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FLIGHT AND ATTACK BEHAVIOR OF MOUNTAIN PINE BEETLES IN LODGEPOLE PINE OF NORTHERN UTAH AND SOUTHERN IDAHO

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ABSTRACT

*Temperature appears to be the most important factor influencing flight and attack behavior of the mountain pine beetle (*Dendroctonus ponderosae *Hopk.). To a large extent, temperature governs onset, daily time and length of emergence and flight, and the location of initial attack. The optimum temperature range for adult mountain pine beetle activity extends from about 19°C to about 32°C; higher or lower temperatures limit beetle activity. Even though the sex ratio of attacking beetles favored the female in this study, all females were mated within at least 10 days of a mass attack on lodgepole pine (*Pinus contorta *Dougl.). Mated females constructed galleries at a greater rate than unmated females.*

Infestations of the mountain pine beetle (*Dendroctonus ponderosae* Hopk.) have long been a part of the lodgepole pine (*Pinus contorta* Dougl.) forests of the intermountain area.

Factors influencing the flight and attack behavior of *Dendroctonus* beetles have been investigated by many workers (Rudinsky and Vité 1956; Miller and Keen 1960; Gara and Vité 1962; Atkins 1966); however, much remains to be learned about the behavior of the mountain pine beetle.

Flights and attacks of these beetles were observed for three consecutive summers (1970-1972) in lodgepole pine stands of northern Utah and southern Idaho. Study areas contained sufficient numbers of trees of large diameter to sustain active and increasing beetle populations. Observations of beetle behavior were confined to a single location within each infestation area. Daily observations were begun as soon as beetle emergence and attacks were in process and lasted until the flight period had ceased.

FLIGHT BEHAVIOR

Influence of temperature.--Emergence and flight of *Dendroctonus ponderosae* usually began in late morning when the air temperature had risen to about 19°C and continued until dusk when the temperature had dropped to about the same level. Maximum flight activity generally was from 4 p.m. to 6 p.m. (m.d.t.), when the temperature was 23°C or higher. As table 1 shows, these observations closely agree with the work of Blackman (1931), Reid (1962a), Shepherd (1966), McCambridge (1967, 1971), and Gray and others (1972). During peak emergence the first summer, the maximum temperature reached or surpassed 32°C on two occasions. On these 2 days, beetle emergence and attacks were reduced. Gray and others (1972) found diminished numbers of emerging beetles on days when the temperature exceeded 30°C.

In each of the 3 study years, beetle emergence followed a period of relatively warm, dry weather. Reid (1962a) also found that the flight period usually began after a period of relatively high temperatures and abundant sunshine.

During the present study, many beetles observed at dusk in bark crevices and under bark scales made no attempt to bore into the trees. The following morning, no signs of beetle activity were observed until air temperature warmed to about 17°C. Then many beetles bored into the bark and others took flight. Apparently, beetles that fly late in the evening and remain concealed on the bark surface overnight become active the following morning at a temperature slightly lower than the temperature that triggers emergence and flight. The warming effect of solar radiation is probably the primary reason for this behavior (Powell 1967).

Length of flight period.--For the most part, beetles that emerged early in the flight period attacked lodgepole pines that had been strip attacked or had pitched out beetles the previous year. After a period of sparse, sporadic emergence, the bulk of the beetles emerged, flew, and made their attacks in about 1 week. In 1970, peak emergence and attacks occurred in 7 days, 9 days in 1971, and 7 days in 1972. In 1971, frequent light thunderstorms in the research area may have caused the slightly longer period of peak emergence.

Beetles emerging after peak emergence behave much the same as those that emerged early in the flight period. For the most part, they attack trees that received only a partial or strip attack. When these beetles attack previously uninfested trees, their numbers are usually insufficient and they are subsequently pitched out. In this

Table 1.--*Observer comparisons of the peak emergence and flight of mountain pine beetles*

Observer	Temperature (°C)	Time	Host	Locality
Rasmussen	23	4 p.m.-6 p.m.	Lodgepole	Utah, Idaho
Reid	22	1 p.m.-4 p.m.	Lodgepole	British Columbia
Shepherd	22	--	Lodgepole	British Columbia
Blackman	--	4 p.m.-dusk	Ponderosa	Arizona
Gray and others	20	11 a.m.-2 p.m.	Ponderosa	Washington
McCambridge	20	4 p.m.-6 a.m.	Ponderosa	Colorado

study, lodgepole pines that were not completely mass attacked within 48 hours of the initial attacks became pitchouts; most never were observed to be successfully mass attacked. McCambridge states that in ponderosa pine (*P. ponderosa* Laws.) the mass-attack period generally lasts from 4 days to about 3 weeks. In the latter case, many attacking females are killed by being pitched out (personal communication July 1973, William F. McCambridge, USDA Forest Service, Ft. Collins, Colo.). Blackman (1931) reported that most emergence of this beetle in ponderosa pine takes place within a few days.

