Great Basin Naturalist

Volume 44 | Number 1 Article 19

1-31-1984

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EMERGENCE OF ADULT PANDORA MOTHS IN ARIZONA

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ABSTRACT.— Adult pandora moths began emerging in late July, and peak daily emergence occurred during 10–15 August. The mean density of moths emerging per 929 cm^2 of ground surface ranged from 0.1 to 2.4. The ratio of emerging males to females varied from 3–4:1 during the initial days of emergence to 1:1.5 during the last 10 days of August. Postemergence behavior is described and discussed in relation to egg mass deposition and species survival.

Prior to the current pandora moth, *Coloradia pandora* Blake (Lepidoptera: Saturniidae), infestation on the Kaibab National Forest surrounding Jacob Lake, Arizona, life history information on this insect was derived from the works of Patterson (1929), Massey (1940), and Wygant (1941) on populations in California and Colorado, respectively. Near Jacob Lake in 1980, adults emerged much later than previously recorded. Similarly, other aspects of the pandora moth's life history did not coincide with previous reports. This study was conducted to determine the emergence period of adults and their subsequent behavior.

Study Area and Methods

A general description of the infested area is presented in Schmid et al. (1982b). Four locations were selected within this general area and were assigned plot numbers corresponding to adjacent Forest Service roads or U.S. Highway 89A (Fig. 1). These locations were selected because of abundant pupae, substantial elevational gradients, and different aspects (Table 1).

On each plot, screen cages were placed on the surface of the ground to catch emerging adults. The cages on Forest Service Road 246, Forest Service Road 482, and U.S. Highway 89 plots were placed at three different elevations within each plot, representing (1) flat ridge top, (2) ravine bottom, and (3) midslope—approximately halfway between the ridge top and the ravine bottom (Table 1). Within each elevational position, cages were placed 5 m apart either in a straight line or along the contour.

Cages on the Forest Service Road 257 plot were established to monitor the effects of prescribed burning on pupal mortality. They were on a relatively flat area with insignificant elevational and aspectual influences. The cages were laid out in a north-south pattern with the cages at 20 m intervals, on parallel N-S lines that were 10 m apart.

Cages were installed 21–22 July 1982 and were checked daily thereafter until 30 August 1982. Cage examination began each day at 0600 local time. After adults began emerging, the cages were checked in the morning at the usual time and again just before dark to determine if adults were emerging only during daylight or throughout the entire day. The number of males and females emerging in each cage was recorded daily to determine the sex ratio. The mean number of adults emerging per 929 cm^2 was computed for each elevation on each plot, and the means were compared with a one-factor analysis of variance to determine significant differences among elevational positions, $\alpha = 0.05$.

To determine adult longevity, 12 adults were collected as they emerged on 31 July 1982, were separated according to sex, and were placed in holding cages. The cages were checked daily thereafter until all adults were dead. On 5 August 1982, another 10 females were collected, were placed in cages, and were observed daily until they died.

Various amounts of time were spent each day during the first half of the emergence

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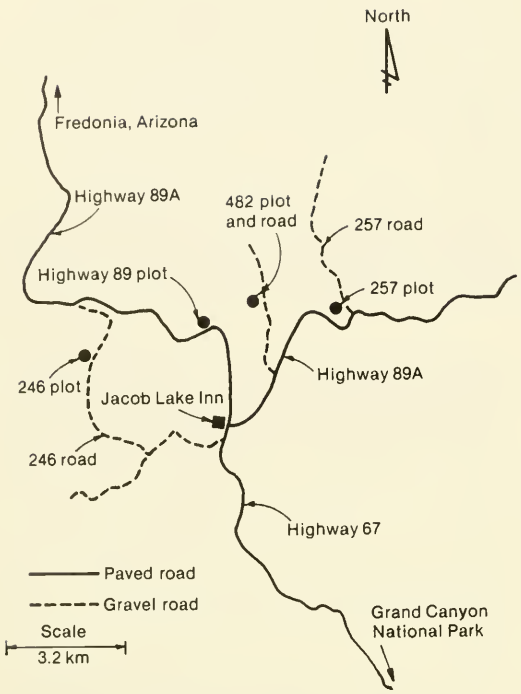

Fig. 1. Geographical location of study areas.

period observing adult behavior as they emerged from the ground. Individual adults were observed for 1–2 hours following emergence. Sex ratios of emerged adults clinging to mature tree boles were determined in the evening.

Results and Discussion

Emergence period.— Adults began emerging on the plots 28 July 1982. A few adults were observed near lights at Jacob Lake a few days earlier, but their numbers were similar to what emerged in the cages. The daily number of emerging adults continued at a low level until 4 August, when the number increased substantially (Fig. 2). Numbers generally increased thereafter, and maximum numbers of adults emerged during 10–15 August. After mid-August, numbers decreased until 30 August, when daily emergence averaged 1–2 adults per day. Adults were observed on 22 September, after the checking of cages had long since ceased, indicating that adults continued to emerge well after most of the population emerged.

