

Fungal infection and gender confusion in the wing-banger cicada *Platypedia putnami*

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Abstract

Platypedia putnami, a cicada active in the early summer of each year, inhabits mixed coniferous forests of the southern Rocky Mountains. We observed in a population of *P. putnami* in the San Mateo Mountains of New Mexico, that 1-2% of the adult cicadas were infected by a fungus yet to be identified, but probably of the genus *Massospora*. Though both males and females are susceptible to infection, a sample of 22 individuals revealed a higher frequency of infection among males (Chi-square=14.7, $P < 0.001$, $df = 1$). The fungus destroys the posterior abdomen, including the genitalia, of the cicadas, rendering them unable to mate. However, the cicada thorax and appendages remain intact and apparently function normally. Consequently, locomotion and courtship signaling (i.e., crepitations, or wing-banging) of infected cicadas were not obviously impaired. Infected individuals exhibited courtship signaling with characteristics intermediate between those of uninfected males and females. In focal studies of 14 infected individuals, all exhibited courtship signaling and constant movement toward other signaling cicadas, regardless of sex. In every focal study, the infected cicada made abdomen-to-abdomen contact with at least one other cicada. Results suggest that the fungus has evolved to permit and even induce infected cicadas to make contact with any sexually receptive conspecific cicada, as well as to solicit contact from other cicadas. This is perhaps a way the fungus can be transmitted to new host individuals.

Introduction

The ability of metazoan parasites to alter the behavior of their animal hosts has been well documented (Clayton and Moore 1997). In fact, several studies of parasites of insects have concluded that the parasites have evolved to affect the behavior of their insect hosts in ways that promote the spread of the parasites among the host populations (Moore 1993, 1995). A few studies of periodical cicadas have described infection of these insects by the fungus *Massospora cicadina* (Alexander and Moore 1962, Williams and Simon 1995), and several internet websites briefly mention possible effects of the fungus on the behavior of the cicada host. However, we have not found any published research on alteration of cicada behavior by *Massospora* infection. In fact, we have found no published references that discuss alteration of host-animal behavior by any fungus.

The wing-banger cicada, *Platypedia putnami*, is indigenous to mixed coniferous forests of the southern

Rocky Mountains. Adults of this annual species are active for a few weeks during the early summer. Wing-bangers are easily distinguished by their unique courtship signals, which consist of crepitations (wing-banging), rather than the more familiar song produced by the timbal organs of males of most cicada species.

Both male and female *P. putnami* produce courtship signals, but the signal patterns of normal males and females are very different and are easily recognized. Males generally signal in a long series of crepitation bouts with several-to-many crepitations per bout. Female signals usually consist of periodic single crepitations made in response to the signals of males they have selected as mates. Another obvious difference between male and female *P. putnami* courtship is that females remain stationary while they respond to the signals of selected males; courting males walk or fly toward the responding females, apparently using the female crepitations as a means of locating them.

During another study of the wing-bangers, we noticed that 1 to 2% of the cicadas had a fungal infection, which destroyed much of the abdomen, including the genitalia, while leaving the thorax and its appendages intact. The infected cicadas also appeared to exhibit sexually ambiguous courtship behavior. We subsequently focused our attention in the field on infected *P. putnami*, testing the hypothesis that their behavior has been altered by the fungal infection.

These behavioral changes appear to facilitate the spread of the fungus among the cicada population.

Methods

We studied a population of *P. putnami* in a mixed coniferous forests at the north end of the San Mateo Mountains in central New Mexico (see Figure 1).

