IMPACT OF REDUCTION MOWING ON FIRE ANTS (HYMENOPTERA: FORMICIDAE) AT GOPHER TORTOISE (TESTUDINES: TESTUDINIDAE) BURROWS

by

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This thesis was prepared under the direction of the candidate's thesis advisors, Dr. Jon Moore and Dr. James Wetterer, and has been approved by the members of his supervisory committee. It was submitted to the faculty of The Honors College and was accepted in partial fulfillment of the requirements for the degree of Bachelor of Arts in Liberal Arts and Sciences.

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ABSTRACT

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Many species prey upon the threatened gopher tortoises, including the Red Imported Fire Ant *Solenopsis invicta*. While human alterations to native habitat have led to a decline in gopher tortoises, "disturbance specialists" like *S. invicta* often thrive on such changes. This study examines three ant surveys at gopher tortoise burrows within a section of residential "greenway" in southeastern Florida before and after "reduction mowing". While the presence of *S. invicta* did decrease after the reduction mowing, the numbers of native ants and ant species richness in general also showed a significant decline. Another invasive ant, the Little Fire Ant, *Wasmannia auropunctata* (Roger, 1863), showed a significant increase after the mowing. While not as destructive as *S. invicta*, *W. auropunctata* has been documented to be a significant pest to many terrestrial vertebrates and should be considered a potential threat in future gopher tortoise and land management schemes.

To my family for the support

To Dr. Moore, Dr. Wetterer and Dr. O'Brien for the inspiration

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INTRODUCTION

Gopher tortoise (*Gopherus polyphemus*) populations in southeastern Florida have been in steady decline as a direct and indirect result of habitat destruction and they are currently classified as a threatened species by the state of Florida (Florida Fish & Wildlife Conservation Commission 2012). Gopher tortoises prefer habitat with sandy open spaces for burrowing, basking and foraging for their preferred food sources of grasses and forbs (Diemer 1992). For these reasons, the most common land management techniques employed to maintain gopher tortoise habitat are prescribed burns and reduction mowing (Wade and Lumsford 1989; Main and Tanner 1999).

South Florida pine flatwood ecosystems are naturally pyrogenic and have historically been defined by frequent and periodic fire disturbances. For numerous reasons occasional fires promote the overall vigor of many endemic pine flatwoods flora and fauna (Wade and Lumsford 1989; Myers and Ewel 1990). One important result of these fires is the opening up of understory and the creation of open sandy spaces where grasses and forbs can quickly grow. The mechanical shredding and reduction of understory growth by tractors and stump grinders (see Figures 1 and 2) is a comparatively convenient and effective method for reducing excessive understory growth and is employed frequently. Often this practice is combined with the use of herbicides and burning, however, areas in close proximity to development usually confine management practices to reduction mowing and herbicide application only (Menges and Gordon 2010). While it has been documented that gopher tortoises readily colonize areas opened up by reduction mowing (Del Signore 2007), the ecological outcome of mowing is fundamentally different than that of burning, leaving a thick layer of mulch (see Figure

10) instead of a thin layer of ash. This difference could have an extensive impact on the species compositions of mowed sites, which, in turn, may impact the health of the tortoises and their ecology.

In many southeastern ecosystems gopher tortoises are a keystone species providing valuable microhabitat and ecological services through the creation of their burrows (Eisenberg 1983; Jones et al. 1994). Numerous pine flatwoods species are permanent or semi-permanent commensals of tortoise burrows and many of these inquilines themselves are threatened or species of special concern including the eastern indigo snake (*Drymarchon corais couperi*), the Florida gopher frog (*Rana capito aesopus*) and the Florida mouse (*Podomys floridanus*) (Kent et al. 1997). The excavated sand "aprons" surrounding the entrance to tortoise burrows serve as nesting sites for both *Gopherus polyphemus* as well as some of their oviparous commensals (Diemer 1986; see Figures 3 - 5). Many vertebrates attack eggs and neonates at the aprons and mortality rates within the first few weeks after laying have been documented to be as high as 87% (Alford 1980; Landers et al. 1980; Diemer 1992). In addition to predation by vertebrates, predatory ants contribute to neonate mortality. Landers et al. (1980) observed as many as ten *G. polyphemus* hatchlings being "destroyed" by swarms of the South American fire ant *Solenopsis invicta*.