Although these data accurately reflect the general emergence pattern, it does not reflect the total number of emerging moths. If an adult emerged for every 929 cm^2 of ground (approximately weighted average from Table 2), then more than 100,000 adults emerged from each infested hectare. If this density is assumed for the approximately 8000 hectares moderately to severely defoliated by the previous larval generation, then approximately 800 million moths have flown during the emergence period. Although this figure is based on limited emergence data and an approximation for total infested area and, thus, may be considered speculative, the numbers observed around the lights at Jacob Lake, around the bases of trees, and flying in the woods suggest otherwise.

Adults emerged at the lower-elevation Forest Service Road 257 plot about 10 days before the first emerging adults on the U.S. Highway 89A plot. The combination of higher elevation and north aspect probably caused slower development on the U.S. Highway 89A plot.

Moths emerged after late summer rains began on the North Kaibab. Rains soften the dry, cementlike soil surface and allow the adult to emerge with less difficulty and consequent increased population survival.

Density of emerging adults.— The number of adults emerging per 929 cm^2 ranged from 0 to 13 (Table 2). Mean densities on ridge tops and midslopes were generally higher than in ravines, but a significant difference between ridge top and ravine was

Table 1. Characteristics of the four emergence plots.

Plot	Aspect	Elevational range	Number of cages/ plot	Number of cages/ elevational position	Cage size
Forest Service Road 246	East	2348–2378 m	51	17	1858 cm^2
U.S. Highway 89A	North	2363–2386 m	51	17	1858 cm^2
Forest Service Road 482	West	2317–2348 m	48	16	1858 cm^2
Forest Service Road 257	None	2325 m	100	100	929 cm^2

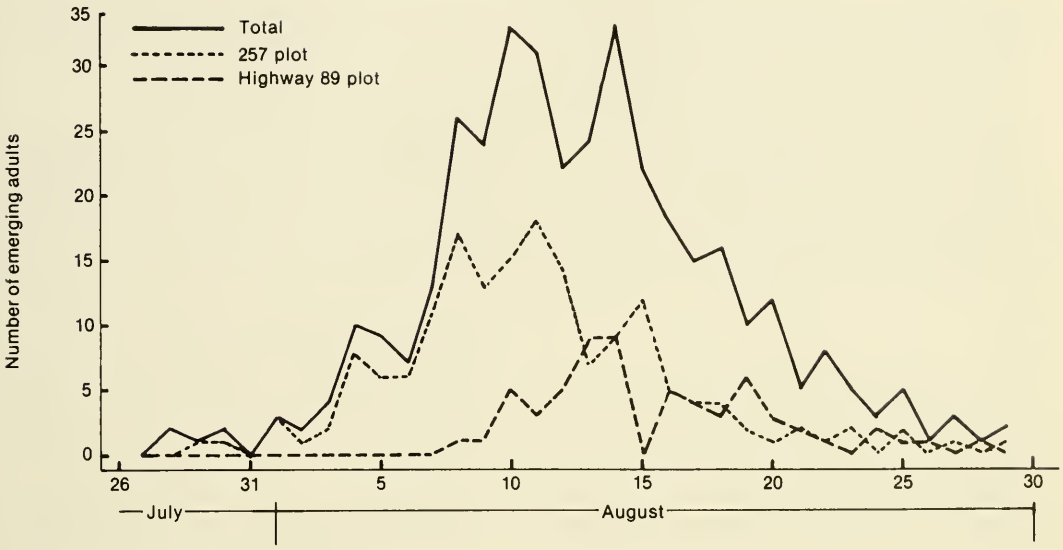

Fig. 2. Daily emergence of pandora moths, 1982.

found only on the 482 plot (Table 2). The low densities in ravine bottoms were expected, because previous observations indicated defoliation was less on trees there. The reason for this elevational variability is not known, but because females are generally active only at night, and the ravine bottoms are noticeably cooler, females may be most active in the warmer thermoclines on the ridge tops and less active in the ravine bottoms. This explanation may also account for the broader pattern of infestation, wherein successive ridges had greater densities of larvae and greater defoliation than did broad, lower elevation areas between them.

SEX RATIO.— Both sexes emerged during the first 10 days of the emergence period, but males outnumbered females by a 3–4:1 margin. As the emergence period progressed, the sex ratio shifted so it was essentially 1:1 during peak emergence and then 1:1.5 during the last 10 days that emergence was monitored.

