NORTHERN BOBWHITE AND RED IMPORTED FIRE ANT INTERACTIONS: WHAT EVIDENCE DO WE HAVE?

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Abstract: The red imported fire ant (RIFA) (*Solenopsis invicta*) is an exotic invader that has caused significant damage throughout the southeastern United States. Observations of interactions between RIFA and wildlife, including Northern bobwhite (*Colinus virginianus*) have led to widely disparate views. We discuss the current experimental evidence that is available concerning the impacts of RIFA on northern bobwhite and suggest future directions for research.

Introduction

Four species of fire ants (genus *Solenopsis*) are native to the United States, two of which are considered pests (Vinson 1997). However, two additional pest species of fire ants have been accidentally introduced to the United States from South America this century—black imported fire ants (*S. richteri*) and red imported fire ants (RIFA; *S. invicta*). Both species probably arrived in the United States at the port of Mobile, Alabama, as stowaways in soil used as ballast for ships (Vinson 1997). RIFA were recognized by taxonomists as being very resilient and potentially difficult to eradicate, and were thus given the scientific name *Solenopsis invicta*, meaning the invincible fire ant (Vinson 1997). Our inability to control the spread of this pest despite huge governmental efforts has proven that the ant was appropriately named.

RIFA have expanded their range in the United States to include nearly the entire southeastern United States, from North Carolina to Texas. Isolated infestations now occur in New Mexico, Arizona, and California. These invaders have caused a multitude of problems including crop destruction (Brinkley 1989), damage to electrical transformers (Vinson and Sorenson 1986), and serious injury to humans (Lockey 1979). In one extreme case of injury to a human, RIFA stung an 84-year-old woman an estimated 10,000 times while she slept in her bed. The woman recovered after a 4-day stint in the hospital (Diaz et al. 1989). Observations such as this have led to much speculation about the impacts of RIFA on wildlife. It is intuitive that animals that nest on the ground, such as northern bobwhite (*Colinus virginianus*), must encounter RIFA. Some observers have concluded that animals that are immobile near RIFA colonies, such as hatching northern bobwhite chicks, must certainly suffer a similar fate as the sleeping woman. Others have observed relatively dense northern bobwhite populations in areas occupied by RIFA and concluded that RIFA must not limit bobwhite populations. These observers concede that RIFA must cause mortality of some chicks in the population, but this mortality rate is not sufficient to cause northern bobwhite populations to decline below limits set by other factors (e.g., predation by vertebrates, food limitation, drought). Are either of these explanations correct?

Observation or Experimental Evidence, This is the Question

Just like a court case, scientific explanations are supported or rejected by examining the available evidence. The evidence may be based either upon simple observation or results of a controlled experiment. Explanations based solely on observations may be unreliable. For example, we observe the same pickup parked at an auto service station just about every time we go home from work for lunch. From this observation we deduce that this truck must break down frequently, because we know the owner and employees of this station and recognize their cars. Alternative explanations for our observation include (1) one of the owners purchased a new truck or (2) the truck belongs to the auto parts delivery person who makes his delivery to the station about the same time we go home for lunch each day. Explanations of the cause of a particular phenomenon can only be reliably supported by experimental evidence (Romesberg 1981). Patterns (observations of the same or similar phenomena multiple times) are, however, the starting point for research. Research experiments are designed to determine the cause (explain) of patterns. We must use experimental evidence if we wish to understand how RIFA can impact northern bobwhite.

What Evidence Do We Have?

Experiments are generally designed so that they can differentiate between alternative explanations of a pattern. Allen et al. (1995) detected a pattern between northern bobwhite declines in Texas and RIFA infestation. They found that the beginnings of northern bobwhite declines in Texas counties were correlated with the timing of each county's invasion by RIFA. RIFA could be causing northern bobwhite populations to decline. This explanation, however, could be erroneous. If RIFA indeed cause northern bobwhite populations to decline, then removal of RIFA should halt the decline or cause an increase. Allen et al. (1995) performed an experiment to test this prediction in the Coastal Plain of Texas. Northern bobwhite density more than doubled on areas treated with an insecticide designed to kill RIFA, as compared to untreated areas. This experiment provided evidence that RIFA can limit northern bobwhite population size. Just like a jury, however, scientists don't like to rely on one piece of evidence. We are certain the scientists who declared that the earth was flat in Columbus's day wished that they had conducted just a few more experiments before their declaration.

