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POTENTIAL FIRE ANT (HYMENOPTERA: FORMICIDAE) IMPACT ON THE ENDANGERED SCHAUS SWALLOWTAIL (LEPIDOPTERA: PAPILIONIDAE)

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ABSTRACT

The Schaus swallowtail, *Papilio aristodemus ponceanus*, historically occurred in tropical hardwood hammocks from South Miami to the upper Florida Keys and is currently listed as federally endangered. Much of the remaining hardwood hammock habitat is fragmented by roads and human development that may alter the microhabitat within the hammocks and increase the probability of invasion by non-native predators and competitors. One non-indigenous species that has recently invaded the Florida Keys, and that may impact the Schaus swallowtail is the red imported fire ant (*Solenopsis invicta* Buren). We estimated abundance of red imported fire ants in Schaus swallowtail habitat on Key Largo, and the decrease in red imported fire ants resulting from the application of chemical ant baits. In addition, we conducted laboratory experiments to determine how vulnerable swallowtail life stages are to red imported fire ant predation. We found red imported fire ants at 50% of transects in the hardwood hammock, up to 40 m from hammock edge. Chemical treatments were only partially effective in decreasing red imported fire ant abundance, and the effect was short-lived. All immature swallowtail life stages were vulnerable to predation by red imported fire ants. Habitat restoration that decreases red imported fire ant abundance may be the most cost-effective and long-term method of decreasing impacts from red imported fire ants.

Key Words: Florida, habitat loss, invasive species, non-indigenous species, *Papilio aristodemus*, *Solenopsis invicta*

RESUMEN

El *Papilio aristodemus ponceanus* ocurria historicamente en bosques tropicales de madera dura ("tropical hardwood hammocks") desde el sur de Miami hasta en norte de los Cayos de la Florida, y esta actualmente listado como bajo peligro por el gobierno federal. La mayoria de hábitat de este bosque tropical esta fragmentado por calles y desarrollo humano que puede alterar el microhabitat dentro de los bosques e incrementar la probabilidad de invasión por predadores y competidores exóticos. Una especie no indígena que recientemente ha invadido los Cayos Floridanos, y que puede impactar a *P. aristodemus* es la hormiga brava roja (*Solenopsis invicta* Buren). Estimamos la abundancia de *S. invicta* en habitats de *P. aristodemus* en Cayo Largo, y la reducción en *S. invicta* como resultado de la aplicación de trampas químicas de hormigas. En adición, llevamos a cabo experimentos de laboratorio para determinar que tan vulnerable son las etapas de vida de *P. aristodemus* a predación por *S. invicta*. Encontramos *S. invicta* en un 50% de lotes en los bosques, hasta 40 m del borde del bosque. Tratamientos químicos fueron solo parcialmente efectivos para disminuir la abundancia de *S. invicta*, y el efecto fue de corta duración. Todas las etapas de vida de *P. aristodemus* fueron vulnerables a predación por *S. invicta*. La restauración del hábitat que reducen la abundancia de *S. invicta* puede ser el método mas efectivo en costo y a largo plazo para reducir los impactos de *S. invicta*.

The Schaus Swallowtail, *Papilio* (Heraclides) *aristodemus ponceanus*, is a large dark brown and yellow butterfly that historically occurred in hardwood hammocks from South Miami to the upper keys of Florida (Emmel 1995). Hardwood hammocks are closed-canopy broad-leaved forests with a high diversity (>150 species) of both evergreen and semi-evergreen tropical tree species. Adult swallowtails spend most of their time within the hardwood hammock, but will fly in clearings and along roads (Rutkowski 1971, Brown 1976). Nectaring activity occurs on >30 species of wild plants along the margins of the hammock but rarely occurs in areas open to direct sunlight (Rutkowski 1971). Adult females lay eggs on a small number of host tree species that occur primarily on the edges and in tree gaps of hardwood hammocks in portions of Monroe and

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Dade Counties, Florida, including torchwood, *Amyris elemifera* (L.), and wild lime, *Zanthoxylum fagara* (L.) Sarg., (Emmel 1986, 1995). Both of these trees are relatively small and tend to produce suckers around the base. It appears that leaves on these suckers may be the preferred oviposition locations for Schaus (Bagget 1982; Emmel 1995). Young torchwood and wild lime leaves are the primary food of most Schaus caterpillars. Like other butterflies, the Schaus is an important pollinator of native plants, serves as a food source for insectivorous species, and contributes to the biological diversity of the Florida Keys.