Solenopsis invicta (Figure 7), known as the red imported fire ant, presents one of the biggest threats in this context. Largely recognized as one of the most costly exotic animals in southern parts of the United States (Jetter et al. 2002; Allen et al. 2004) *S. invicta* impact several aspects of natural communities. Numerous studies have documented the effects of *S. invicta* on North American birds, especially ground nesting species (Ridlehuber 1982; Sikes and Arnold 1986; Steigman 1993; Drees 1994; Lockley

1995; Powell 1995; Dickinson 1995; Giuliano et al. 1996; Mueller et al. 1999; Kopachena et al. 2000) and herptofauna, particularly eggs, neonates and terrestrial amphibians (Cintra 1995; Allen et al. 1997; Reagan et al. 2000; Krahe 2005; Todd et al. 2008). Preliminary research regarding the specific effect of *S. invicta* attack on gopher tortoise neonates suggests that even non-lethal encounters drastically reduce survivorship (Epperson and Hiese 2003) and this notion is supported by analogous studies with sea turtles where *S. invicta* colonies have been documented systematically attacking and predating pipping turtles in the nest (Wilmers et al. 1996; Moulis 1996; Allen et al 2001; Krahe 2005; Wetterer and Wood 2005). Even adult box turtles (*Terrapene carolina*) have been observed being attacked and predated by swarms of this pernicious ant (Montegomery 1996; Wetterer and Moore 2005). Adult gopher tortoises will abandon burrows that have been taken over by *S. invicta* and will also avoid grazing plants around or on fire ant mounds (Figure 6, J. Moore, pers. observ.).

Two other fire ants can be cited as potential threat species to gopher tortoises and their commensals in southeastern Florida. Another South American Solenopsis species, *Solenopsis geminata*, or the tropical fire ant, has also been documented attacking hatchling birds and reptiles (Travis 1941; Mrazek 1974). The little red fire ant (*Wasmannia auropunctata;* see Figure 8), while only about 2 millimeters long, poses a serious threat to terrestrial vertebrates as well, especially where it occurs in high densities. *Wasmannia auropunctata* is a well established “tramp ant” in many subtropical regions of the world and has been implicated in the blinding of large vertebrates ranging from house cats to elephants in Gabon (Wetterer et al. 1999; Wetterer and Porter 2003) and similar observations have been reported in the Solomon Islands with dogs and native ground nesting fowl (Wetterer 1997).

Due to the demonstrated negative impacts of fire ants on ground dwelling vertebrates their potential expansion should be of special concern to gopher tortoise conservation and management schemes. More than this, ants are ideal indicators of environmental change for a number of reasons. Ants are major biotic elements in most terrestrial ecosystems and constitute an important part of the soil biomass with far reaching biological, chemical and physical impacts on communities (Folgarait 1998). Ants are highly nested, representative of their prevailing habitats and function at many trophic levels within ecosystems as predators, prey, detritivores, mutualists and herbivores (Alonso et al. 2000). Due to these facts, ants are highly sensitive to immediate environmental change as well as reliably sampled and monitored (Alonso et al. 2000). In assessing the ecological implications of reduction mowing in a managed wild area in South Florida, fire ants present an easily accessible variable for determining potentially harmful outcomes of mowing on gopher tortoise ecology.

MATERIAL AND METHODS

The Study Site

The Abacoa greenway is a series of fragmented land reserves of about 105 ha surrounded by sprawling suburban development in Jupiter, Florida. The greenway system comprises about 13% of the Abacoa development's area. The study site "Range VIa" (26.90°N, 80.11°W) is located at the intersection of Fredrick Small Blvd and Central Blvd, which border the site from the north and east respectively. To the south and southwest of Range VIa is a depressed area which serves as a retention basin during times of flooding but remains dry for most of the year. An approximately two-meter wide footpath encompasses the entire periphery of this range and is mowed every two or three weeks. Bisecting Range VIa east to west is a straight line of relatively open area left from when a cattle fence was there more than two decades ago. From northwest to southeast is a similar stretch of open area where a recently (<12 years) dug pipeline is located. In the original paper, Moore and Wetterer (2005) described Range VIa as a typical example of southeastern pine flatwoods:

> The relatively undisturbed portions of the range consist of typical flatwood scrub (Myers and Ewel 1990) with a sparse canopy of mature slash pines (*Pinus elliottii*), an understory of saw palmetto (*Serenoa repens*) thickets and scrubby oaks (*Quercu* spp.), and open spaces dominated by wiregrass (*Aristida beyrichiana* Trin. & Rupr.), with lesser amounts of runner oak (*Quercus minima*) and deer moss lichens (*Cladina* spp. and *Cladonia* spp.). The old fence line is dominated by bunches of wiregrass and chalky bluestem (*Andropogon virginicus*) with small stands of young slash pine saplings and gallberry (*Ilex glabra*). The pipeline area is largely open sand with low grasses and herbs growing in patches. The path around the outer edge of the wooded range is primarily covered with bahiagrass (*Paspalum notatum*).

