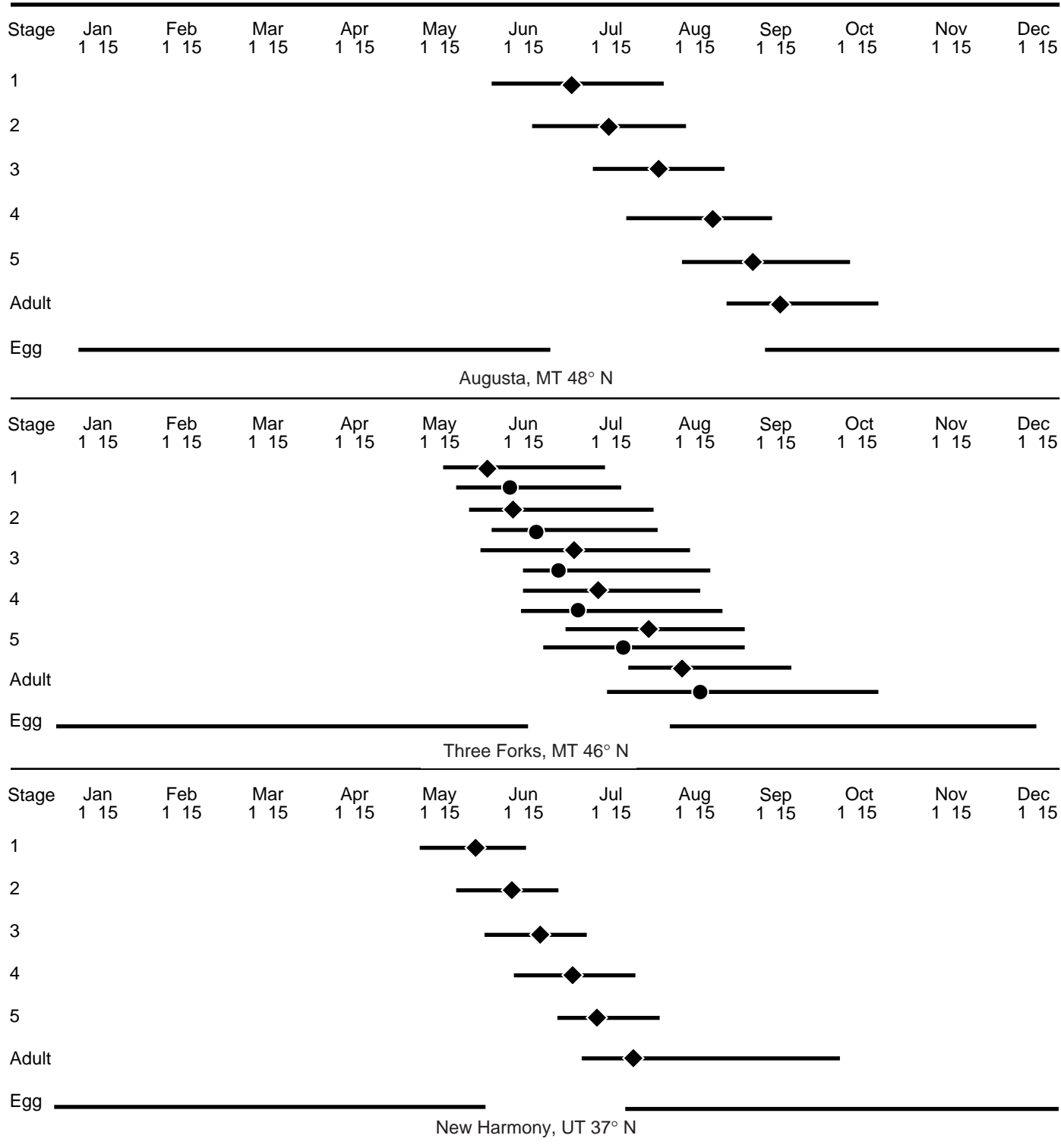
New Harmony (early May), there was still 2 inches of snow on the ground at Rubys Inn. Of course, it should be noted that an altitude of 7,000 ft (2,133 m) or greater in the Western United States at latitudes south of 40° N. is the beginning of the subalpine zone and at latitudes north of 40° N. is the subalpine to alpine zone.

