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Consuming Fire Ants Reduces Northern Bobwhite Survival and Weight Gain

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ABSTRACT Northern bobwhite quail, *Colinus virginianus* (L.) (Galliformes: Odontophoridae), population declines are well documented, but pinpointing the reasons for these decreases has proven elusive. Bobwhite population declines are attributed primarily to loss of habitat and land use changes. This, however, does not entirely explain population declines in areas intensively managed for bobwhites. Although previous research demonstrates the negative impact of red imported fire ant (*Solenopsis invicta* Buren) (Hymenoptera: Formicidae) on northern bobwhites, the mechanisms underlying this effect are largely unknown. To meet the protein demands of early growth and development, bobwhite chicks predominantly consume small insects, of which ants are a substantial proportion. Fire ants alter ant community dynamics by often reducing native ant diversity and abundance while concurrently increasing the abundance of individuals. Fire ants have negative effects on chicks, but they are also a large potential protein source, making it difficult to disentangle their net effect on bobwhite chicks. To help investigate these effects, we conducted a laboratory experiment to understand (1) whether or not bobwhites consume fire ants, and (2) how the benefits of this consumption compare to the deleterious impacts of bobwhite chick exposure to fire ants. Sixty bobwhite chicks were separated into two groups of 30; one group was provided with starter feed only and the second group was provided with feed and fire ants. Bobwhite chicks were observed feeding on fire ants. Chicks that fed on fire ants had reduced survival and weight gain. Our results show that, while fire ants increase potential food sources for northern bobwhite, their net effect on bobwhite chicks is deleterious. This information will help inform land managers and commercial bobwhite rearing operations.

KEY WORDS Formicidae, *Solenopsis invicta*, Odontophoridae, *Colinus virginianus*

Northern bobwhite quail, *Colinus virginianus* (L.) (Galliformes: Odontophoridae), populations are declining throughout their range (Brennan 1991, Williams et al. 2004). This decline is due to a number of factors, including land-use changes (Stoddard 1931, Rosene 1969, Brennan 1991), pesticide applications (Rosene 1959, 1969, Brennan 1991), and land management actions (Stoddard 1931,

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Rosene 1969). Populations in the southern portion of the species range are declining at a faster rate than elsewhere (Brennan 1991). Greater declines in the southern USA may be due, in part, to the effects of the introduced red fire ant (*Solenopsis invicta* Buren) (Hymenoptera: Formicidae) (Allen et al. 1993, 1995, 2000).

Fire ants were introduced accidentally into the United States in the 1930s through the port of Mobile, Alabama (Wilson 1951, Williams et al. 2001), and they spread rapidly throughout the southeastern USA (Callcott & Collins 1996) and then to New Mexico, Arizona, and California (Williams et al. 2001). Fire ants have been introduced to other areas of the earth as well, including Australia (Shattuck & Barnett 2005), the Caribbean, and Asia (Ascunce et al. 2011). Fire ants cause a wide array of problems to humans, livestock, and native biota (Vinson & Sorensen 1986, Allen et al. 1997a, 2004, Wojcik et al. 2001). Mature fire ant colonies may contain as many as 230,000 individual ants (Vinson & Sorenson 1986, Tschinkel 1998) that forage widely in the surrounding landscape. Fire ants are efficient at recruiting nest mates to food sources, and fire ants feed on a wide range of food items (Vinson 1994). Fire ants primarily feed on other insects, but will consume almost any animal or plant material (Vinson & Sorenson 1986). Negative impacts from fire ants have been documented on a broad assortment of invertebrates (Porter & Savignano 1990, Epperson & Allen 2010) and vertebrates (Ridlehuber 1982, Sikes & Arnold 1986, Smith et al. 1990, Holtcamp et al. 1997, Allen et al. 1997b, 2004).