While not mentioned in the 2005 publication, by the time of this description the understory was intensely overgrown. The saw palmetto especially had reached a prodigious height of 12 feet or more in some places and possessed a corresponding level of density (Moore pers. observ.).

The reduction mowing in Oct-Nov 2006 reduced the overgrown understory of the range to a distributed layer of mulched debris (Del Signore 2007; see Figures 9 & 10). This mulch layer varied in thickness from less than an inch at the thinnest to more than a foot at the thickest. Isolated patches of saw palmetto were left standing, typically around gopher tortoise burrows, as well as almost all of the slash pines, larger oaks, and dahoon holly (*Ilex cassine*). While tortoise burrows were flagged and purposefully avoided by the mowing crew, a few burrows were inadvertently collapsed by the activity of the mowing equipment. The previously open areas of the pipeline and old cow fence were left relatively undisturbed, as were any large patches of wiregrass and deer moss lichens.

By 2008, some amount of regrowth had occurred (Figure 11), but the site was still clear and defined by a thick layer of mulch. While saprophytic fungi mycelium had thoroughly colonized the mulch by 2008 herbaceous plants, such as grasses and forbs, were infrequent and terrestrial lichens had not yet recolonized mowed areas. By 2012 the site had regrown considerably and resembled the overgrown version of the 2002 habitat (Figure 12). The saw palmetto, gallberry, runner oak, and several other woody plants especially had a strong resurgence.

In 2002 there were 85 marked tortoises and 164 marked burrows in the range with a density of 9.3 tortoises per hectare (Wetterer and Moore 2005; Moore pers. observ.). This is an extremely high density, three times higher than the highest mean density (2.7/ha) at Kennedy Space Center in east-central Florida (Breininger et al. 1994). This high density has been estimated to be the carrying capacity of the site (Moore pers. observ.) and is partly due to successful on-site reproduction and the occasional introduction of new individuals by residents and developers from the surrounding area.

However, a decline in tortoises occurred during the study period from 85 known adults and subadults in 2002 and 2008, to an estimated 75 in 2012. Remains of several individuals were discovered in the range that had obviously been poached by knife-wielding individuals, however, not all of the lost tortoises have been accounted for in this way. Given the apparent numbers of juvenile tortoises and the continual introduction of outsiders it is likely that the carrying capacity will be reached again in a few years. The number of marked burrows increased from 164 in 2002 to 456 in 2012. Marked burrows include both those actively used and those that are inactive. While many older burrows are either abandoned or collapsed new burrows are made continuously which maintains the level of active burrows near a constant of 2-3 times the number of tortoises (Moore pers. observ.).

Wetterer and Moore (2005) determined that a distinction must be made between “periphery” and “interior” habitat. This distinction reflects the fundamental difference in microhabitat between the frequently disturbed peripheral pathway and the more forested interior of the greenway. In their native range of South American grasslands *Solenopsis invicta* prefer open areas of grass and sand where they form loosely mounded colonies. These ants show a similar propensity for open areas, such as lawns, pastures, fields and dirt tracks, in their introduced ranges (Wojoik 1994).

Data Collection

The first survey was conducted in 2002 (Wetterer and Moore 2005) and the subsequent collections followed the same protocols used in that study. In all three surveys ants were collected with baited traps using ±1 gram of water-packed tuna placed inside a folded index card labeled with a burrow's ID number. The baited traps were then placed on the aprons of marked tortoise burrows at approximately 0.2 meters from the burrow entrances. The traps were set and left for 2 hours ±10 minutes, this was considered to be an appropriate amount of time to have sufficient recruitment of ants while not risking the complete removal of bait. After approximately 2 hours, traps were collected and placed into sealed plastic bags. The ants were killed by freezing them in the bags. Using a binocular dissecting microscope, fine paintbrushes and forceps, ants were counted and fixed into vials of 70% alcohol. Identification was aided by a field guide (Fisher and Cover 2007), as well as determinations by Dr. Jim Wetterer (Florida Atlantic University) and Dr. Mark Deyrup (Archbold Biological Station). The 2002 collection was conducted by Drs. Wetterer and Moore, whereas in 2008 the collection was conducted by Dr. Moore and myself and in 2012 the collectors included myself, Dr. Wetterer, Dr. Moore and an undergraduate field biology class. Burrows sampled were as random as possible based on the distribution of burrows at the time, however, efforts were made to sample evenly from both the interior and periphery across the entire site.

