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The green June beetle (*Cotinis nitida*) (Coleoptera: Scarabaeidae): local variation in the beetle's major avian predators and in the competition for mates

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ABSTRACT

The green June beetle (*Cotinis nitida*) was observed in northern Virginia for a second and third flight season. The study yielded some results that were consistent with earlier findings, namely that mate-locating beetles were vulnerable to attack by avian predators and matings occurred primarily early in the flight season. Novel findings included the following: (1) blue jays (*Cyanocitta cristata*) were the major predators, not common grackles (*Quiscalus quiscala*), (2) some jays appeared to selectively prey on female beetles, (3) competition for mates among male beetles could be so intense that some males attempted to copulate with already mated (unreceptive) females, and (4) the sex ratio of the beetle population feeding on wild blackberries remained near equality late in the flight season despite the fact that the sex ratio of the population of beetles at the emergence site became highly female-biased over time.

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Introduction

The green June beetle (*Cotinis nitida*) is an abundant but relatively little studied species in the eastern United States whose larvae feed on decaying organic material in lawns and whose adults consume berries and other fruits (Vittum et al. 1999; Brandhorst-Hubbard et al. 2001; Cowell et al. 2012). It is known that males locate receptive adult females as they emerge from the soil by tracking a sex pheromone released by potential mates (Domek & Johnston 1987). Competition for access to females perched in the grass can be strong with several males arriving near the same individual in the space of a few seconds (Davis & Luginbill 1921; Chittenden & Fink 1922). Alcock (2014) reported that the first male to reach a receptive female quickly copulated with her, after which the female became unattractive to additional males.

Because males are conspicuous when flying low over lawns in search of calling females, avian predators fly to, capture and kill males as they approach potential mates. Because females in search of oviposition sites employ much the same flight pattern as males, they too are vulnerable to attack by certain bird predators when they slow their cruising flight and land on the lawn prior to burrowing into the turf. Thus

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both male sexually selected mate-locating behaviour and female naturally selected parental behaviour expose the beetles to predatory attack (Alcock 2014).

In the summer of 2014, I repeated my study of the green June beetle at the same location as in the previous year. These more recent observations confirm some of the conclusions reached in the earlier study while providing additional details and new findings with respect to avian predation and male–male competition, and these findings make up the substance of this report. In addition, I observed predation on the beetle in the summer of 2015, with observations made at this time included here.

Material and methods

The study was conducted primarily on the large grassy lawn (38°52′26.07″N; 77° 54′21.18″W) around the house at Monterey Farm near Marshall, VA on 25 days between 28 June and 1 August 2014 and on 7 days between 26 June and 7 July 2015. In 2014, if a beetle landed fairly close to my observation post near the house, I often hurried to it and picked it up in order to sex the insect using the procedures described by Pszczolkowski et al. (2008). These data permit an analysis of the sex ratio of mate-searching and ovipositing beetles during the season when the lawn was the site of emerging, mating and egg-laying green June beetles. If, however, I arrived to find the beetle near or on a female positioned in the grass, I observed the outcome of the interaction between these individuals and any other males that arrived soon thereafter. During the same observation periods (generally 2.5 to 3.0 hrs usually starting at 10:00 AM E.S.T.), I monitored the behaviour of birds that appeared on or near the lawn in order to hunt for beetle prey on 14 days from 28 June to 14 July. The use of 10 × 42 Pentax binoculars was helpful for this component of the study.

From 21 July to 1 August 2014, I captured beetles feeding on wild blackberry (*Rubus* sp.) brambles at two locations on the farm to determine the sex ratio of the species at a time when activity at the lawn had all but ended.

Results

Predation on the green June beetle

During the 14 observation periods in the summer of 2014, I recorded 263 successful attacks by birds on *Cotinis nitida*: 246 (94%) by blue jays (*Cyanocitta cristata*), 11 (4%) by red-winged blackbirds (*Agelaius phoeniceus*), four (1.5%) by brown thrashers (*Toxostoma rufum*), and two (0.5%) by common grackles (*Quiscalus quiscala*). During 7 days in 2015, I recorded 262 successful attacks on the beetle: 226 (85%) by blue jays, with the remainder carried out by red-winged blackbirds, brown thrashers, common grackles and red-bellied woodpeckers (*Melanerpes carolinus*). Of the 18 successful attacks (7.5% of the total) by the woodpeckers, four involved thefts of beetles discovered by blue jays.