Northern bobwhites consume insects to meet their protein needs, which are especially high during reproductive periods in hens and growth periods of young chicks (Cottam 1932, Handley 1932, Nestler et al. 1942, Hurst 1972, Lochmiller et al. 1993, Giuliano et al. 1996b). Without sufficient protein in their diets, the reproductive output of hens is reduced (Aboul-Ela et al. 1992, Giuliano et al. 1996b), and chick growth is compromised (Lochmiller et al. 1993). Bobwhites are known to eat native ants as a part of their insect diet (Hurst 1972, Lehmann 1984), including ants of the genus *Solenopsis* (Hurst 1972). Lehmann (1984) found species of the order Hymenoptera, which were primarily ants (Hurst 1972), in approximately 40% of 383 crops collected from chicks 2–15 d old in Texas. Due to their large colony sizes (Tschinkel 1998) and aggressive behavior, fire ants out-compete and displace many native ant populations while increasing overall abundance of ants in the area (Vinson 1994, Wojcik 1994), potentially providing a more readily available protein source for bobwhites.

Fire ant stings negatively affect bobwhite chick survival and weight gain (Giuliano et al. 1996a, Mueller et al. 1999) however, and behavioral patterns of chicks are altered in fire ant infested areas (Pederson et al. 1996). Mueller et al. (1999) found that bobwhite chick survival declined as fire ant activity in bobwhite nests increased, but they did not suggest a mechanism for this decreased survival. Giuliano et al. (1996a) documented that bobwhite chicks exposed to fire ants (and subsequently stung) for only a short period of time exhibited reduced survival and weight gain. Behavior of bobwhite chicks, such as moving, sleeping and feeding, can be altered in areas infested with fire ants (Pederson et al. 1996). Little is know about the effects of direct fire ant consumption by bobwhite chicks. However, because fire ants reduce native ant populations (Porter & Savignano 1990) and reduce native insect abundance and biomass (Allen et al. 2001), fire ants may be the most readily available food source in infested areas. This experiment was undertaken to determine if bobwhite chicks will consume fire ants, and to determine if there are negative effects on body weight and survival resulting from consumption.

Materials and Methods

We obtained 60 northern bobwhite chicks from Quail Valley Farms, Inc. (Indian Trail, NC) on the day of hatching. Each chick served as a replicate and was randomly assigned to a treatment or a control group of 30 chicks each. Each group was placed into a separate brooder box and provided equal amounts of Purina game bird starter feed (Ralston Purina Company, St. Louis, MO) at levels commensurate with industry and research standards and water *ad libitum*. Brooder box temperature was maintained at 37.8 ± 2°C. Brooders were maintained in an isolated room in the Godley-Snell Research Center at Clemson University, Clemson, SC. Each chick was banded with individually numbered leg bands and weighed daily for the 11-day duration of the study. The Clemson University Animal Research Committee approved of this experiment (protocol number AUP# 99-066).

In addition to starter feed and water, the treatment group was provided live fire ants. Approximately 20–30 ants were placed in the treatment groups feeding tray along with the feed, adding ants as needed to maintain 20–30 ants about every 2 h on days 1–4. All feeding trays (including the ones used in the control brooder) were coated around the rim with Fluon® (Bioquip Products, Rancho Dominguez, CA) (Ready & Vinson 1995) to reduce the escape of fire ants. The day chicks hatched (day 0), fire ants were available to chicks in the treatment group for 30 min. Chicks in the treatment group were continuously observed to determine if any consumed fire ants. After 30 min, the fire ants were removed from the brooder and both groups were provided fresh starter feed. On days 1–4, ants were provided to the treatment group for approximately 6 h daily, adding ants every 2 h as needed. Any ants remaining after 6 h were removed. After day 4, ants were no longer provided to the treatment group, but chick survival and weight gain were monitored for 7 additional days. Each day fresh starter feed was provided to each group. Each morning, all living chicks were weighed to the nearest 0.1 g.

