EFFECTS OF FIRE ANTS (HYMENOPTERA: FORMICIDAE) ON HATCHING TURTLES AND PREVALENCE OF FIRE ANTS ON SEA TURTLE NESTING BEACHES IN FLORIDA

CRAIG R. ALLEN[1], ELIZABETH A. FORYS[2], KENNETH G. RICE[3], AND DANIEL P. WOJCIK[4]

[1]U.S. Geological Survey, Biological Resources Division, South Carolina Cooperative Fish and Wildlife Research Unit, Clemson University, Clemson, SC 29634

[2]Department of Environmental Science, Eckerd College, St. Petersburg, FL 33711

[3]U.S. Geological Survey, Biological Resources Division, Florida Caribbean Science Center Restoration Ecology Branch, Everglades National Park Field Station, Homestead, FL 33034

[4]U.S. Department of Agriculture, Center for Medical, Agricultural and Veterinary Entomology Gainesville, FL 32608

ABSTRACT

Red imported fire ants (*Solenopsis invicta* Buren) have increasingly been observed in loggerhead (*Caretta caretta* L.) and green (*Chelonia mydas* L.) sea turtle nests in Florida, and in the nests of freshwater turtles. They may be attracted to the disturbance, mucous and moisture associated with turtle nesting and establish foraging tunnels into turtle nests shortly after egg-laying, thus increasing the vulnerability of hatchlings to fire ant predation. We conducted experiments on a freshwater turtle (*Pseudemys nelsoni* Carr) to determine the potential impacts of *S. invicta* on turtle hatchlings. Over 70% of hatchlings were killed by *S. invicta* during pipping or shortly after hatching. To determine the extent of *S. invicta* infestation of sea turtle nesting beaches, we sampled known nesting beaches throughout the state of Florida. Beach surveys indicated that *S. invicta* are present and often abundant on most beaches and dunes along the Florida coast.

Key Words: *Caretta caretta*, endangered species, fire ant, invasive species, *Pseudemys nelsoni*, *Solenopsis invicta*, turtles

RESUMEN

Se han observado hormigas bravas (*Solenopsis invicta* Buren) cada vez mas en nidos de tortugas marinas (*Caretta caretta* L.) y (*Chelonia mydas* L.) en la Florida, y en los nidos de tortugas de agua dulce. Estas hormigas pueden ser atraídas al disturbio, mucosidad y humedad asociada con anidaje de tortugas y establecen túneles de forraje hacia nidos de tortuga poco después de la puesta de huevos, así incrementando la vulnerabilidad de los recién nacidos a predación por la hormiga brava. Llevamos a cabo experimentos con una tortuga de agua dulce (*Pseudemys nelsoni* Carr) para determinar el impacto potencial de *S. invicta* en tortugas recién nacidas. Mas del 70% de los recién nacidos fueron muertos por *S. invicta* durante el proceso de salir del cascaron o poco después de salir. Para determinar la extensión de infestación de *S. invicta* en playas donde anidan tortugas marina, muestreamos playas conocidas por tener nidos por todo el estado de la Florida. Exámenes de playas indicaron que *S. invicta* esta presente y mucha la mayoría de las playas y dunas a lo largo de la costa Floridana.

There has been considerable concern and debate over the potential impact of fire ants on nesting sea turtles, but little quantitative evidence exits. Information on the impact of *Solenopsis invicta* (Buren) on hatchling turtles has been largely incidental and anecdotal. Fire ants may impact turtle populations directly by preying on hatchlings and/or indirectly by stinging hatchlings, resulting in reduced weight gain and survival.

Wilmers et al. (1996) documented an increase in the presence of fire ants in green (*Chelonia mydas* L.) and loggerhead (*Caretta caretta* L.) turtle nests on undeveloped island beaches off Florida. Red imported fire ants were observed feeding on pipped eggs, and stinging, killing and subsequently feeding on turtle hatchlings (Wilmers et al. 1996). Moulis (1997) documented a 15% decrease in hatchling release rate for loggerhead sea turtles emerging from nests infested with fire ants as compared to uninfested nests. The ultimate effect of this predation on sea turtle populations and the magnitude of the problem else-where is unknown. The nesting period (May-August) for loggerheads in the eastern United States (Johnson et al. 1996) corresponds with a concentrated period of brood production in *S. invicta.* During that time, protein needs for fire ants are maximal (Sorensen et al. 1983). For secure turtle populations, high juvenile mortality may not affect population size (Congdon & Gibbons 1990), but for small populations, decreases in annual cohort size may affect population viability (Heppell et al. 1996).