Foraging blue jays perched from about 5–10 m above the ground in trees adjacent to the lawn. From these perches, the jays sailed down when they detected a beetle about to land or immediately after the insect dropped onto the grass. The

predator then either simply picked up the beetle and flew back to its perch where it dismembered and ate the prey, *or* the jay 'hammered' the prey in the lawn using its beak to strike a beetle (hidden from view) with repeated blows before picking up the disabled or dead beetle and returning to its perch to consume the prey. On 3 days (12–14 July 2014), when a total of 57 successful attacks by blue jays were observed, the pickup approach was employed 25 times while the hammering technique was used 32 times.

Over the 2 years, two cases involved a jay carrying a pair *in copula* back to its perch. Eight other cases of predation involved a jay that approached a beetle landing on the lawn only to have this beetle 'escape' or be ignored while the jay hammered another beetle in the grass. (Once the jay actually caught one beetle and flipped this insect away before turning its attention to a second beetle in the lawn.) Seven additional records were made of jays dropping beetles they had captured or ignoring nearby beetles flying slowly as in the final approach to a perched female. These records suggest that the predators sometimes used male behaviour to locate female prey.

On 16 days between 28 June and 18 July 2014, mating pairs were noted. The large majority of the 84 recorded copulations (72 of 84, or 86%) were observed during the first part of the study, on the 8 days between 28 June and 5 July. During the 8 days from 8 July to 14 July plus 18 July, just 12 matings were seen, seven of which occurred on 8–9 July.

The competitive mating system of the green June beetle

Competition among males for access to calling females was intense. Of the 84 matings observed in 2014, 50 (60%) involved an additional male or males arriving near a calling female within a few seconds of the arrival of the first male. Moreover, on 3 and 4 July, four instances occurred of mating balls or stacks of several males forming around a female (Figure 1). In addition, 14 cases were seen over 4 days (3–5 and 8 July) in which a second male attempted to mate while the female was already in copula (Figure 2). In these cases, the male that had copulated with the female toppled backward while still attached to the female. This action exposed the female's back, which the second male mounted while attempting to copulate with her, an attempt that persisted after the first male disengaged and left. The behaviours illustrated in the two figures were not observed during the previous study. In no instance, however, was a female known to have mated with two males in quick succession during the current study.

The changing sex ratio of beetle populations observed at the lawn

Females were on occasion captured very soon after they had landed as they slipped into the grass. Individuals that disappeared before I could find them (probably by burrowing quickly into the lawn turf) were assumed to be females. (Males invariably remained on the surface of the lawn as they scrambled toward a calling female.) In the 8-day period from 28 June to 5 July, the number of known females collected by hand after they had landed on the lawn was 26, with an additional 10 probable females (those that disappeared before they could be picked up by the observer). Between 5

Figure 1. A stack of males piled up on the back of a receptive female. Note that the top male is facing in a different direction from the others and that he has everted his aedeagus, a sign of his strong sexual motivation.

Figure 2. The first male (on the left) to reach a female has fallen back exposing the upper surface of his mate. A male arriving a short time later has mounted the female and is attempting (unsuccessfully) to copulate with her while she is in copula with the first male. Even after the first male disengaged and left the female she remained unreceptive to the second male.

July and 18 July 2014 (8 days of observation as well), 46 known females with 10 additional probable females were recorded. From one 8-day block to the other, the number of males captured after they had landed on the lawn fell from 130 to 18 (Chi squared = 63.1, df = 1, $P < 0.001$). Thus, as the season progressed, matings declined, males cruising over the lawn became scarce, whereas ovipositing females became more numerous.

The sex ratio of green June beetles feeding on blackberries

After 21 July 2014, I became aware of an abundance of beetles feeding on wild blackberry fruits (*Rubus* sp.). Subsequently, I irregularly examined two patches of fruit-bearing brambles in two widely separated locations, sexing the beetles feeding on fruit there on 10 days between 21 July and 1 August (on 1 day both sites were sampled). During this time more males ($n = 152$) were captured than females ($n = 126$); Chi squared = 2.43, $P > 0.10$. In other words, even though matings were very rare or absent at the lawn site after 10 July, males and females were more or less equally abundant (at least on blackberry fruits) long after the apparent peak of sexual activity had passed.