The Kaplan-Meier method was used to estimate daily survival in treatment and control groups (Kaplan & Meier 1958, White & Garrott 1990), and Fisher's Exact Test was used to compare survival between treatment and control groups at the end of the study (SAS Institute, Inc. 2000). A repeated measures ANCOVA was used to determine effects of consuming fire ants on weight gain of chicks that survived to the end of the study (SAS Institute, Inc. 2000). Weight on hatching day was used as a covariate. A Shapiro-Wilk test was conducted to test for normality (SAS Institute, Inc. 2000).

Results

Chicks were observed pecking and walking through the feeding tray when fire ants were provided on Day 0 and Day 1. By walking through the feeding trays, some ants were physically moved by the chicks on the floor of the brooder. Chicks were observed pecking at these ants on the floor of the brooder. Occasionally, ants were observed on the legs of chicks, causing chicks to shake their legs or peck at the ants on their legs. We discontinued direct observations of feeding behaviors after day 1 to reduce observer effects on chick behavior. Approximately 75 fire ants per day were provided to the treatment group on days 1–4. Some ants were observed on the edge of the feeding tray, but this was rare. Thus, we believe that bobwhite chicks collectively consumed the majority of ants that disappeared from the trays on days 1–4.

After day 6 and through the remainder of the study, survival of chicks in the treatment group was lower than the control group (Figure 1) and the 95% confidence intervals for the treatment and control groups did not overlap. Chick survival at the end of the experiment (day 11) differed significantly between the experimental group provided fire ants and the control group (Fisher's Exact Two Sided Test, $P = 0.01$; Table 1). The first death of a chick was recorded on day 4 for the treatment group and on day 6 for the control group, but no deaths were observed in the control group after day 8 (Table 1).

Survival of chicks in the experimental group was significantly lower than the survival rate of chicks in the control group (53.3% and 86.7%, respectively) (Table 1). The survival rate of the bobwhite chicks in our control group was commensurate with those reported by Quart et al. (1987) (93.1% to 97.4% the first week after hatching) and Wilson (1989) (79.8% to 95.7% from hatching to 21 d).

Bobwhite chick body mass was normally distributed (W = 0.98, $P = 0.37$). Analysis of surviving chick weights revealed a significant time (day) by treatment effect ($F_{1,\ 10} = 8.25$, $P < 0.01$), and surviving chicks in the experimental group were consistently smaller than those in the treatment group ($F_{1,\ 40} = 6.83$, $P = 0.01$, Table 2). Weight gain of the control group was similar to that measured by Ouart et al. (1987).

Discussion

While fire ants represent a potential protein source for bobwhite quail, their consumption has negative consequences on chick survival and body weight. In our study, bobwhite chicks that consumed fire ants as part of their diet had lower weight gain and lower survival than those not provided with fire ants, a result supported in the literature (Brockelman 1975, Dhondt 1979, Garnet 1981, Krementz et al. 1989, Vander Jeugd et al. 1998).

Bobwhite chicks are precocious and generally begin searching for food within hours of hatching (Palmer et al. 2001). If fire ants are present, the likelihood is high that bobwhite chicks will interact with them. Because our work took place in a laboratory, we cannot directly apply our results to bobwhite chicks in the wild, as survival of pen-raised chicks is consistently higher than that of wild-raised chicks (Rosene 1969, Demaso et al. 1997). However, our study confirms the indication that exposure and/or consumption of fire ants has a negative effect on bobwhite chick body weight and survival.

The exact mechanism that reduced survival and weight gain of bobwhite chicks in this experiment is not known. However, the positive impact of weight on survival is likely attributable to lighter chicks being more susceptible to diseases, parasites, and predators (Brockelman 1975, Dhondt 1979, Garnet 1981, Krementz et al. 1989, Vander Jeugd et al. 1998), and concurrent decreases in overall individual fitness (Potti 1999).