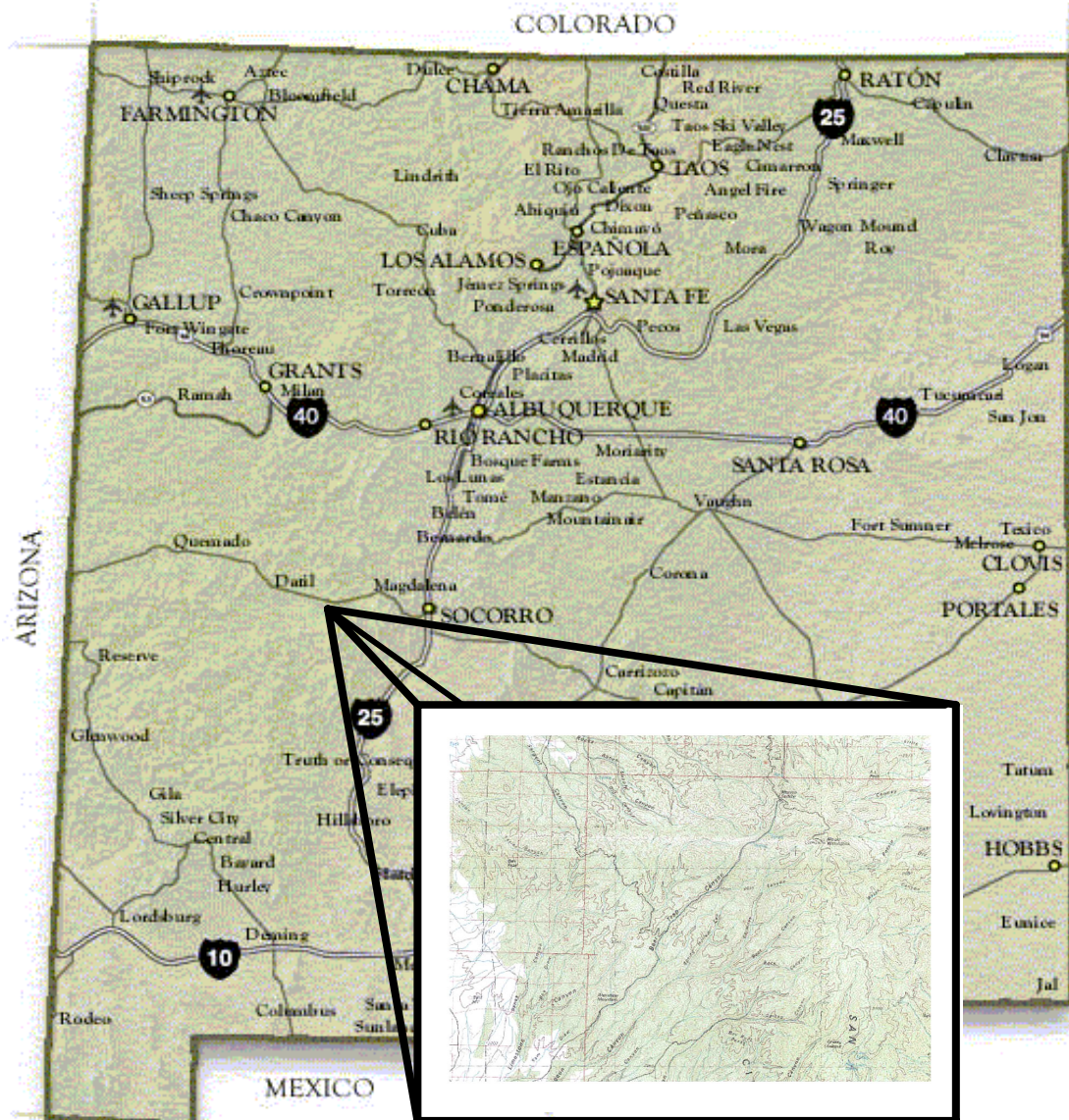


Figure 1. Map of New Mexico showing study site location. The insert provides a detailed topographical map of the site.

The research was conducted 21 to 31 May 2001. Infected cicadas were observed during peak signaling periods: 0900 to 1100 and 1400 to 1700 hours MDT.

We captured, killed, and dried 22 infected cicadas. As the posterior abdomen of each had been destroyed by fungus, we were unable to distinguish male from female in the field (see Figure 2). However, in the lab we dissected them and were able to distinguish male from female by examining internal structures of the anterior abdomen; eggs and ovarioles are present in the abdomens of females, whereas the abdomens of males are basically hollow. We used Chi-square analysis to determine if males and females were infected with equal frequency.



(a) Fungal infected with severe abdominal injury due to fungal growth.



(b) Uninfected male.

Figure 2. *Platypedia putnami*

In order to compare courtship signaling patterns of infected versus non-infected cicadas, we conducted focal studies of infected normal males and normal females. For a 2 minute period, we recorded crepitations of each cicada, recording both the total number of crepitations, and the number of crepitations made per bout. We used ANOVA to compare the total number of crepitations made by infected cicadas, normal males, and normal females. In order to compare average number of crepitations per bout among these three groups, we used a Kruskal-Wallis test, as these data were not normally distributed.

Results

Dissection of 22 infected cicadas revealed a higher frequency of infection among males than among females (Chi-square = 14.7, $P < 0.0001$, $df = 1$).

ANOVA showed that among normal males, normal females, and infected cicadas, significant differences in total crepitations per 2 minute period were evident. Figure 3 summarizes these differences.

Comparison of the average number of crepitations/bout among samples of normal males, normal females, and infected cicadas, indicates that significant differences existed among all groups (Kruskal-Wallis test, $H = 26.75$, $P < 0.0001$). As shown in Figure 4, the signaling pattern of infected cicadas was intermediate between the patterns of normal males and females.