The sometimes maddening but inherent characteristic of experimentation is that you often generate as many new questions as pieces of evidence. The experiment of Allen et al. (1995) provided evidence that RIFA can limit northern bobwhite populations. If this is the case, what is the mechanism? Several pieces of evidence suggest mechanisms by which RIFA limit the number of chicks that survive to become a member of the fall population. Northern bobwhite populations fluctuate primarily due to their differential success at reproducing each year (Roseberry and Klimstra 1984). Given the right conditions, northern bobwhite populations can grow quickly, because hens can lay an average of 14 eggs per nest and can renest following nest destruction or success when conditions are favorable during the reproductive season (Mueller et al. 1999). Artificial nest studies have demonstrated that foraging RIFA can recruit to northern bobwhite eggs and kill unhatched chicks (usually all chicks in the nest) by entering the egg through a cut made by the chick as they attempt to exit the egg (Allen 1993). Other studies have demonstrated that RIFA can sting hatched chicks, a sufficient number of times to decrease foraging time, impair vision and locomotion because of swelling, and even directly kill them (Pedersen et al. 1996, Mueller et al. 1999). Chicks that have reduced vision and locomotion would be less able to escape predators and keep up with the rest of the brood and the hen. Chicks that cannot keep up with the rest of the brood the first few weeks of life will almost certainly die because they cannot regulate their own body heat and must be protected from cold temperatures by the hen (Blem and Zara 1980, Choi and Bakken 1991). Reduced chick foraging time could lead to reduced body growth and development (Schew and Ricklefs 1998). RIFA may also reduce growth and development of northern bobwhite chicks by directly competing with them for food. Chicks require a high protein diet early in life (Serafin 1982). This means chicks must eat lots of insects, because they are one of the richest sources of protein available (Robel et al. 1995, Dabbert et al. 1996). Entomologists have found a reduced density and diversity of insects in areas inhabited by RIFA as compared to areas not inhabited by RIFA (Porter and Savignano 1990). This body of information provides us evidence of possible mechanisms by which RIFA may reduce the number of northern bobwhite chicks that survive to enter the fall population. But how do we know if and how these factors act and/or interact in the real world? You guessed it, another experiment.

A Field Experiment

My research team initiated an experiment in 1997 to compare hatching success and survival rate between broods that hatched from nests protected from RIFA using an insecticide and controls (Mueller et al. 1999). We captured hens in early spring and fitted them with a radio transmitter. We then used telemetry to locate and monitor hens and their nests. We protected half the nests by broadcasting an insecticide onto a 60- x 60-m area centered on the nests. Chicks hatching in control nests were exposed to the naturally occurring density of RIFA in the area of the nest. We measured hatching success on the day of hatch by determining the proportion of eggs that hatched successfully. We measured brood survival when chicks were 21 days old by flushing the hen and chicks and determining the proportion of hatched chicks that were still alive. Hens led broods away from the nests a few hours after hatch; thus broods that hatched from protected and unprotected nests were subject to the same habitat conditions and RIFA densities after hatch. Broods only benefited from the insecticide treatment during hatch and a few hours posthatch. This entire experiment was repeated in 1998.

Our results were surprising. Unlike the artificial nest studies, only 2% of northern bobwhite chicks in unprotected nests were killed by RIFA while hatching (Mueller et al. 1999). However, survival of chicks from nests treated with insecticide was more than twice that of chicks from unprotected nests (60% versus 22%) (Mueller et al. 1999).

Mortality caused by RIFA appears to be additive to other mortality factors that have historically caused northern bobwhite chick mortality before the appearance of RIFA. In our study, 38% of all mortality of chicks to 21 days of age was attributable to RIFA stings at hatching. Mortality caused by RIFA can only be compensatory (substituting for historical mortality factors) if subsequent chick survival is higher. This change in survival could result from the lower density of northern bobwhite chicks in areas with RIFA. For example, the surviving chicks may have more food to eat or be less susceptible to disease due to the lower density of chicks. We can use a simple mathematical model to examine the potential for RIFA mortality to be compensatory. If we compare the expected chick production from 1,000 nests protected from RIFA with that of 1,000 unprotected nests using the data of Mueller et al. (1999), we would expect 3,192 and 1,170 chicks to survive to 21 days-of-age, respectively (Table 1). If only 50% of chicks from protected nests survive to 15 weeks-of-age (Fatora 1966), chicks from unprotected nests cannot match their number even if they experience 100% survival during this same time period (Table 1). It seems very unlikely that chick mortality caused by RIFA is compensatory in the Coastal Plain of Texas. Further, our data suggest that food limitation may not be a problem for northern bobwhite chicks that cohabit areas in the Texas Coastal Plain with RIFA. Northern bobwhite chicks from treated nests that ranged in areas inhabited by RIFA (mean of 290 mounds/ha) in our study attained 101% of a predicted 37.9 g body mass at 22 days of age (Mueller 1999).

