Evaluation of the Infestation Rate of Blaesoxipha alcedo in the Carrion Roller Scarab Canthon cyanellus cyanellus and Its Effect on Reproductive Behavior

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ABSTRACT. This study documents Blaesoxipha alcedo (Aldrich; Diptera: Sarcophagidae) parasitizing the necrophagous ball roller beetle Canthon cyanellus cyanellus LeConte collected over 2 yr, and evaluates the reproductive behavior of parasitized beetles. Up to 52% of the beetles collected in the field had been parasitized and exhibited modified sexual behavior. In general, 21% of the males and 24% of the females had been parasitized. The number of parasitized males peaked in August 2000 (52%), but that of females in May 2001 (52%). The lowest percentage of parasitized males (7%) was recorded in September 2000, June 2001, and July 2001; for females, parasitism was lowest in June 2000 (10%). The larva of this sarcophagid fly penetrates the host through the tegumentary membrane, leaving a scar. The larvae feed on the gonads of male and female C. c. cyanellus, castrating them, causing the loss of their ability to recognize individuals of the opposite sex, preventing reproduction, and lowering overall reproductive success.

Key Words: Sarcophagidae, endoparasite, parasite-associated behavioral changes, Scarabaeinae

Some Sarcophaginae are parasitoids that infect a variety of arthropods, and of these, some have been used in forest and crop pest biological control programs (Pape et al. 2004, Scudder and Canning 2006, Salas-Aratza and Salazar-Solis 2009). However, because of their generalist nature, parasitoids can sometimes have adverse effects on native species that carry out important functions within the ecosystem (Boettner et al. 2000, Oberhauser et al. 2007).

In addition to causing high rates of mortality, one of the effects of the parasitoids on many insect species is the modification of their reproductive behavior (Uchida and Ehara 1953, Godfray 1994). In most cases, parasites partially or totally castrate the host, which then changes its reproductive behavior and alters its hormonal balance, and there are other modifications to the host’s reproductive effort that favor the development of the parasitoid (Baudoin 1975, Beami 2006). With partial castration, the host has a chance of producing offspring before dying, whereas with total castration, reproduction becomes impossible (Bonds 2006).

The ball roller beetle, Canthon cyanellus cyanellus LeConte is a necrophagous species that lives in the tropical forests of the Americas (Halffter 1977, Favila 1993, Favila and Díaz 1996, Villalobos et al. 1998). This species feeds and breeds using the carcasses of small mammals, and its feeding and reproductive behaviors contribute to recycling nutrients back into the soil, as do other dung and carrion beetles of the subfamily Scarabaeinae (Nichols et al. 2008). Individuals of both sexes locate the food source by smell, and males also emit pheromones once at the carcass to attract a female and form a breeding pair (Halffter et al. 1983, Favila 2001). Sexual recognition is chemically mediated and occurs over a short distance on or near the carcass (Favila and Díaz 1996, Ortiz-Domínguez et al. 2006b). The male and female make head-to-head contact, extending their palps and antennae to touch the cuticle of the potential partner. If the beetles are of the same sex, they will fight for the food, but if they are of the opposite sex, they will make a ball from the carrion and roll it to a site about 2 m away from the food supply where they will bury it just below the surface for nesting (Favila and Díaz 1996, Favila 2001). Generally, the male rolls the ball and the female is transported on it. When the beetles are immature, they will

Materials and Methods

Evaluation of Infestation Rate in Field. Each month, from January 2000 to December 2001, 65 pitfall traps baited with squid were set on a cattle ranch near Papantla, Veracruz, Mexico (20° 25′ N, 97° 27′ W) for 48 h in order to capture live specimens of C. c. cyanellus. The specimens collected were kept in plastic containers with 2.5 cm of sterile soil and fed pieces of fish every third day in a rearing room (27 ± 1°C, 70 ± 10% relative humidity, and a photoperiod of 12:12 [L:D] h; Favila 1993). Specimens were kept in the rearing room until behavioral testing was carried out or until they had been killed by a parasitoid. Mortality associated with the presence of B. alcedo was recorded for every monthly capture.