The Schaus swallowtail was listed as Federally endangered in 1984 because of population declines caused by the destruction of its tropical hardwood hammock habitat, mosquito control practices, and over-harvesting by collectors. Reintroductions occurred between 1995 and 1997 (U.S. Fish and Wildlife Service 1999) and in 1998 the Schaus swallowtail was documented on 13 areas on the mainland and the Upper and Middle Keys.

Currently, efforts are underway to protect the remaining hardwood hammocks in south Florida from commercial and residential development as well as from pesticide spraying (U.S. Fish and Wildlife Service 1999). Even if these measures are successful, much of the existing habitat is already fragmented by roads and human development that may alter the microhabitat within the hammocks (Saunders et al. 1991) and increase the probability of invasion by non-native predators and competitors (Usher 1988).

An invasive non-native species that may have a negative impact on the Schaus swallowtail is the red imported fire ant (*Solenopsis invicta* Buren). Red imported fire ants were first recorded in the upper Florida Keys in 1976 (Callcott & Collins 1996), but were considered to be restricted to disturbed areas (Deyrup et al. 1988; Porter 1992). During a Keys-wide ant survey in 1996, *S. invicta* was identified on 10 of the 14 major keys (Forys et al. 1999). *Solenopsis invicta* was found in every major habitat type including hardwood hammocks, pinelands, salt and freshwater marshes, and disturbed areas (e.g., roadsides, parking lots) (Forys et al. 1999). While little research has been conducted on red imported fire ant predation on Lepidoptera, the presence of *S. invicta* in the tropical hardwood hammocks is of particular concern for the Schaus swallowtail because red imported fire ants are known to prey on a wide range of other invertebrates (Porter & Savignano 1990). Schaus swallowtail eggs, larvae, and pupae may be vulnerable because they occur on tree species (e.g., torchwood, wild lime) that generally occupy habitat edge where red imported fire ant infestations tend to be the highest.

The objective of this study was to 1) measure the abundance of red imported fire ants in Schaus swallowtail habitat, 2) determine if swallowtail eggs, larvae and pupae are readily discovered and consumed by red imported fire ants, and 3) explore the effectiveness of fire ant control in areas important to Schaus swallowtail reproduction.

Materials and Methods

Red Imported Fire Ant Foraging

To determine fire ant abundance and ability to forage into closed canopy tropical hardwood hammock, we established bait transects on North Key Largo, Florida. North Key Largo is a long and narrow (<1 km) island at the northernmost portion of the Florida Keys. There are several residential developments, but most of North Key Largo is federally and state owned. In the center of the key, a well-traveled highway (SR 905) bisects the hardwood hammock. Recently, Schaus swallowtails have been successfully reintroduced in this area (U.S. Fish and Wildlife Service 1999).

Twenty transects were placed perpendicular to SR 905 into the Key Largo hammock. Ten of the transects were on the federally-owned north side of SR 905 and the other 10 were directly across the road on the state-owned south side of SR 905. Habitat on both sides of SR 905 was similar. Transects were separated by 100 m and consisted of 10 sampling stations spaced 5 m apart beginning at known fire ant infested areas (the roadside) and continuing perpendicular into the intact hardwood hammock.

At each of the 10 sampling stations along all 20 transects, we placed two terrestrial and two arboreal baits, with members of each pair separated by >1 m. The paired terrestrial baits (one honey, one hamburger meat) were placed directly on the ground on pieces of aluminum foil. The paired arboreal baits were placed in plastic condiment cups with 5-10, 3-6 mm holes punched throughout the cup. Both arboreal cups were placed 1-1.5 m from the ground in a tree as close to the terrestrial bait as was possible.

Predation on Swallowtails

To determine the attractiveness and vulnerability of Schaus swallowtails to red imported fire ants we conducted an experiment using eggs, larvae, and pupae of the giant swallowtail (*P. cresphontes*) Cramer as a surrogate species. The giant swallowtail is a common Key's resident that is similar to the Schaus swallowtail in its distribution and natural history. Both species of swallowtails occur in the Florida Keys, utilize species of Rutaceae as host plants, and lay eggs singly on leaves. The larvae of both eat new leaves, do not use nests, pupae of both hibernate and are similar in structure and appearance (Scott 1986). The giant swallowtail reproduces more frequently (has multiple broods in one year) and adults can be

found throughout the year, while the Schaus swallowtail has only one set of brood a year and adults are found mid March through mid September (Emmel 1995).