We also detected another important relationship. Chick survival is related to the number of RIFA captured within a 30-minute period in a standardized bait cup placed in northern bobwhite nests on the day after hatch (Mueller et al. 1999). Our data indicate that when 300 or more RIFA recruit to the nest one day post-hatch, chick survival is essentially zero. If less than 300 RIFA recruit to the nest then survival of chicks is similar to that of chicks that hatched from nests protected from RIFA attack using insecticide (Fig. 1). Thus, not all areas of the landscape harbor enough RIFA to kill northern bobwhite broods.

Differences in climate may cause differences in the way northern bobwhite populations from different regions of the southeastern United States respond to chick mortality caused by RIFA. Reproductive activities of northern bobwhite are sensitive to rainfall regimes. Drought causes fewer hens to nest and reduces the number of renesting attempts (Guthery et al. 1988). RIFA predation on chicks, however, does not appear to be impacted by rainfall (Mueller et al. 1999). We can examine this relationship using another simple mathematical model. We can use an arbitrary number of 1,000 nest attempts by hens in a population and estimate that a population protected from RIFA could expect 1,596 chicks to reach 15 weeks-of-age (Table 2). Guthery et al. (1988) provided evidence that drought conditions could reduce the number of hens that are able to breed by 40%. This would reduce the number of nesting attempts in our hypothetical population to 600 and the number of chicks reaching 15 weeks-of-age to 798 (this assumes no drought impact on chick survival which is unlikely). If we now combine the negative impacts of drought on nest attempts and RIFA on chick survival to 21 days-of-age, the number of chicks that survive to 15 weeks-of-age falls to 293 (Table 2). A combination of drought and RIFA predation can have severe impacts on northern bobwhite population size. Droughts are a much more frequent feature of the climate of some regions of the southeast as compared to others (Diaz 1983, Soule 1992).

Methods available to control RIFA on large areas of land using insecticides cost about $20/ha/treatment (Drees et al. 1996) and treatments may last < 3 months (Apperson et al. 1984). Use of insecticides may also be ecologically undesirable because the insecticide also kills native ants reducing competition for recolonization by RIFA. My research team is now focusing on possible methods to lessen the impacts of RIFA on northern bobwhite populations in Texas. Data from a related study suggests the density of RIFA mounds increases after soil disturbance (Tschinkel 1988). We are currently experimentally testing the possibility that the benefits of burning and disking (soil disturbance) treatments for northern bobwhite habitat management could be outweighed by increased RIFA predation on chicks that results from greater densities of RIFA after soil disturbance. Wealso plan to study methods to mitigate the impacts of RIFA on northern bobwhite populations by attempting to identify economically and ecologically desirable techniques to decrease other sources of chick mortality. We plan to develop management guidelines in the future to help landowners estimate and deal with the impact of RIFA on their properties.

Literature Cited

Allen, C. R. 1993. Responses of wildlife to red imported fire ant population reductions in the South Texas Coastal Prairie. M. S. Thesis, Texas Tech Univ., Lubbock. pp.

Allen, C. R., S. Demarais, and R. S. Lutz. 1995. Red imported fire ants impacts on northern bobwhite populations. Ecol. Appl. 5:632-638.

Apperson, C. S., R. B. Leidy, and E. E. Powell. 1984. Effects of Amdro® on the red imported fire ant (Hymanoptera: Formicidae) and some nontarget species and persistence of Amdro® on a pasture habitat in North Carolina. J. Econ. Entomol. 77:1012-1018.

Blem, C. R., and J. Zara. 1980. The energetics of young bobwhite (*Colinus virginianus*). Comp. Biochem. Physiol. 67A:611-615.

Brinkley, C. K. 1989. Economic impact of the red imported fire ant *Solenopsis invicta* Buren, in Texas. M.S. Thesis, Texas Tech Univ., Lubbock. 91pp.

Choi, I., and G. S. Bakken. 1991. Locomotion and muscle function during postnatal development of the northern bobwhite (*Colinus virginianus*): Effect of body temperature. Physiol. Zool. 64:653-672.