Our objectives were to assess the potential impacts of the invasive non-indigenous ant, *S. invicta*, on hatching turtles by using the eggs of a freshwater species (Florida red-bellied turtle, *Pseudemys nelsoni* Carr) in a controlled experimental setting. *Pseudomys nelsoni* often lays its eggs in alligator nests, approximately 20% of which are infested with fire ants in central Florida (Allen et al. 1997). In addition, we determined the geographic extent of *S. invicta* occurrence on sea turtle nesting beaches throughout the state of Florida by sampling beaches with baits attractive to ants.

Materials and Methods

To assess the potential for *S. invicta* impact on the eggs and hatchlings of turtles we conducted a laboratory experiment using *P. nelsoni* eggs. The eggs of this freshwater turtle species are elliptical and approximately 2.5 cm long, occur in clutches of about 15, and are found regularly in American alligator nests in Florida. Although the shape of eggs in this species is different from the generally round shape of sea turtle eggs, and egg and clutch size vary among turtle species, we have observed no differences in attractiveness among eggs of several different species regardless of size or shape. *Pseudemys nelsoni* and many other turtle species, including sea turtles, share the trait of emerging from the nest only after most or all of the clutch has hatched.

Ten clutches of *P. nelsoni* eggs were collected (1996) from Lake Apopka in central Florida and transferred to ten 61 × 36 × 13 cm enclosures at the U.S.D.A.-A.R.S. Imported Fire Ant Laboratory, in Gainesville, Florida. Five clutches served as controls. For both control and treated clutches, eggs were placed in sphagnum nesting material adjacent to a shallow pan of water, which allowed individual hatchlings immediate access to water upon emergence. Treated clutches were maintained identically to control clutches, but were exposed to a field-collected mound of *S. invicta* at the opposing end of each enclosure. This controlled situation simulated the natural conditions for the many *P. nelsoni* clutches which share alligator nests with fire ant mounds (Allen et al. 1997). The enclosures allowed fire ants to forage among the clutch as may occur within natural turtle nests (Wilmers et al. 1996; Allen et al. 1997). Fire ants were provided with honey as a food source. Eggs were observed twice daily as they approached hatching and constantly as pipping commenced. Surviving turtles were transferred to the Florida Game and Fresh Water Fish Commission incubation facilities (Gainesville, FL) with food supplied *ad libitum*, and measured weekly for 6 weeks to determine if differences in weight gain between treated and untreated groups existed (Allen et al. 1997).

To determine the presence of *S. invicta* on sea-turtle nesting beaches, we sampled for fire ants at 18 known sea turtle nesting beaches throughout Florida. Collection localities are given in Table 1. Transects consisting of approximately 20 samples at 10-m intervals were established along dune lines. Multiple transects (2 to 7) were sampled at each locality. Baits on all transects consisted of ground beef, except for those in Duval, St. Johns and Volusia counties, which consisted of a sugar-based bait attractive to a variety of ants, newly formulated by the U.S.D.A.-A.R.S. Baits were left in the field for approximately 1 h before being collected and transported to U.S.D.A.-A.R.S. facilities in Gainesville, Florida, for sorting and identification of ant species.

Results

Pseudemys nelsoni clutch size varied from 6-16 eggs, but only 2-11 of the eggs in a given clutch ultimately hatched. In control groups, 59% of the eggs did not hatch, and in those exposed to fire ants 37% did not hatch. The cause or causes of inviability were not determined but may be attributed to flooding or crushing by the attendant female alligator prior to collection. During and after hatching, 100% of hatching turtles in control groups (17) survived, and were eventually released. The proportion successfully hatching in clutches exposed to fire ants (10 of 35) was significantly less (median = 33%, range 0-55%; Mann-Whitney Rank Sum Test t = 40.0, df = 8, P = 0.008). Approximately half of the mortalities occurred while the hatchlings were still in the egg, while most others died less than 1 h after emergence. Fire ants did not breach turtle eggs, but entered the eggs as soon as a pipped hole was present. Too few individuals exposed to fire ants survived to assess differences in weight gain between the two groups.

We collected 734 ant bait samples and a total of 31,392 ants from Florida sea turtle nesting beaches. About 40% of the collected ants (12,658) were *S. invicta*. Fire ants were detected foraging along dune lines on sea turtle nesting beaches in all regions of the state, and were detected on 13 of 18 specific sites (Table 1). Within those 18 sites, fire ant occurrence on baits varied from 0 to 63%, and represented from 0 to 97% of the individuals collected. Fire ant occurrence followed no obvious geographic pattern. Ants were abundant at some very remote locations (e.g., Boca Grande Key near Key West) but were uncommon on beaches at some locations that have undergone extensive human disturbance (e.g., northeastern Florida beaches).