Of the 218 beetles were marked with paint pens on the thorax between 22 and 27 July 2014, only two marked individuals were ever seen again in the areas where the beetles were censused. The population of foraging beetles late in the flight season was evidently very large and fluid, so that I was not simply recapturing particular individuals over and over at the brambles where this part of the study occurred.

Discussion

Avian predation

Birds, including blue jays, are known to be important predators of the green June beetle during the time when females are emerging and males are searching for mates (Chittenden & Fink 1922). One of the new findings of the current study was the extent to which bird predation on the beetles can change from one year to the next. The predominant bird predator in 2014 and 2015 on the farm lawn was the blue jay, whereas in 2013 the common grackle was responsible for a large majority of observed kills. I do not know why common grackles were common one year and all but absent the next, while the red-bellied woodpecker was only observed feeding on the beetles in 2015 (sometimes stealing prey from blue jays). However, in all years, the beetles proved to be highly vulnerable to avian predators of one species or another.

A second novel finding of the current study is the suggestion that at least some birds preferred female beetle prey. The fact that in both years some jays clearly ignored (presumptive male) beetles cruising slowly toward a presumptive female while often hammering beetles that the birds then located in the lawn (females?) hints that certain individuals were focusing their attention on female prey rather than on male beetles, whose behaviour revealed the location of females perched in the grass.

Competition for mates

A third finding from the current study involved the nature of male–male competition for mates. In 2013, I failed to observe the mating stacks and balls (Figure 1) that were briefly a feature of the beetle's mating system in 2014, although these have been observed elsewhere (Chittenden & Fink 1922). Perhaps the willingness of many males to assemble around one female under some circumstances is a function of an operational sex ratio that is highly skewed toward males, a phenomenon that apparently occurred on only a few days of the flight season of the green June beetle at this northern Virginian site. Mating balls are commonplace among a variety of animals, ranging from certain toads and frogs with explosive mating assemblages (Wells 2007) to garter snakes that crawl out en masse from overwintering dens (Whittier et al. 1985; Shine et al. 2000) to various ground nesting bees, whose females nest in dense aggregations resulting in large numbers of emerging bees of both sexes the following year (Alcock 2013). In all these cases, many males search for a relatively few receptive females on any given day. When one male finds a female, other males nearby are highly sexually motivated with the result that groups of males surround the receptive female and struggle to control and copulate with her (Alcock 2013). In cases of this sort, females typically lose their receptivity after mating. Data in support of this conclusion for the green June beetle are provided by instances in which males 'courted' females mating with other males (Figure 2) but were unable to copulate with their 'partners' even after the first male withdrew his aedeagus and released his mate.

An allied aspect of male competition for mates involves the timing of male activity. The vast majority of copulations on the lawn occurred early in the flight season of the beetle in 2014, as was true in 2013 as well. Alcock (2014) interpreted this result to mean that males were under selection pressure to emerge early in the flight season, and that as time passed they died or disappeared so that females became relatively more common over the lawn as they searched for oviposition sites later in the flight season. The sex ratio data collected from beetles that landed on the lawn in 2014 are consistent with that interpretation.

However, if protandry were the case, one would also predict that the sex ratio of beetles captured while foraging for food very late in the flight season would be highly biased toward females. This prediction was not met during the summer of 2014 inasmuch as foraging males were as common as or more common than foraging females late in the flight season. If males do live as long as females, perhaps they find mates in locations other than the lawns around the farmhouse, a possibility suggested by the finding that in some places in Virginia the beetles are abundant for from 4 to 6 weeks during the summer (Chittenden and Fink 1922). The heavily vegetated hayfields of the farm might provide long-lived males with access to some receptive virgin females as the flight season progresses. Alternatively, perhaps after a period of oviposition in places where tall grasses occur, females emerge again and become sexually receptive anew. More studies of habitats other than manicured lawns will be necessary to determine why males remain so abundant in areas with fruit-bearing brambles on the farm when they have disappeared from places where they were common earlier in the flight season.

Disclosure statement

No potential conflict of interest was reported by the author.

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