BEHAVIOR.— Adults crawled upward through the soil and litter from their pupal site, so the first evidence of their emergence was movement of the litter. After emerging, they crawled over the litter surface until they encountered any upward oriented object, including tree boles, dead limbs, grass stems, *Solidago* sp., *Lupinus* sp., cones, and stumps. All were climbed when encountered, but most of the herbaceous plants failed to support the adult. When the stems broke or

TABLE 2. Number of emerging pandora moth adults per 929 cm^2.

Site	Forest Service Road 246 plot	U.S. Highway 89A plot	Forest Service Road 482 plot	Forest Service Road 257 plot
	$\bar{x} \pm$ S.D.			
Ridge top	.4 ± .8 a[1]	.8 ± 1.2 a	2.4 ± 3.2a	1.7 ± 2.4
Midslope	.6 ± 1.1 a	.8 ± 1.1 a	0.4 ± 0.8a b	NA
Ravine bottom	.1 ± .2 a	.2 ± 0.4 a	0.2 ± 0.4b	NA
	Range			
Ridge top	0–3.0	0–4.0	0–12.5	0–13
Midslope	0–3.5	0–4.5	0– 2.5	NA
Ravine bottom	0–0.5	0–1.5	0– 1.5	NA

NA = Not applicable

[1]Within a particular location, means followed by the same letter are not significantly different, $\alpha = .05$.

bent, sending the adult to the ground, the adult resumed crawling and either repeated this process with other herbaceous stems or finally encountered a wooden object. Ninety-nine percent of the time adults settled on the boles of all sizes of ponderosa pine.

Adults sought upward-oriented objects to find a place to hang and expand their wings. The wings are not fully formed when they emerge, and the wings begin to expand once the adults settle on an upward-oriented object.

Most adults settled on the tree boles from within a few centimeters to 2 m above ground, with maximum ascension being influenced by tree size and perhaps the distance the adult crawled over the ground surface before reaching the tree. On seedlings and saplings, adults climbed to various heights, and frequently climbed as high as they could go. On larger trees, adults settled various distances aboveground ranging from a few centimeters to over 6 m in a few cases. Some adults that crawled for 10–20 m before encountering a tree settled within 1 m of the ground, and others that crawled lesser horizontal distances settled higher on the bole.

Adults appeared to discern large trees when they were within 2 m of them, but seemed to encounter seedlings and saplings by chance. Adults frequently crawled past seedlings and saplings that could have provided suitable resting places and continued crawling until encountering another object. Large trees were not bypassed when the adult was within 2 m of them, but adults frequently did not crawl to large trees that were closest to their emergence hole when the distance to the closest tree was more than 2 m.

Adults usually settled in a shaded spot on the tree where they could hang without the abdomen touching any surface. They settled into this position with a lateral rocking motion, during which the antennae were folded close to their ventrolateral surface just above the legs. The wings were expanded within 15 minutes. At first, the leading edge of the unexpanded wings were oriented laterally from the body. As they expanded, the leading edges came together over the dorsal surface of the abdomen and projected outward from the body. The wings remained in this position for another 30 to 45 minutes. Then the leading edges were brought to the lateral sides of the abdomen and the trailing edges formed a triangular tent over the abdomen.

Adults usually remained in the same positions on the boles for the remaining daylight hours unless disturbed or unless their location became exposed to direct sunlight. In such cases, the disturbed adults frequently moved higher on the tree. On sunny days, adults emerging in the morning were usually found on the north and west sides of the trees. Adults emerging in the afternoon were found on the north and east sides of the trees. On cloudy days, more adults were seen on southern exposures.

During the first days of the emergence period, little flight and mating activity was observed. Few females mated during the wing expansion period, and no egg masses were observed on tree boles. As the emergence period progressed, more mature adults were present, and hundreds of males were observed flying during the daylight hours. Males frequently hovered 8–15 cm away from the boles and flew vertically or laterally around the circumference at this distance, apparently in search of females. Newly emerged females frequently mated as soon as they began crawling up the tree or while at rest during wing expansion. As a result, egg masses became abundant in the first 1–2 meters of the bole. This probably accounts for the greater density of egg masses in the first 30 cm of the bole as observed by Schmid et al. (1982a). Furthermore, the highly disproportionate sex ratio favoring males in the initial days of emergence decreases the possibility that females go unmated. This apparently increases the chances of survival of the species.

Females generally were not observed flying during daylight hours. This observation, the tendency to avoid direct sunlight and the tremendous nighttime activity around lights at Jacob Lake, indicates most adults, particularly females, are active at night. Males nearing death were the adults most active during daylight hours.

LONGEVITY.— All but one caged adult died within one week after emergence. The cages kept them relatively inactive so their life spans may have been artificially shortened.

However, seven days is probably the life span of the adult in the forest.

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