Dabbert, C. B., R. L. Lochmiller, P. W. Waldroup, and R. G. Teeter. 1996. Examination of the dietary methionine requirements of breeding Northern bobwhite, *Colinus virginianus*. Poult. Sci. 75:991-997.

Diaz, H. F. 1983. Drought in the United States: some aspects of major dry and wet periods in the contiguous United States, 1895-1981. J. Climate Appl. Meteor. 22:3-16.

Diaz, J. D., R. F. Lockey, J. J. Stablein, and H. K. Mines. 1989. Multiple stings by imported fire ants (*Solenopsis invicta*), without systemic effects. S. Med. J. 82:775-777.

Drees, B. M., C. L. Barr, S. B. Vinson, R. E. Gold, M. E. Merchant, and D. Kostroun. 1996. Managing red imported fire ants in urban areas. Texas Agricult. Exten. Serv. College Station.

Fatora, J. R., E. E. Provost, and J. H. Jenkins. 1966. Preliminary report on breeding periodicity and brood mortality in bobwhite quail on the AEC Savannah River Plant. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 20:146-154.

Guthery, F. S., N. E. Koerth, and D. S. Smith. 1988. Reproduction of northern bobwhites in semiarid environments. J. Wildl. Manage. 52:144-149.

Lockey, T. C. 1979. Allergic and other adverse reactions caused by the imported fire ant. Adv. Allerg. Clin. Immunol. Pergamon Press, N.Y., pp. 441-448.

Mueller, J. M. 1999. Effect of red imported fire ants on reproduction, health, and survival of northern bobwhites. Ph. D. Dis., Texas Tech Univ, Lubbock. 65pp.

Mueller, J. M., C. B. Dabbert, S. Demarais, and A. R. Forbes. 1999. Northern bobwhite chick mortality caused by red imported fire ants. J. Wildl. Manage. In press.

Pedersen, E. K., W. E. Grant, and M. T. Longnecker. 1996. Effects of red imported fire ants on newly-hatched northern bobwhite. J. Wildl. Manage. 60:164-169.

Porter, S. D., and D. A. Savignano. 1990. Invasion of polygyne fire ants decimates native ants and disrupts native arthropod community. Ecol. 71:2095-2106.

Robel, R. J., B. M. Press, B. L. Henning, K. W. Johnson, H. D. Blocker, and K. E. Kemp. 1995. Nutrient and energetic characteristics of sweepnet-collected invertebrates. J. Field Ornithol. 66:44-53.

Romesberg, H. C. 1981. Wildlife science: Gaining reliable knowledge. J. Wildl. Manage. 45:293-313.

Roseberry, J. L., and W. D. Klimstra. 1984. Population ecology of the bobwhite. Southern Illinois University Press, Carbondale, pp.

Schew, W. A., and R. E. Ricklefs. 1998. Developmental plasticity, pages 288-304 In J. M. Starck, and R. E. Ricklefs (Editors) Avian growth and development. Oxford University Press.

Serafin, J. A. 1982. Influence of protein level and supplemental methionine in practical rations for young endangered masked bobwhite quail. Poult. Sci. 61:988-990.

Soule, P. T. 1992. Spatial patterns of drought frequency and duration in the contiguous USA based on multiple drought event definitions. Int. J. Climatol. 12:11-24.

Tschinkel, W. R. 1988. Distribution of fire ants *Solenopsis invicta* and *Solenopsis geminata* (Hymenoptera: Formicidae) in northern Florida in relation to habitat and disturbance. Ann. Entomol. Soc. Am. 81:76-81.

Vinson, S. B. 1997. Invasion of the red imported fire ant (Hymenoptera: Formicidae): spread, biology, and impact. Am. Entomol. 43:23-39.

Vinson, S. B., and A. A. Sorenson. 1986. Imported fire ants: life history and impact. Texas Dept. of Agric., Austin. 28 pp.

Table 1. A simple mathematical comparison of chick production in areas with and without RIFA. The possible compensatory nature of RIFA mortality is also considered.

Nest attempts expected[a]	Nests surviving to hatch[b]	Presence of RIFA	Number of chicks surviving to 21 days-of-age[c]	Number of chicks surviving to 15 weeks-of-age
1,000	380	No	3,192	1,596[d]
1,000	380	Yes	1,170	585[d] (1,170)[e]

an arbitrary number set for a hypothetical population
Expect 38% nest success (Mueller et al. 1999)
Expect 60% chick survival without RIFA and 22% survival with RIFA present (Mueller et al. 1999)
Expect 50% survival to 15 weeks-of-age if RIFA predation is not compensatory
Number in parentheses is the number of chicks surviving to 15 weeks-of-age if no mortalities occur after 21 days-of-age

Table 2. A simple mathematical comparison of chick production among areas with no environmental hindrances, areas with drought, and areas with drought and RIFA.