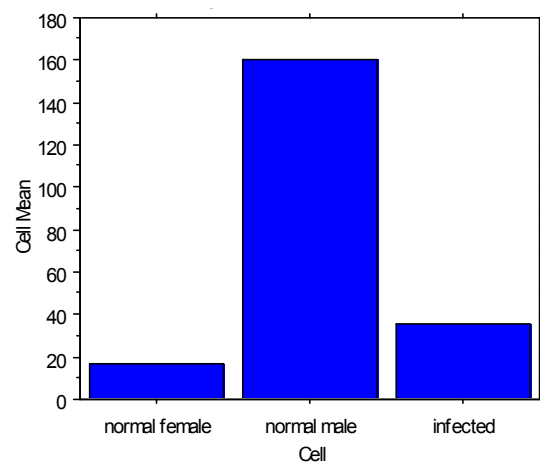


Figure 3. Normal male vs normal female ($P < 0.0001$); normal female vs infected ($P = 0.2676$); normal male vs infected ($P < 0.0001$)

During focal studies of infected cicadas we recorded that every infected cicada walked or flew towards other signaling cicadas, regardless of the sex of the signaling cicada. In other words, each infected cicada would approach both male and female signalers. We also observed that every infected cicada produced courtship signals as it moved toward other signaling cicadas. Additionally, each infected cicada located and made abdomen-to-abdomen contact with at least one other individual.

Discussion

Although fungal infection of the *P. putnami* by the fungus *Massospora sp.* destroys most of the abdomen of infected adult cicadas, locomotion appears to be unimpaired in infected individuals. In fact, every infected individual that we observed exhibited constant movement toward other signaling cicadas. Infected cicadas appeared to be attracted to courtship signals produced by both male and female conspecifics. Though infected cicadas cannot mate, they solicit mating attempts of other cicadas by exhibiting courtship signaling. The signaling pattern of infected cicadas, however, was intermediate between those of normal males and of normal females. This may result in solicitation of both males and females. Although males are more likely to be infected, the signaling patterns of infected individuals are more female-like than male-like. Because normal females remain stationary during courtship and normal males move about, a female-like

signal is more likely to attract other cicadas, than is a male-like signal. Results support the hypothesis that the fungal infection alters the behavior of cicadas. The behavioral changes appear to increase the chances of direct contact with other cicadas. It is likely that this facilitates the spread of the fungal infection among the wing-banger cicada population.

Acknowledgements

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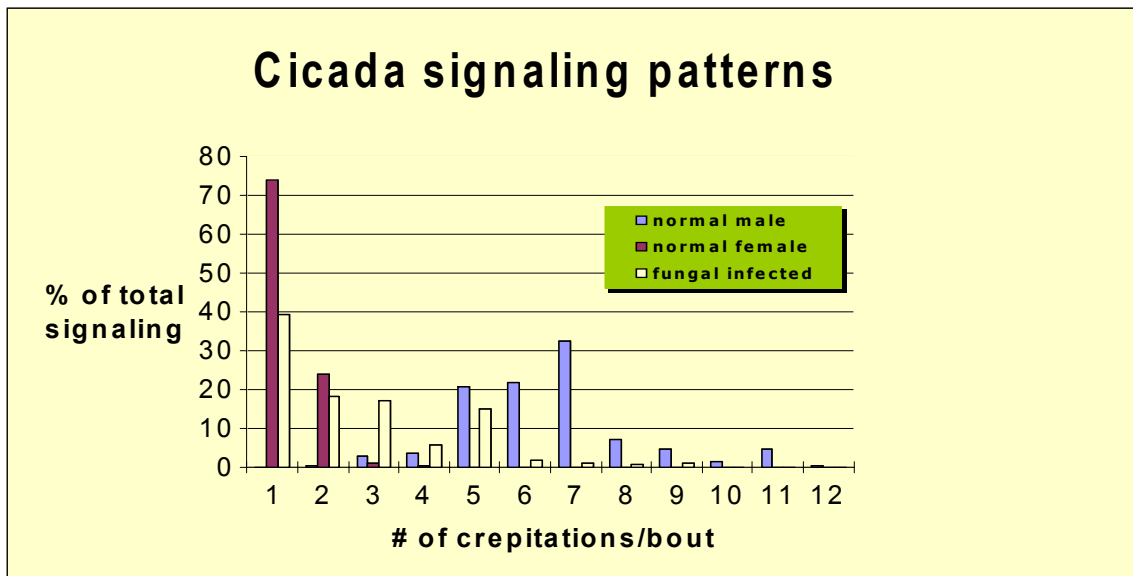


Figure 4. Comparison of crepitations/bout among uninfected males, uninfected females, and infected cicadas