B. alcedo Biology. In 2000, a small scar was observed on the integument between the pronotum and the thorax of all beetles from which after death a third stage B. alcedo larva emerged through the pygidium plate. In 2001, thirty-five beetles, each of which had this scar on their
Table 1. Percentage of C. c. cyanellus parasitized by B. alcedo over two annual cycles (2000 and 2001) in Papantla, Veracruz, Mexico

| Month     | Males collected | % Males parasitized | Females collected | % Females parasitized |
|-----------|----------------|---------------------|------------------|----------------------|
| April 2000| 99             | 43                  | 65               | 20                   |
| May 2000  | 145            | 34                  | 93               | 34                   |
| June 2000 | 80             | 14                  | 68               | 10                   |
| July 2000 | 90             | 8                   | 101              | 17                   |
| Aug. 2000 | 56             | 52                  | 22               | 18                   |
| Sept. 2000| 27             | 7                   | 63               | 11                   |
| Oct. 2000 | 57             | 16                  | 53               | 32                   |
| Mar. 2001 | 65             | 14                  | 78               | 12                   |
| April 2001| 71             | 18                  | 84               | 33                   |
| May 2001  | 53             | 28                  | 54               | 32                   |
| June 2001 | 90             | 7                   | 32               | 13                   |
| July 2001 | 43             | 7                   | 77               | 16                   |
| Aug. 2001 | 70             | 24                  | 43               | 42                   |
| Total     | 946            | 21                  | 833              | 24                   |

Discussion

To our knowledge, this is the first report of a sarcophagid fly parasitizing the necrophagous ball roller beetle C. c. cyanellus. Monteeith and Storey (1981) mention the presence of the diptera Leptotroca myrmecophila Knab and Malloc, a phoretic fly that tunnels into the nest ball of the beetle Cephalodesmus armiger Westwood, but the actual relationship between these two species has not been studied in detail. Favila and Díaz (1996) mention that Phoridae flies attempt to lay eggs on carrion balls rolled by beetles, but did not find that they parasitize adult beetles.

We found that as much as 50% of the population of this species may be parasitized and consequently die. This is high considering that, for many years, our research group has collected live C. c. cyanellus along the coast of the Gulf of Mexico (Favila 1988, 2005; Halffter et al. 1992; Favila and Díaz 1996; Favila 2005; Ortiz-Domínguez et al. 2006a), and had never found a parasitized specimen in the populations of central and southern Veracruz state until now. Studies are therefore required to accurately determine the geographical distribution of the Sarcophagidae and of B. alcedo in particular, assess whether this parasitoid could affect other populations of C. c. cyanellus, and even other Scarabaeinae under natural conditions. The effect of this parasitoid on the biology of parasitized dung beetles to recycle dung, but especially carrion, also should be analyzed.

At the behavioral level, it is known that under natural conditions sexually mature male–female pairs of C. c. cyanellus show cooperative prenesting behavior, such as cutting and rolling a food ball together. In this study, we found that neither males nor females of reproductive age show this cooperative behavior when they are parasitized by B. alcedo larvae. In contrast, they display uncooperative behavior such as individual rolling, and pushing or even fighting with their partner for possession of the food. In the absence of parasitization, such uncooperative behavior is characteristic of immature males and females, or of adults of the same sex (Favila 1988). The absence of cooperative behavior in parasitized individuals was clearly related to the total castration of the host that modified the behavior of the beetle as a result of unknown hormonal changes. When parasitized beetles were placed together with unparasitized beetles of the opposite sex, no offspring were ever produced, also indicating that B. alcedo larvae totally castrate parasitized beetles.

Total or partial castration of the hosts by parasitoids is a phenomenon that could have beneficial effects as pest control (Greathed et al. 1994, Ramirez-Salinas et al. 2006). However, in this particular case, the parasitoid has a harmful effect that is detrimental to the reproductive success of C. c. cyanellus, a species that is beneficial to the ecosystem for its nutrient recycling capability. Our results indicate that B. alcedo...
is a natural enemy of *C. c. cyanellus*, and could have a detrimental effect on this beetle species at the population level, and perhaps on other populations of Scarabaeinae. Further studies are required to fully understand the biology of this Sarcophagidae species, and to analyze the long-term effects on the dynamic of *C. c. cyanellus* populations, and those of other dung beetles that are potential hosts of this parasitoid.

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