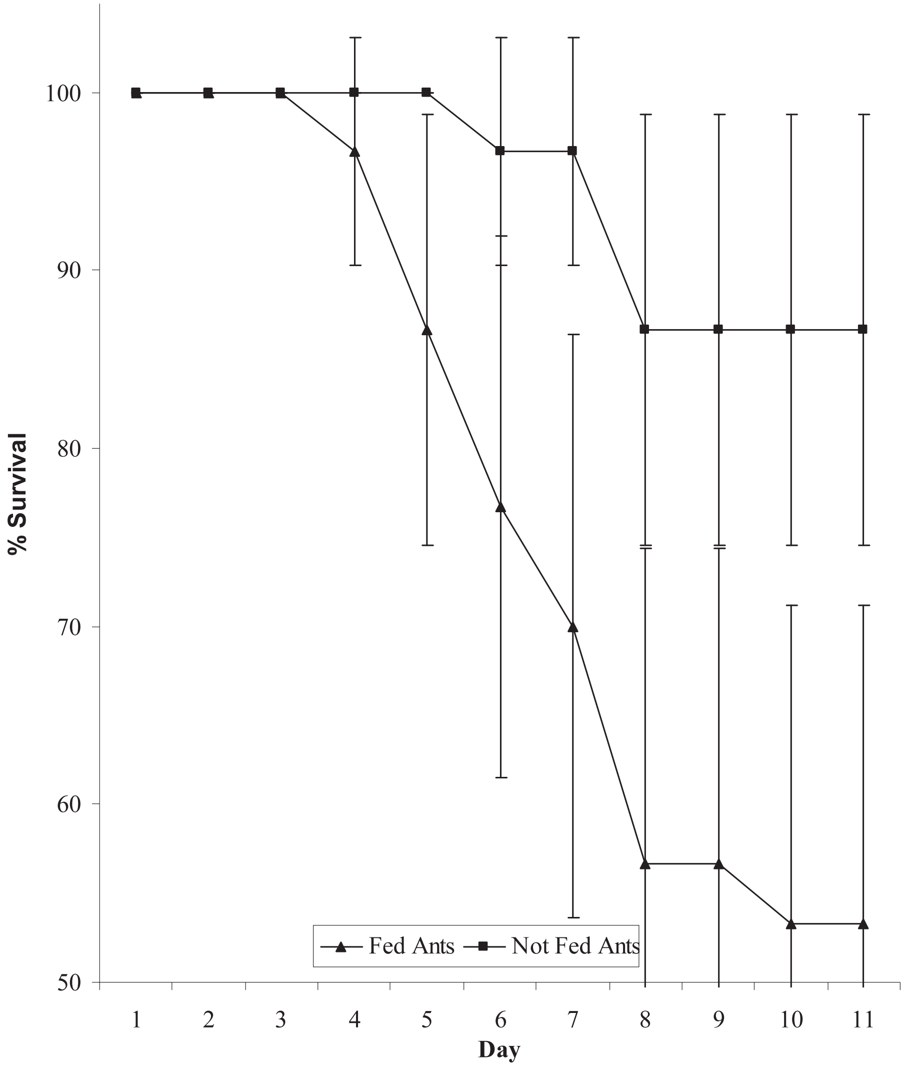

Fig. 1. Survival rate (±95% confidence intervals) of northern bobwhite chicks provided fire ants as a food source and chicks not provided fire ants. Ants were provided on Day 0 through Day 4.

With the exception of a single chick that died prior to weight loss, all other chicks exposed to fire ants that died during the study had been gaining weight before their death and they showed no other apparent signs of stress. However, potential mechanisms of chick death include chronic damage from the ingestion of potentially noxious fire ant venom, stings during consumption, or some combination thereof. Fire ant stings to external body parts of chicks were not considered to have any apparent effect on the outcome of this particular

Table 1. Total number surviving and Kaplan-Meier survival rate (±95% confidence interval) of northern bobwhite chicks provided fire ants as a food source (treatment) and chicks not provided fire ants (control). Ants were provided on Day 0 through Day 4.