GIS Mapping

Thanks to Dr. Jon Moore's extensive work with the tortoises in Range VIa, every known burrow has a cataloged GPS coordinate. These coordinates were taken with a hand-held GPS and are accurate down to ±5 meters. Using the mapping software ArcGIS and these coordinates, results were obtained that reliably demonstrate the change in distributions of the sampled ants. Calculating the area of Range VIa and defining the periphery required the use of a “heads up” digitizing method. As this methodology is only as precise as hand marked points on a map an additional two measurements were taken and the mean area of all three measurements (9.34 hectares) used as the total. Selecting by attributes and using the “buffer” function isolated burrows within 30 meters of either side of the mean calculated perimeter and produced a precise peripheral area of 7.15 hectares. This method of calculating the periphery was used to include tortoise burrows dug into the slope leading from the bottom of the catchment basin up to the upland level. While Range VIa is only 9.34 ha of elevated upland the expanded periphery of the study site extended beyond the range into the adjacent water catchment areas and the "periphery" includes burrows within 30 meters of the pathway inside the range as well. The "interior" portion's area was calculated with the same method as the range's perimeter (mean area of 4.86 ha). Given these measurements, the total area of the study site is 12.01 ha. Statistical analysis was conducted by selecting categories of ants at burrows per year using the GPS coordinates for the burrows and the calculated measurements for the interior and periphery of the site.

Figure 1. Shredding mower.

Figure 2. Stump grinder.

Figure 3. Softshell Turtle (*Apalone spinifera*) eggs on top of *Gopherus polyphemus* eggs buried in an apron in Range VIa.

Figure 4. Newly hatched *Gopherus polyphemus.*

Figure 5. Gopher tortoise burrow and "apron".

Figure 6. *Solenopsis invicta* mound.

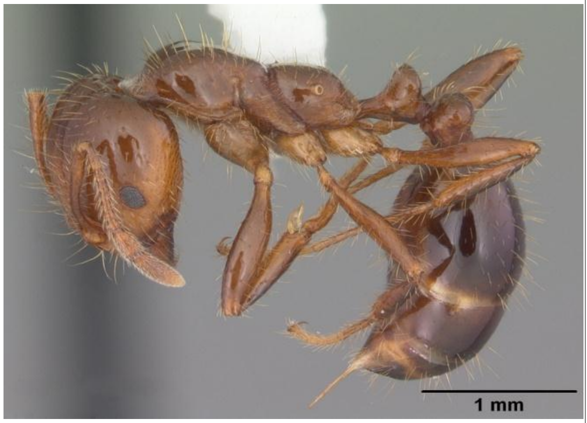


Figure 7. *Solenopsis invicta*.

Figure 8. *Wasmannia auropunctata*.

Figure 9. Range VIa in 2006, before mowing.

Figure 10. Range VIa in 2006, after mowing.

Figure 11. Range VIa in 2007 (1 year after mowing).

Figure 12. Range VIa in 2013 (7 years after mowing).

RESULTS

All three collection events together surveyed 238 of the 456 marked burrows, 154 in 2002, 107 in 2008 and 76 in 2012. In each collection year some traps (<10 in each case) had to be excluded because of removal of bait by larger animals. In 2002, 19 species were documented, with *Solenopsis invicta* being the most frequently encountered (33%) (Wetterer and Moore, 2005). The collections in 2008 and 2012 documented 15 and 11 species, respectively. The most common species in 2008 was, again, *S. invicta* (26/100 burrows; 26%), while in 2012 the most frequently encountered species was *Wasmannia auropunctata* (26/74 burrows; 35%). Both the 2008 and 2012 surveys resulted in many more burrows with no ants. While a negative result, it might also be indicative of faunal loss.