TABLE 1. RESULTS OF FIRE ANT SAMPLING IN SEA TURTLE NESTING HABITAT IN FLORIDA.

Region	Site	No. baits	% baits with *S. invicta*	No. *S. invicta*	No. other ants	% *S. invicta*
East Coast North	Crescent Beach	30	0	0	612	0
	Daytona Beach	30	7	52	90	37
	Appollo State Park	30	0	0	658	0
Panhandle	Cape San Blas	40	18	867	1,732	33
Southwest	Clam Pass Park South	20	60	869	98	90
	Vanderbilt Beach	40	18	691	1,103	39
	Park Shore Beach	39	21	142	30	83
	Collier Co., Gullivan Key	69	1	3	1675	0.1
	Collier Co., Turtle Key	21	0	0	1163	0
	Collier Co., "B" Key	30	63	4,480	127	97
	West Panther Key	20	0	0	987	0
Westcentral	Pinellas Co., Sand Key	60	35	3,570	1,143	76
	Pinellas Co., Passe Grille	60	7	188	2,546	7
Southeast	Indian River Co., Sebastian Inlet	60	5	153	798	16
	Palm Beach Co., J. D. MacArthur State Park	60	0	0	1,174	0
Keys	Boca Grande	50	26	1,613	2,392	40
	Marquesas	50	4	29	582	5
	Matecumbe	25	4	1	1,914	0.5
Totals		734	15	12,658	18,824	29

DISCUSSION

Our surveys found *S. invicta* present on most beaches, at both the wrack and dune lines. Our and other observations indicate that fire ants often are present in sea turtle nest cavities (e.g., Wilmers et al. 1996; Parris et al. 2001). The egg-laying process may initially attract fire ants because it represents a local disturbance and food source. Mucous associated with the egg laying process is an attractive food for fire ants and sea turtle nest cavities provide a desirable micro-climate for fire ants. It appears that fire ants cannot breach intact sea or freshwater turtle eggs (Wojcik & Allen, unpublished data). However, once fire ants build subterranean foraging trails to a site that has provided food, such as turtle nest cavities, they maintain those foraging tunnels. Additionally, post-laying disturbances caused by predators such as raccoons (*Procyon lotor* L.) or ghost crabs (*Ocypode* sp.) that fracture some eggs may attract fire ants to nest cavities. Thus, fire ants may maintain a presence in the nest cavity until hatching.

Our experiments with *P. nelsoni* eggs indicate that turtle hatchlings are both highly attractive and vulnerable to fire ants. Presumably, endangered species such as sea turtles or gopher tortoises attempting to hatch from nests with established fire ant foraging tunnels are equally as vulnerable. Fire ants often use the burrow aprons of gopher tortoises as colony sites (personal observation). Nearly half of the *P. nelsoni* killed by *S. invicta* successfully exited from their eggs and reached the water before succumbing to the effects of envenomization. In a natural setting, these individuals would have been considered to have hatched successfully, thus under-estimating fire ant-induced mortality by about 50%. Our laboratory research only documented direct mortality of hatchlings. However, other research has shown serious indirect effects on individual animals (American alligators, *Alligator mississippiensis* Daudin, Allen et al. 1997; northern bobwhite, *Colinus virginianus* L., Giuliano et al. 1996) stung non-lethally by *S. invicta*. These effects included the loss of digits and appendages, and reduced weight gain, both likely to affect survival in the wild.

This work indicates that hatching turtles are very vulnerable to predation by *S. invicta* and that *S. invicta* is now a common component of the ant community of sea turtle nesting beaches. However, population-level impacts are unknown. Moulis (1997) documented a 15% decrease in hatchling release rate for sea turtles (*C. caretta*) emerging from nests infested with fire ants as compared to uninfested nests, but predation by vertebrate predators (e.g., raccoons) can vary between 5 to 90% (Ratnaswamy et al. 1997).

Fire ant populations are increasing in terms of both the spatial extent of infestation (Cokendolpher & Phillips 1989; Callcott & Collins 1996) and population densities of sites already infested (Wojcik 1994). Due to the sensitivity of using sea turtle hatchlings as experimental units, this research did not document the extent of *S. invicta* utilization of sea turtle nesting cavities or interactions between sea turtles and fire ants in natural settings. However, our experiment with *P. nelsoni* was conservative because hatchlings had immediate access to water upon emergence, whereas in the wild, hatchlings of many species may spend several hours in the nest cavity before emergence. We conclude that there is a very real potential for negative impacts by *S. invicta* on hatchling turtles.