ATTACK BEHAVIOR

Selection of entry sites.--After alighting on a lodgepole pine most *D. ponderosae* move upward, often obliquely. Apparently, searching for a suitable niche, they examine many bark scales and crevices before boring. When beetles fail to find an acceptable niche, even on attacked trees, they take flight after searching less than 30 minutes.

The mountain pine beetle avoided smooth areas, burrowing into the bark under bark scales and in bark crevices. During this 3-year study, initial attacks occurred under bark scales 61 percent of the time and in bark crevices the remaining 39 percent. Shepherd (1965) demonstrated that *D. ponderosae* attacked rough bark more often than smooth bark. Miller and Keen (1960) reported that *D. brevicomis* normally selects the corky and rough layers of outer bark, avoiding those that are smooth and thin.

Aspect of initial attacks.--Observations made the last 2 study years revealed that 36 percent of the initial *Dendroctonus* attacks on lodgepole pine occurred on the north aspect, 25 percent on the west, 21 percent on the east, and 18 percent on the south. Shepherd (1965) found significant differences in total number of attacks per square foot among aspects; north aspects received the largest number, south aspects the smallest, and east and west aspects an intermediate number. Reid (1963) also found attack density greatest on the north aspect. Powell (1967) demonstrated that north aspects of trees had lower surface temperatures than south aspects and were about 1°C cooler than air temperatures. Temperature probably accounts for differences in the number of initial attacks among aspects. At the time of beetle attack, bark surface temperatures can be quite high. According to Shepherd (1966), *D. ponderosae* reverse their phototactic reaction between 35°C and 37.5°C and become photonegative.

Height of initial attacks.--The heights of initial attacks on trees were recorded in 1971 and 1972. Data indicated that 79 percent of the initial mountain pine beetle attacks were between 4 and 6.9 feet above ground level, 93 percent between 4 and 7.9 feet, and the remaining 6 percent below 4 feet. The mean height of attack for the 2 years was 4.69 feet. After the initial attack was made, succeeding attacks generally spread from that point up, down, and around the bole. These data are similar to general trends reported by McCambridge (1967) on ponderosa pine.

Sex ratios.--In 1972, a number of trees were marked and dated at the time they were mass attacked. Later, 10 galleries per tree were excised and examined. Data recorded included: date of mass attack, time lapse from mass attack to gallery examination, presence or absence of male beetles, presence or absence of eggs, and total gallery length. Female beetles were present in every gallery examined; the possibility of some being reemerged parents was not considered.

From a curve fitted to the data (Jensen and Homeyer 1971), it was estimated that 92 percent of the females were mated within 7 days of mass attack and 100 percent within 10 days (fig. 1). This graph includes data from galleries that had eggs, but not necessarily a male parent present. The sex ratio of the parent beetles encountered is presented in table 2. The sex ratio of the attacking population was about 1:2.3 males to females, not much different from the 1:2 sex ratio Reid (1958) found in