As in the 2002 survey, *S. invicta* was significantly more frequent at edge (19/46 = 41%) than interior burrows (7/45 = 13%; $X^2 = 10.332$; $P < 0.001$) in 2008. However, in 2012 *S. invicta* became evenly distributed across the site with no significant difference between the periphery and the interior ($X^2 = .228$; $P > 0.25$). *Wasmannia auropunctata* was evenly distributed throughout the site in all collection events with no statistically significant difference between edge and interior burrows ($X^2 = 0.064$; $P > 0.25$ from 2002 to 2012). However, *W. auropunctata* experienced an extremely significant ($X^2 = 180.5$; $P << 0.001$) increase in relative abundance from 2002 (3%) to 2008 (22%) and in 2012 an additional but insignificant ($X^2 = .73$; $P > 0.25$) increase in abundance (from 22% to 35%) occurred.

Native ants experienced a significant decrease in relative abundance between 2002 (57%) and 2008 (35%; $X^2 = 40.91$; $P < 0.001$). Similar to the abundance change seen in *W. auropunctata*, this trend continued but less significantly ($X^2 = 1.29$; $P > 0.25$)

in 2012. The relative proportion of abundances in all exotic ants did not significantly change between any of the three collection events.

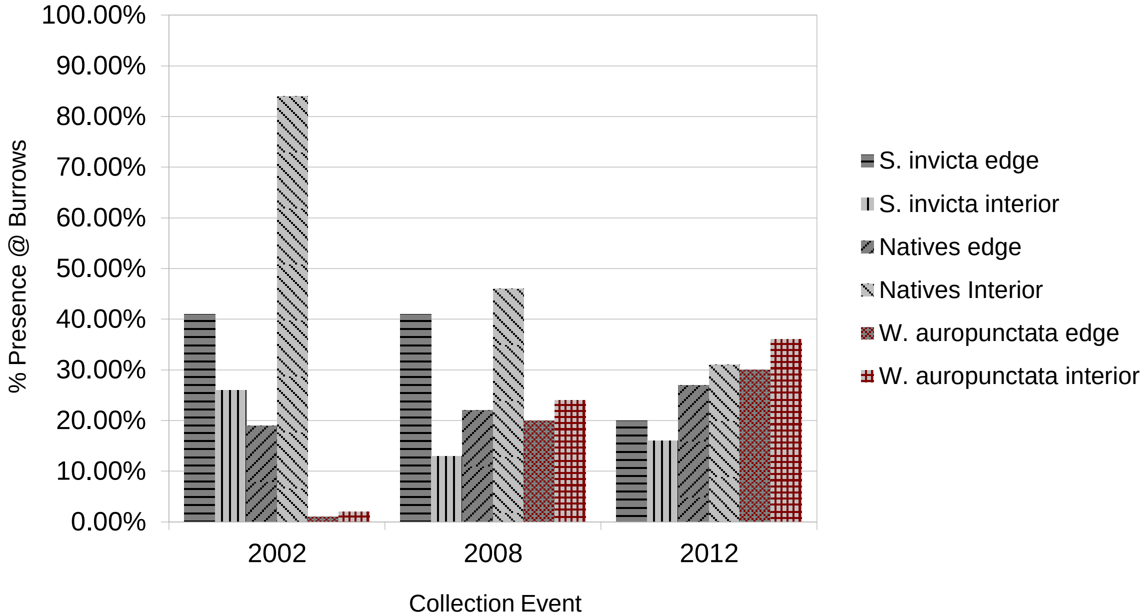
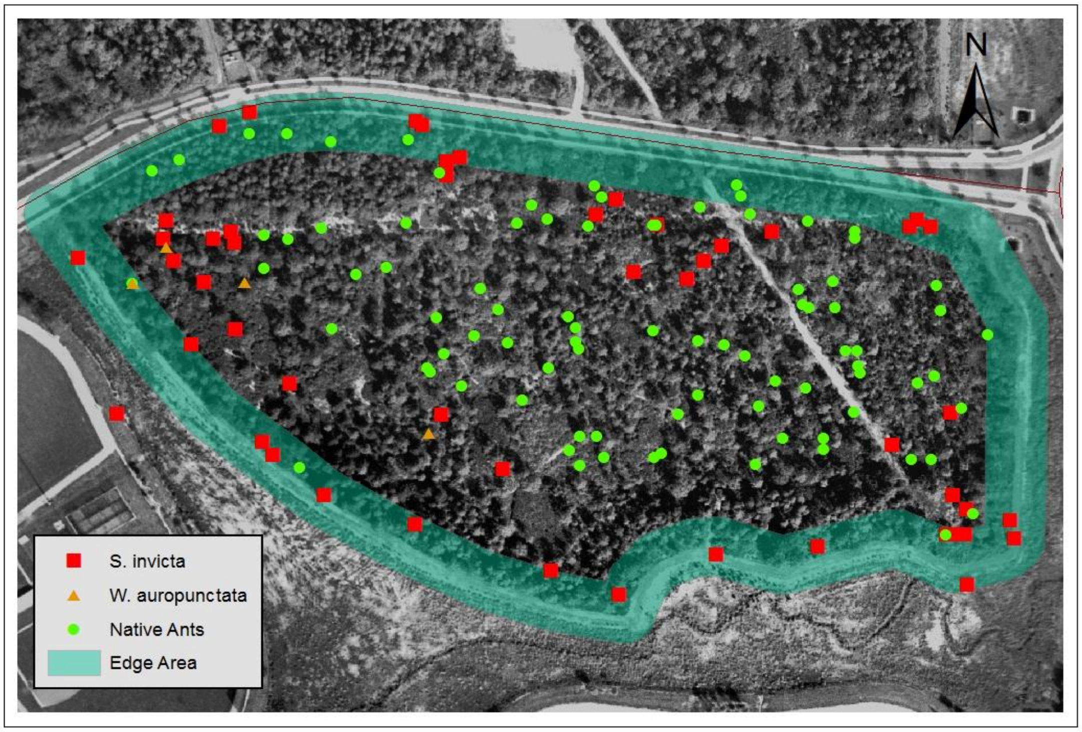
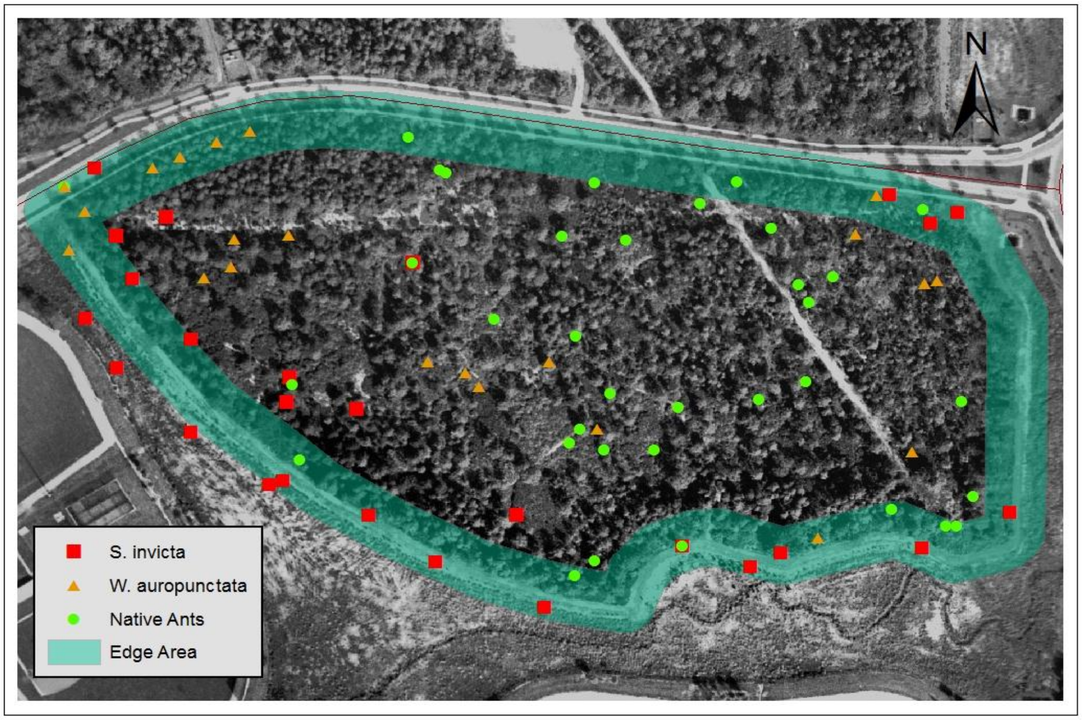


Figure 13. Changes in percent abundance of native ants and fire ants during the study period

2002 Results



2008 Results



Figures 14 & 15. GIS results from 2002 and 2008.