When dealing with rangeland sites at altitudes higher than 7,000 ft, you should remember that mountainous areas have local temperature patterns. If you need to know phenology of grasshoppers in these areas, then temperature needs to be recorded and monitored over time to produce a data base. However, much of the rangeland in the Western United States where we would expect a need for grasshopper integrated pest management is at altitudes below 6,000 ft (1,830 m), and thus, what is mentioned here is applicable.
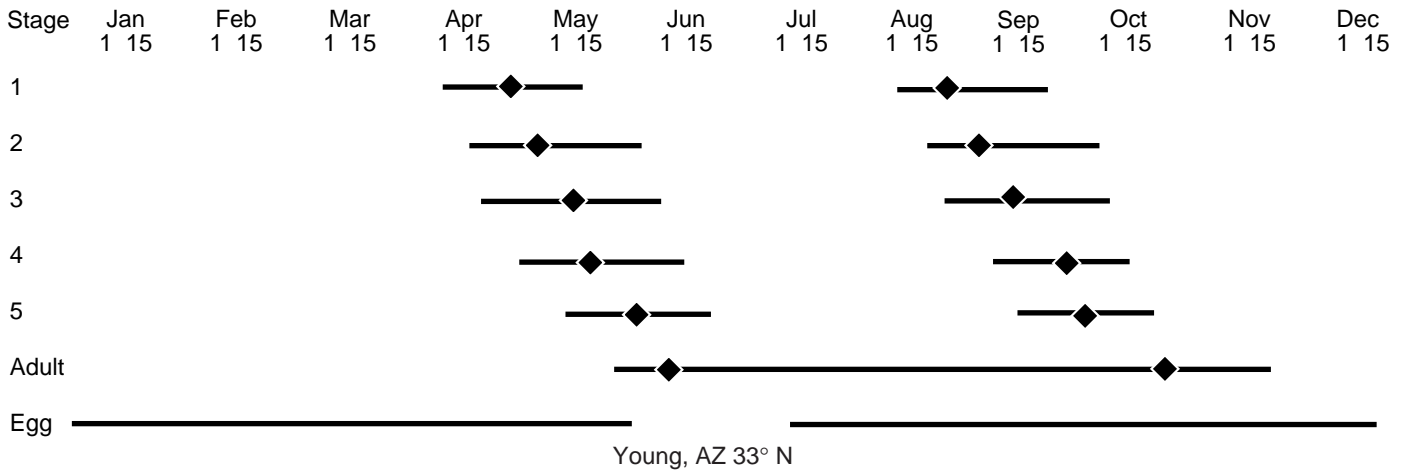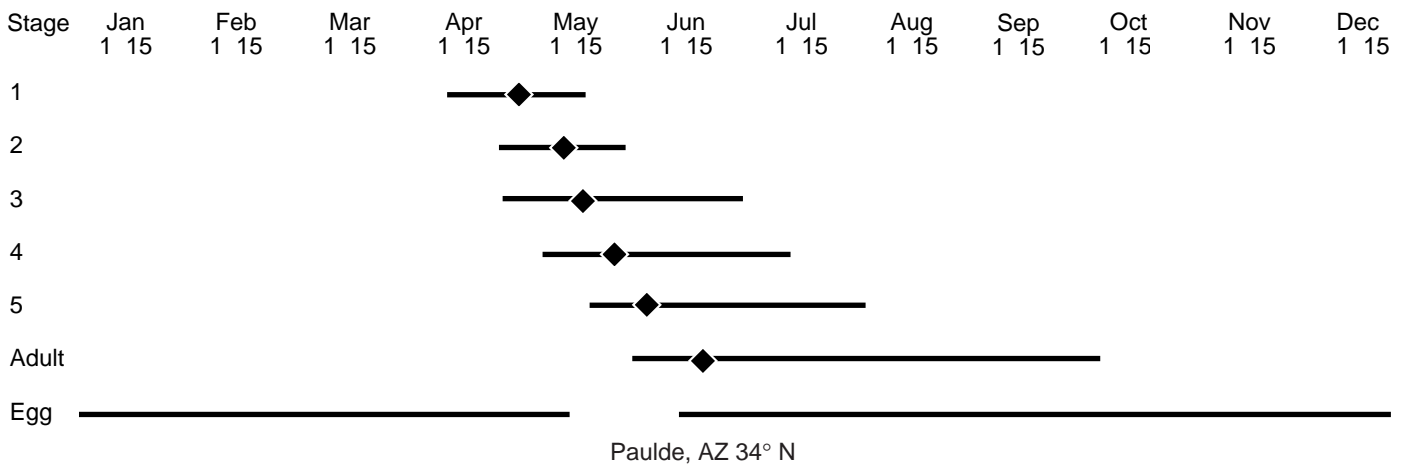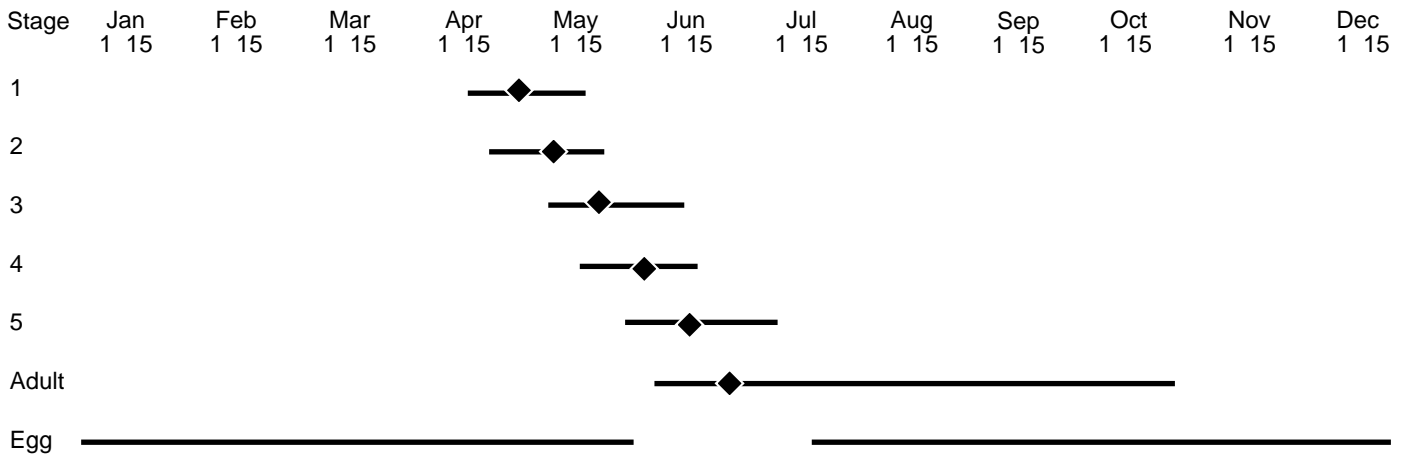
Sampling for phenological development at many of the sites in 1992 was difficult due to wet weather and low populations of *M. sanguinipes*. However, three sites, Three Forks, MT, and San Carlos and Bonita, AZ, were sampled enough times and had high enough populations to derive phenological diagrams. Therefore, we were able to compare phenological development for 2 years at those three sites (fig. IV.6–1). Occurrence of most stages was a few days later in 1993 than in 1992 even though the two seasons were quite different. In 1992, there was a dry spring and a wet summer south of 40° N. and an average (normal) spring and summer north of 40° N. In 1993, areas south of 40° N. suffered an extremely wet spring with a hot, dry summer while areas north of 40° N. had a cold, wet spring and summer.