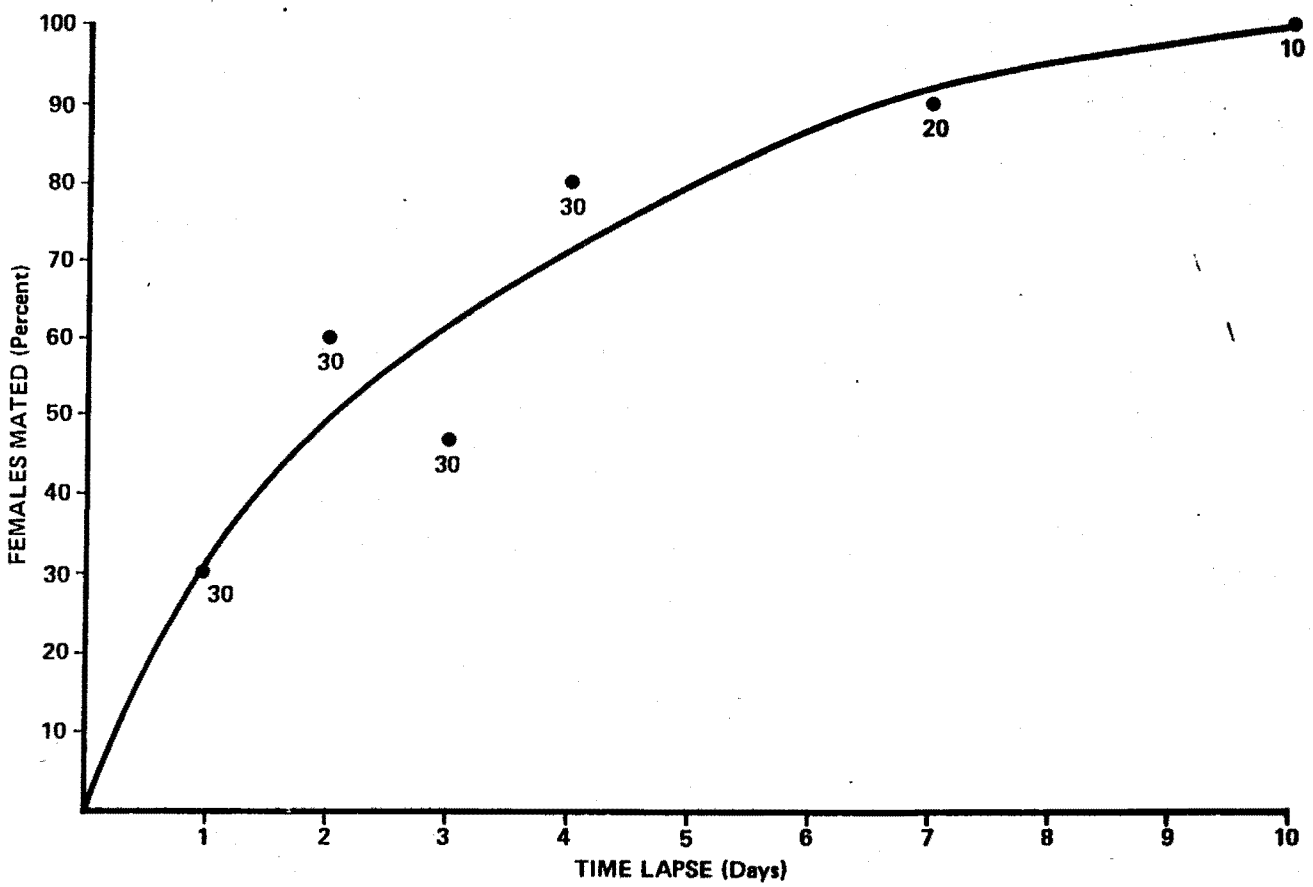

Figure 1.--Percent of females mated in relation to time elapsed from mass attack. The number of observations associated with each plotted point is indicated.

$$\hat{Y} = 100 - 1.018(10 - X)^{1.85} - 2.79 \times 10^{-10}(10 - X)^{11}$$

$$R^2 = 0.89$$

Table 2.--*Sex ratio of parent mountain pine beetles within galleries after varying lengths of time from mass attack*

Time lapse (days)	Number galleries sampled	Galleries containing		Sex ratio (all galleries) ♂:♀
		Both parents	Female only	
1	30	9	21	1:3.3
2	30	18	12	1:1.7
3	30	14	16	1:2.1
4	30	13	17	1:2.3
7	20	8	12	1:2.5
10	10	4	6	1:2.5
Total	150	66	84	1:2.3

recently attacked lodgepole pine. Assuming that none of the females were mated before emergence and flight (McCambridge [1970] found that about 2 percent were mated in ponderosa pine), they were mated shortly after mass attack. The sex ratio of beetles emerging from trees attacked within the study area in 1971 was 1:2.9. Other workers (Reid 1962b; Safranyik and Jahren 1970) also found that newly emerged female mountain pine beetles outnumber males. Because the emerging population had a slightly larger proportion of females than the attacking population, females apparently have a higher flight mortality than males. However, because the male will mate with more than one female, this imbalance is not limiting.

Rate of gallery construction.--The data were analyzed to show the difference in the rate of gallery construction by mated and unmated females (fig. 2). The female was considered to be mated if a male or eggs were present. Results of a weighted covariance analysis suggest that differences in gallery length are real. Reid (1958) also found that mated females extended their galleries at a greater rate than unmated females. Unmated females may elongate their galleries at a lower rate because longer galleries are more difficult to keep free of boring residue. If the gallery were to become plugged the male would be excluded and mating could not take place.