Ten eggs, larvae (third and fourth instar), and pupae were purchased from a commercial butterfly farm (Robert Brown, Butterfly Paradise, 19940 Adams Rd., Ft. Myers, FL). Each egg, larva, and pupa was individually attached 1 m off the ground on a wild lime tree placed in enclosures with active red imported fire ant colony. For comparison we also placed 10 balls of hamburger meat of equal size to the larvae and pupae one meter off the ground on a wild lime tree in an additional 10 enclosures with an active red imported fire ant colonies. The eggs had been laid on wild lime leaves and we attached these leaves to the wild lime tree using gardeners wire. The pupae were placed in small porous cups and were attached to the wild lime tree. The larvae were directly placed on leaves. The enclosures were monitored for three hours and both the length of time for the fire ants to discover (make first contact) and entirely consume the hamburger balls and swallowtail eggs, larvae, and pupae were recorded. A t-test was used to compare the time to discovery for each swallowtail life stage and the hamburger meat. No statistical comparisons were made between time to consumption for the life stages and hamburger meat because the life stage differed in shape and consistency from the meat.

Effectiveness of Fire Ant Control

Five, 50-m sections of the shoulder of the main road that bisects the Key Largo hammock (SR905) were treated in July, 1997, using a fire ant bait, Amdro®, broadcast from the back of a four-wheeler and leaving 5, 50-m untreated areas as controls. Areas >100 m were left between treatment and control areas. The active ingredient in Amdro® is hydramethylnon, a metabolic inhibitor that usually kills queens, workers and the colony within 2-4 weeks (Williams 1994).

To measure the effectiveness of this treatment, red imported fire ant abundance was monitored by placing hamburger and honey baits every 5 m along 50-m transects extending into the hammock at the midpoint of each treatment and control areas before and after treatment. These transects were surveyed twice before treatment in March and July 1997, and three times after treatment in October and December 1997 and March 1998. We compared the number of red imported fire ants collected at each hammock transect in the treated and untreated areas for each survey using a Mann-Whitney U Test because the data was not normally distributed and/or variances were not equal.

RESULTS

Red Imported Fire Ant Foraging

In the North Key Largo hammock, red imported fire ants were identified on 8 of the 10 transects from the south side of SR905 and 2 of the 10 transects from the north side of SR905. Most of the baits with red imported fire ants were near the road. The maximum foraging distance into the hammock was 40 m. Red imported fire ants were detected arboreally at 3 transects on the south side of the road, up to a distance of 25 m into the hammock.

Predation on Swallowtails

Red imported fire ants predated all of the immature swallowtail life stages. Fire ants discovered the butterfly stages faster than the hamburger meat although this difference was significant only for the larval life stage ($t = 4.66$, d.f. $= 18$, $P < 0.0001$) (Table 1). The larval stage was the first to be discovered by fire ants and was consumed the fastest (Table 1). However, three larvae escaped predation during the three h experiment by moving to higher branches of the wild lime tree after being initially detected by a fire ant. All of the pupae and eggs were discovered and consumed by fire ants. It took ants the longest to consume the pupal life stage because the fire ants had to first breach the hard exterior of the pupa.

TABLE 1. AVERAGE LENGTH OF TIME IN MINUTES, WITH STANDARD DEVIATIONS IN PARENTHESES, FOR RED IMPORTED FIRE ANTS TO DISCOVER AND COMPLETELY CONSUME DIFFERENT LIFE STAGES OF THE GIANT SWALLOWTAIL COMPARED TO RAW MEAT.

Life stage (or meat)	Time to discovery		Time to full consumption		Percent escaping discovery
Eggs	30.8	(37.2)	18.2	(4.8)	0
Larvae	6.7*	(5.4)	10.3	(1.9)	30
Pupae	46.2	(22.5)	93.8	(28.6)	0
hamburger meat	48.3	(27.7)	32.2	(5.6)	10

*$P < 0.05$.

Effectiveness of Fire Ant Control

Before treating with Amdro®, the average number of red imported fire ants in the proposed treatment areas and untreated areas did not differ significantly (March 1997: T = 92.5, P = 0.36, n_1 = 10, n_2 = 10; July 1997: T = 101.0, P = 0.78, n_1 = 10, n_2 = 10). In October, 1997, three months after the July treatment, there were no red imported fire ants at any of the bait transects in the treated area and this was significantly fewer than in the untreated areas (T = 75.0, P = 0.03, n_1 = 10, n_2 = 10). However, five and eight months after the treatment, the number of red imported fire ants was not significantly lower in the treated areas (December 1997: T = 92.0, P = 0.34, n_1 = 10, n_2 = 10; March 1998: T = 109.5, P = 0.76, n_1 = 10, n_2 = 10). Overall, the number of red imported fire ants declined in both treated and untreated areas after the July 1997 treatment, probably due to the unusually dry conditions during that time period (Fig. 1).