Nest attempts expected[a]	Nest attempts reduced[b]	Nest attempts initiated	Nests surviving to hatch[c]	Presence of RIFA	Number of chicks surviving to 21 days-of-age[d]	Number of chicks surviving to 15 weeks-of-age[e]
1,000	No	1,000	380	No	3,192	1,596
1,000	By drought	600	190	No	1,596	798
1,000	By drought	600	190	Yes	585	293

[a] an arbitrary number set for a hypothetical population
[b] Drought is expected to lower the nest attempts by 40% (Guthery et al. 1988)
[c] Expect 38% nest success (Mueller et al. 1999)
[d] Expect 60% chick survival without RIFA and 22% survival with RIFA present (Mueller et al. 1999)
[e] Expect 50% survival to 15 weeks-of-age if RIFA predation is not compensatory

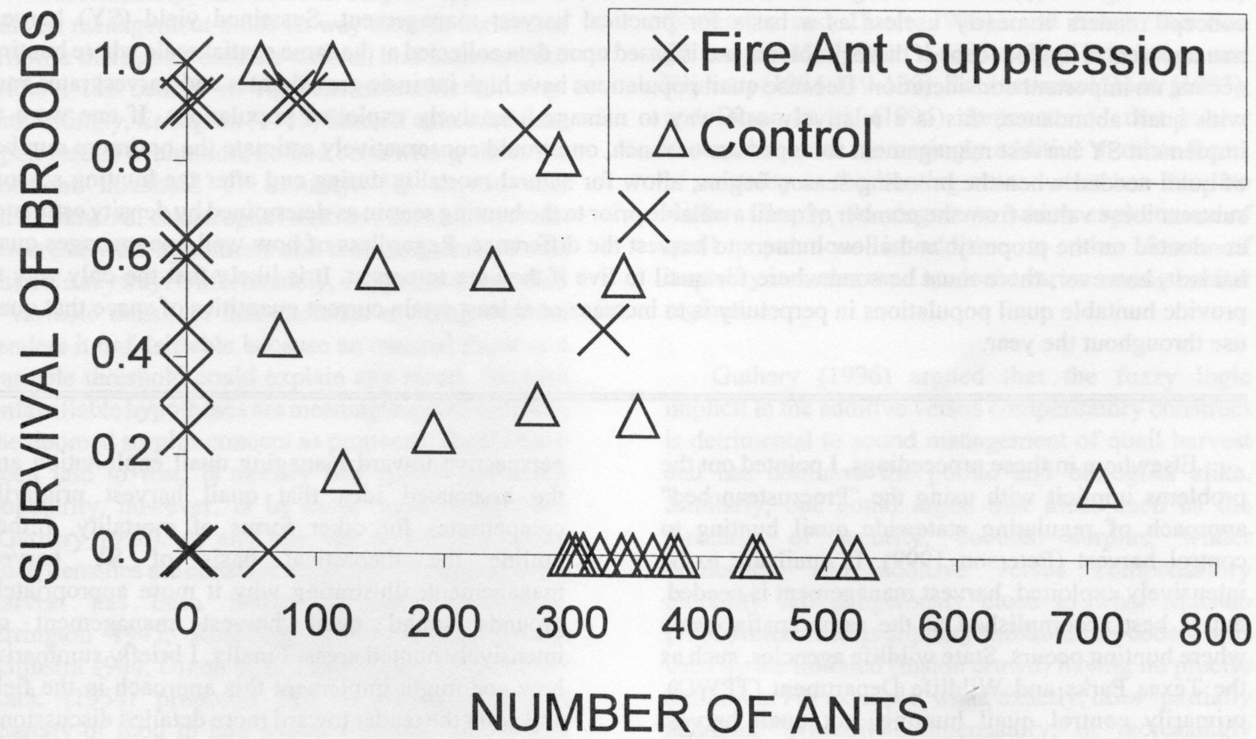

Figure 1. Relationship between proportion of northern bobwhite broods surviving to 3 weeks and number of red imported fire ants recruiting to a bait cup in 30 min on the day after hatch (n = 43). Broods from nests treated to suppress red imported fire ants are displayed separately from broods from control nests (Mueller et al. 1999).