The reason why there was not much difference in grasshopper development between the 2 years at each of the three areas is speculative. However, grasshopper nymphs are mobile and can seek warm microhabitats, such as bare, south-sloping areas during the day or under leaves at the base of plants at night, to adjust their internal temperature (thermoregulation). Thus, they can maintain metabolism at optimum levels (Kemp 1986, Hardman and Mukerji 1982). In cool weather, grasshoppers can increase their body temperature through basking (sunbathing) or sitting in areas that maximize collection of radiant heat. In warm to hot weather, grasshoppers keep their body temperature cooler than ambient air by seeking

Figure IV.6–1—Phenological occurrence of life stages for *Melanoplus sanguinipes* at two sites in Montana and six sites south of 40° N., 1993 (◆) and 1992 (●)[1]

Stage	Jan 1 15	Feb 1 15	Mar 1 15	Apr 1 15	May 1 15	Jun 1 15	Jul 1 15	Aug 1 15	Sep 1 15	Oct 1 15	Nov 1 15	Dec 1 15

Augusta, MT 48° N

Three Forks, MT 46° N

New Harmony, UT 37° N

[1]The position of the diamond (◆) or circle (●) indicates the peak occurrence of the stage. The long solid lines indicate occurrence only.

House Rock, AZ 36° N

Stage	Jan 1 15	Feb 1 15	Mar 1 15	Apr 1 15	May 1 15	Jun 1 15	Jul 1 15	Aug 1 15	Sep 1 15	Oct 1 15	Nov 1 15	Dec 1 15
1												
2												
3												
4												
5												
Adult												
Egg												

Paulde, AZ 34° N

Stage	Jan 1 15	Feb 1 15	Mar 1 15	Apr 1 15	May 1 15	Jun 1 15	Jul 1 15	Aug 1 15	Sep 1 15	Oct 1 15	Nov 1 15	Dec 1 15
1												
2												
3												
4												
5												
Adult												
Egg												

Young, AZ 33° N

Stage	Jan 1 15	Feb 1 15	Mar 1 15	Apr 1 15	May 1 15	Jun 1 15	Jul 1 15	Aug 1 15	Sep 1 15	Oct 1 15	Nov 1 15	Dec 1 15
1												
2												
3												
4												
5												
Adult												
Egg												

Stage	Jan 1 15	Feb 1 15	Mar 1 15	Apr 1 15	May 1 15	Jun 1 15	Jul 1 15	Aug 1 15	Sep 1 15	Oct 1 15	Nov 1 15	Dec 1 15
1												
2												
3												
4												
5												
Adult												
Egg												

San Carlos, AZ 33° N

Stage	Jan 1 15	Feb 1 15	Mar 1 15	Apr 1 15	May 1 15	Jun 1 15	Jul 1 15	Aug 1 15	Sep 1 15	Oct 1 15	Nov 1 15	Dec 1 15
1												
2												
3												
4												
5												
Adult												
Egg												

Bonita, AZ 32° N

shaded areas and by climbing plants to take advantage of wind and cooling effects coming off the plant surfaces. Thus, the rates at which nymphs develop may remain relatively constant despite variable hot and cold weather. But the time when nymphal development starts will always depend on the time when hatch occurs.

In 1993, we observed what appeared to be a possible second generation at two sites, Young and San Carlos, AZ (fig. IV.6–1). The reason for this phenomenon is unknown; it was not observed in 1992. A second generation of *M. sanguinipes* in the southern areas has been mentioned occasionally in the literature (Barnes 1944, Dean 1982, Hebard 1938, Smith 1943). However, this is the first quantitative data provided as evidence of a second generation. We describe this only as a possible second generation because eggs were not collected in the field throughout the season; therefore, we could not document the early (prediapause) stages of embryonic development that would confirm a second generation.

Relationship to Hopper

The grasshopper phenological simulation module of Hopper (see VI.2) is based on thermal unit accumulation starting on January 1. Although historic National Oceanic and Atmospheric Administration weather data bases were not available for all sites, they were available for areas close to Bonita and San Carlos, AZ, and Augusta, MT. Predicted peaks for each nymphal stage were within 10 days of those shown in figure IV.6–1. We feel that Hopper accurately represents *M. sanguinipes* phenology in the field.

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