Discussion

The lab experiment we conducted provides evidence of the potential for red imported fire ant predation on the Giant swallowtail, and suggests that other species of butterflies that occur in the southeastern United States also may be vulnerable, including Schaus swallowtail. Fire ants predated on all terrestrial life history stages of the swallowtail, although the mobility of larvae afforded some protection. The high rate of predation was surprising due to the suite of anti-predator behaviors that swallowtails exhibit such as laying one egg per leaf, secretive behavior of larvae, and the production of foul-smelling scents from the osmeteria when larvae are disturbed (Rutkowski 1971). The ability of the red imported fire ant to penetrate the pupae was particularly disturbing. While these results were found in a laboratory experiment on a related species, it is probable that red imported fire ants impact Schaus swallowtails in nature. A manipulative field experiment with red imported fire ant population reductions and careful monitoring of Schaus swallowtail life stages and populations would provide definitive evidence.

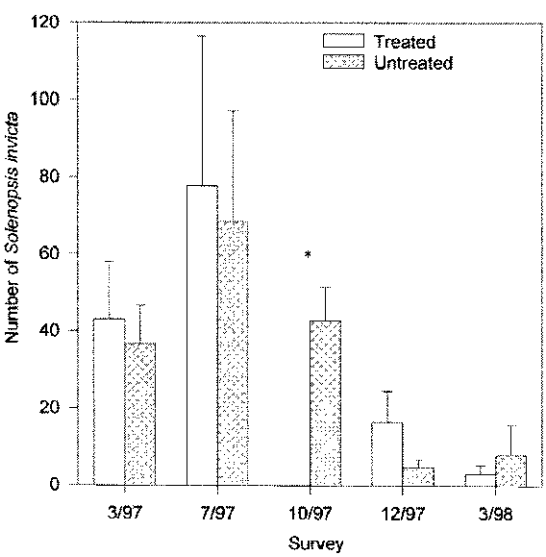

Fig. 1. The average number of red imported fire ants (*Solenopsis invicta*) on baits at the 10 transects treated with Amdro® to kill fire ants and the 10 left untreated. The July 1997 sampling date occurred immediately before the Amdro® treatment. An "*" indicates that the average number of ants significantly differed ($p < 0.05$) between the treated and untreated transects.

Recently, Schaus swallowtail reintroductions occurred in state and federally owned hammocks on northern Key Largo (Emmel 1995; U.S. Fish and Wildlife Service 1999). We found that red imported fire ants were abundant on both the edges of the north Key Largo hammock and up to 40m into the interior. Fire ants were more abundant terrestrially than arboreally, but fire ants did forage arboreally. Because of the abundance of red imported fire ants and the results of the predation experiment, it is possible that fire ants are a threat to the long-term success of Schaus swallowtail reintroductions.

To further increase the chance of survival of the reintroduced Schaus swallowtail populations, red imported fire ant populations should be reduced either through use of fire ant baits or through habitat restoration. However, treatment of the road shoulders with Amdro® in North Key Largo was not as successful as similar treatments elsewhere (Allen et al. 1995). Red imported fire ants were significantly reduced for only three months in the treated area (Fig. 1). While most of the red imported fire ant mounds were on the road shoulder, there may have been mounds within the hardwood hammock that were not affected by treatments which helped to recolonize the treated areas. Some of these colonies may have occurred on old paved roads that remain in the Key Largo hammock. These roads are abandoned and mostly overgrown with vegetation, but they may still serve as favorable fire ant habitat.

Even mowed paths <2 m in width inside the hammock may increase red imported fire ant densities. The south side of the Key Largo hammock consistently had more red imported fire ants than the north. A utility path that runs between power poles on the south side of SR905 may account for the differences seen in the abundance of red imported fire ants on the south and north sides of the road.

Previous studies in this area have indicated that roads bisecting the hammock are especially attractive colonization sites for fire ants (Forys et al. 1999). The removal and restoration of aban-

doned roads and access paths, and limiting disturbance of road shoulders, will probably lower fire ant populations in the area. Reducing the abundance of red imported fire ants in the Key Largo hammock would be beneficial to the Schaus, as well as a suite of other rare invertebrate and vertebrate species that may be susceptible to predation (e.g., Key Largo cotton mouse, *Peromyscus gossypinus*; Key Largo woodrat, *Neotoma floridana smalli*; Florida tree snails, *Liguus fasciatus*).

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