Additional investigation of the effect of *S. invicta* on hatching sea turtles is vital because fire ants occur throughout sea turtle nesting habitat in the United States, they are increasing in abundance, and they clearly have the potential to negatively impact hatchlings of sea turtles, other turtle species, and many other species in terrestrial ecosystems. In the case of sea turtles, further research is also needed to determine why certain beaches possessed higher densities of *S. invicta*, and what beach management activities (e.g., beach renourishment, degree of disturbance, human activity levels) may influence *S. invicta* infestation and spread.

ACKNOWLEDGMENTS

We wish to extend thanks to J. P. Hosford, M. Lamont, and A. Quistorff for aiding in the collection of beach samples. We thank J. Sullenger and B. Mayfield for collecting, processing and identifying the samples from beaches. We thank T. Wilmers for providing access to the Marquesas, and to T. Hopkins for providing access to beaches and housing during sampling in southwest Florida. We thank A. Garmestani for providing access to beaches in the Ten Thousand Islands. We wish to thank R. Carthy, D. Epperson, and R. Moulis for reviewing an earlier draft of this manuscript. Our laboratory work with turtles was approved by the University of Florida Animal Care and Use Committee. The South Carolina Cooperative Fish and Wildlife Research Unit is jointly supported by a cooperative agreement among the USGS/BRD, the South Carolina Department of Natural Resources, Clemson University, and the Wildlife Management Institute.

REFERENCES CITED

ALLEN, C. R., K. G. RICE, D. P. WOJCIK, AND H. F. PERCIVAL. 1997. Effect of red imported fire ant envenomization on neonatal American alligators. J. Herpetol. 31: 318-321.

CALLCOTT, A. A., AND H. L. COLLINS. 1996. Invasion and range expansion of the imported fire ants (Hymenoptera: Formicidae) in North America from 1918-1995. Florida Entomol. 79: 240-251.

COKENDOLPHER, J. C., AND S. A. PHILLIPS, JR. 1989. Rate of spread of the red imported fire ant, *Solenopsis invicta* (Hymenoptera: Formicidae) in Texas. Southwest. Nat. 34: 443-449.

CONGDON, J. D., AND J. W. GIBBONS. 1990. The evolution of turtle life histories, pp. 45-54. *In* J. W. Gibbons (ed.). Life History and Ecology of the Slider Turtle. Smithsonian Institution Press, Washington, D.C.

GIULIANO, W. M., C. R. ALLEN, R. S. LUTZ, AND S. DEMARAIS. 1996. Effects of imported fire ants on northern bobwhite chick survival and body mass. J. Wildl. Manage. 60: 309-313.

HEPPELL, S. S., L. B. CROWDER, AND D. T. CROUSE. 1996. Models to evaluate headstarting as a management tool for long-lived turtles. Ecol. Appl. 6: 556-565.

JOHNSON, K. A. BJORNDAL, AND A. B. BOLTON. 1996. Effects of organized turtle watches on loggerhead (*Caretta caretta*) nesting behavior and hatchling production in Florida. Cons. Biol. 10: 570-577.

MOULIS, R. A. 1997. Predation by the imported fire ant (*Solenopsis invicta*) on loggerhead sea turtle (*Caretta caretta*) nests on Wassaw National Wildlife Refuge, Georgia. Chelonian Cons. Biol. 2: 433-436.

PARRIS, L. N., M. M. LAMONT, AND R. R. CARTHY. 2001. Observations of predation by red imported fire ants (*Solenopsis invicta*) on hatching loggerhead sea turtles (*Caretta caretta*). Herp. Rev. (in press).

RATNASWAMY, M. J., R. J. WARREN, M. T. KRAMER, AND M. D. ADAM. 1997. Comparisons of lethal and nonlethal techniques to reduce raccoon depredation of sea turtle nests. J. Wildl. Manage. 61: 368-376.

SORENSEN, A. A., T. M. BUSCH, AND S. B. VINSON. 1983. Behavior of worker subcastes in the fire ant, *Solenopsis invicta*, in response to proteinaceous food. Physiol. Entomol. 8: 83-92.

WILMERS, T. J., E. S. WILMERS, M. MILLER, AND P. WELLS. 1996. Imported fire ants (*Solenopsis invicta*): a growing menace to sea turtle nests in Key West National Wildlife Refuge, pp. 341-343. *In* J. A. Keinath, D. E. Barnard, J. A. Musick, and B. A. Bell (eds.). Proc. Fifteenth Annual Workshop on Sea Turtle Biology and Conservation.

WOJCIK, D. P. 1994. Impact of the red imported fire ant on native ant species in Florida, pp. 269-281. *In* D. F. Williams (ed.). Exotic Ants: Biology, Impact, and Control of Introduced Species. Westview Press, Boulder, CO.