	Control		Treatment	
Day	Number surviving	Percent survival	Number surviving	Percent survival
1	30	100.0 + 0.0	30	100.0 + 0.0
2	30	100.0 + 0.0	30	100.0 + 0.0
3	30	100.0 + 0.0	30	100.0 + 0.0
4	30	100.0 + 0.0	29	96.7 + 6.4
5	30	100.0 + 0.0	26	86.7 + 12.1
6	29	96.7 + 6.4	23	76.7 + 15.2
7	29	96.7 + 6.4	21	70.0 + 16.4
8	26	86.7 + 12.1	17	56.7 + 17.7
9	26	86.7 + 12.1	17	56.7 + 17.7
10	26	86.7 + 12.1	16	53.3 + 17.9
11	26	86.7 + 12.1	16	53.3 + 17.9

experiment. Giuliano et al. (1996a) documented negative impacts from external stings when a chick was exposed to more than 50 fire ants for 1 min, but the exposure rate in our experiment was less than one fire ant per bobwhite chick at any time when fire ants were provided.

Table 2. Body mass (mean ± SE) of surviving northern bobwhite chicks provided fire ants as a food source (treatment) and chicks not provided fire ants (control). Ants were provided on Day 0 through Day 4.

Day	Control mean (grams)	Treatment mean (grams)	Difference[1]
1	7.244 ± 0.052	7.140 ± 0.067	0.104
2	8.068 ± 0.092	7.834 ± 0.118	0.234
3	9.597 ± 0.165	9.223 ± 0.212	0.374
4	11.424 ± 0.194	10.818 ± 0.250	0.606
5	13.760 ± 0.247	13.053 ± 0.318	0.707
6	15.928 ± 0.290	15.147 ± 0.373	0.781
7	18.068 ± 0.332	16.783 ± 0.426	1.285
8	21.018 ± 0.380	17.478 ± 0.489	3.540
9	23.041 ± 0.439	21.528 ± 0.565	1.513
10	26.346 ± 0.469	24.107 ± 0.602	2.238
11	28.018 ± 0.614	26.508 ± 0.789	1.510

[1]Difference = control mean – treatment mean.

Although we observed that exposure to fire ants reduced chick weight gain and survival, additional research is needed to better pinpoint the underlying mechanism(s) of this effect. Possible mechanisms include stinging inside the gastrointestinal tract, ingestions of venom, and/or stings to external body parts. Specifically, investigating whether bobwhite chicks preferentially consume native ants over fire ants, and the differential impacts of exposure to live and freshly dead fire ants would provide meaningful steps to uncovering unidentified mechanisms. Further laboratory studies could also directly measure the number of fire ants consumed by an individual, and if and when fire ant consumption no longer occurs using video recording equipment. More specifically, an experiment explicitly testing how many ants chicks consume per day when provided a diet of starter feed, live and/or dead fire ants, live and/or dead native ants, and/or some combination thereof would be particularly useful in this regard. Studies should also be conducted to see if bobwhite chicks will consume fire ants in the wild when presented with a larger geographic range, variable food supply and previous exposure to fire ants.

An increasing body of evidence indicates that fire ants have negative impacts on bobwhite quail populations through direct predation on pipping eggs (Stoddard 1931, Lehmann 1946, Rosene 1969), direct predation on chicks (Lehmann 1946), sub-lethal impacts from stings (Giuliano et al. 1996a), changes in chick behavior (Pederson et al. 1996), and potential reduction of insect resources (Porter & Savignano 1990, Allen et al. 2001). Our work adds to this growing pool of knowledge, but a deeper, mechanistic understanding of different variables and their effect size is needed to understand how these processes drive population level bobwhite dynamics (Allen et al. 1995).

Additionally, understanding how land use and cover changes influence bobwhite quails, native ants, and fire ants (Zettler et al. 2004) will allow us to develop a more holistic understanding of bobwhite survival in a changing planet. Management actions that increase sunlight penetration or bare ground cover to support bobwhite populations occurring in concert with ant mating flights (late spring – summer) may increase fire ant population sizes and their interactions with chicks. As a result, wildlife managers interested in bobwhite survival and biologists studying fire ants should work in conjunction to develop smart management plans. Our work may also be expanded to investigate the impact of fire ants on chicks of other game and non-game bird species that consume ants.

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