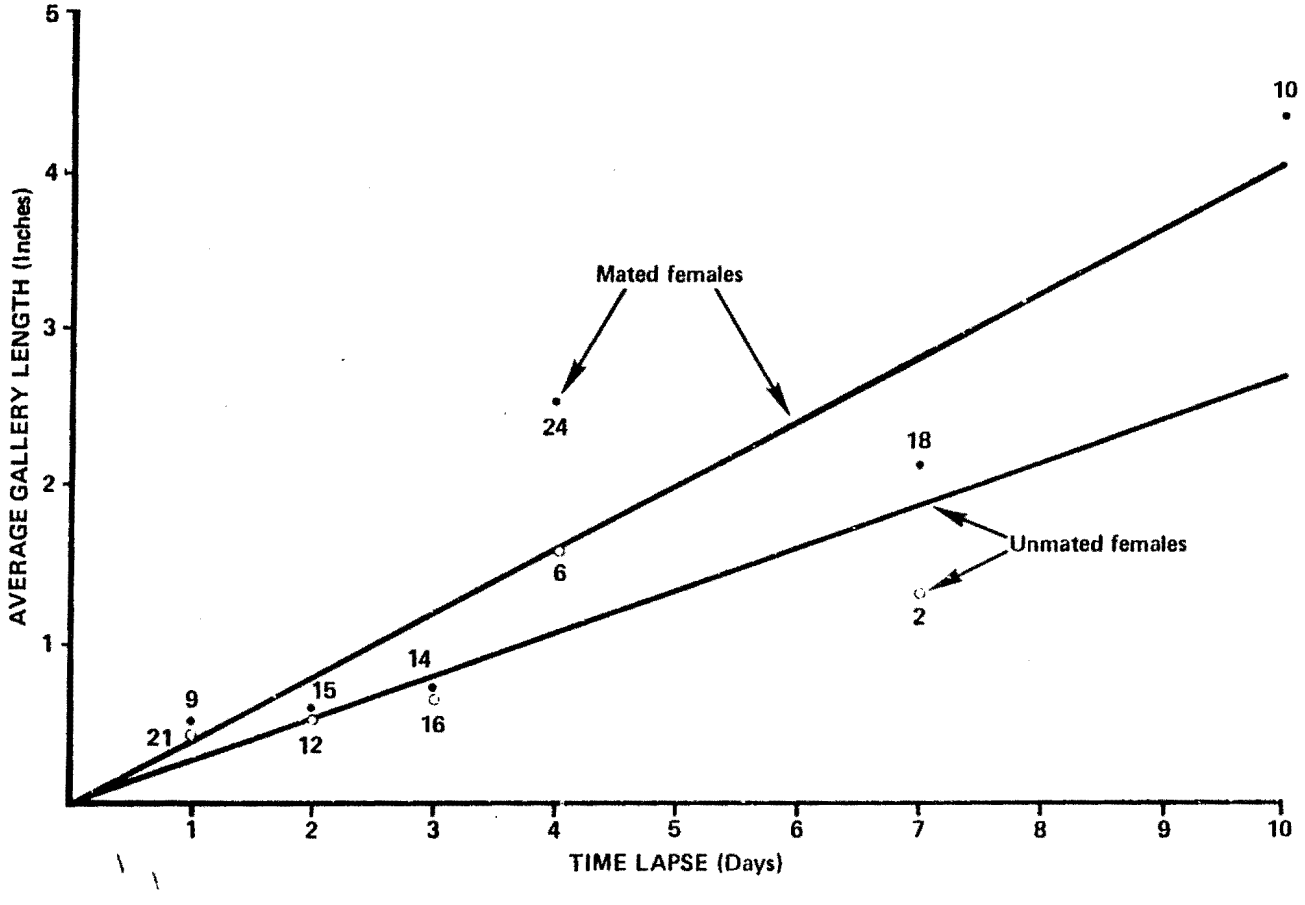

Figure 2.--Comparison of rates of gallery construction by:

Mated females, $\hat{Y} = 0.4054\ X,\ R^2 = 0.53;$

Unmated females, $\hat{Y} = 0.26856\ X,\ R^2 = 0.31.$

The number of observations associated with each plotted point is indicated.

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