2012 Results

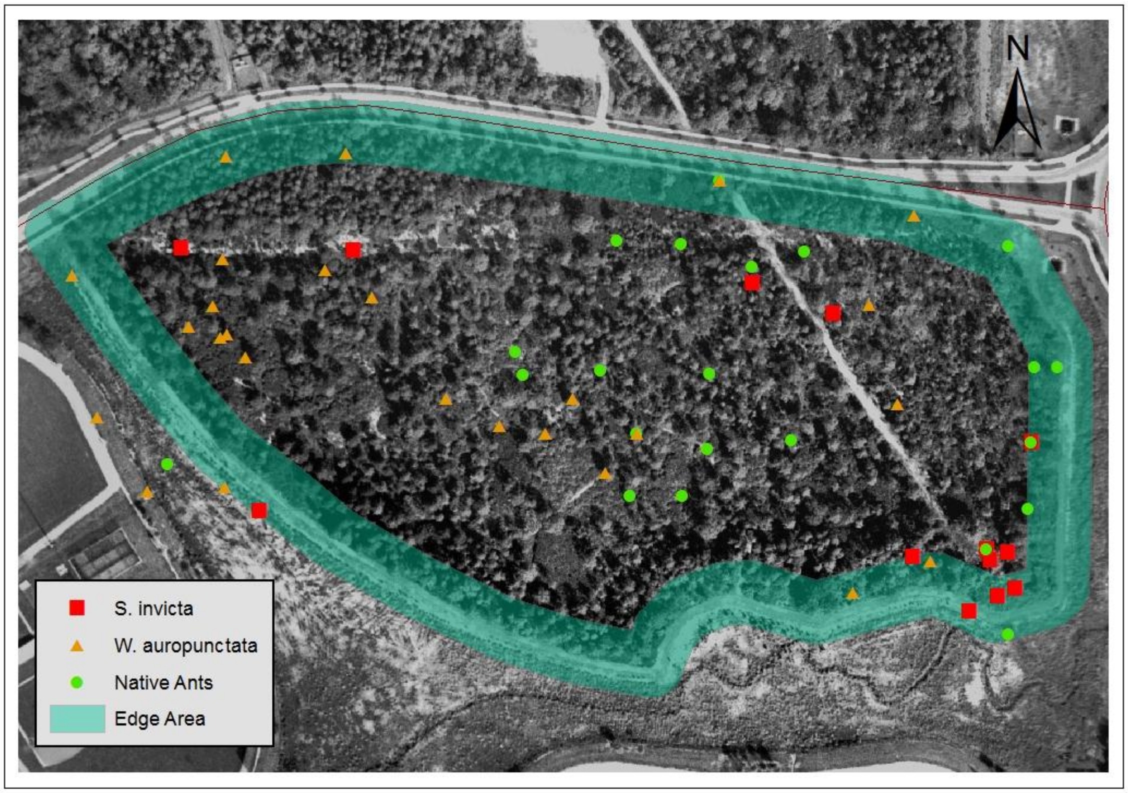


Figure 16. GIS results 2012

DISCUSSION

In their original publication Wetterer and Moore (2005) noted that the prevalence of *Solenopsis invicta* in peripheral areas of Range VIa (Figure 13 & 14) seemed to indicate that it's presence may be facilitated by the "edge" effect of habitat fragmentation (Saunders et al. 1991). The results from the 2008 survey seem to maintain this suspicion (Figure 13 & 15), however, the results from 2012 deviated from this trend (Figure 13 &16). Similarly, while natives significantly preferred interior to edge habitat in 2002 the following surveys documented a significantly more even distribution across the site. The reduction mowing in 2006 can fairly safely be defined as a major disturbance event and the significant decline in abundance and diversity of native ants in 2008 is very likely a reflection of this disturbance. The impact of the mowing disturbance might also be observed in the change in distribution of *S. invicta* and the marked rise of *Wasmannia auropunctata*. The leveling out of all distributions may indicate that the disturbance of reduction mowing had a greater influence on ant populations than the affinities for edge and interior of fire ants and native ants, respectively. Or, it may be that the reduction mowing disturbed the site in such a way as to evenly diminish the native populations and that of *S. invicta* while simultaneously creating habitat favorable to *W. auropunctata* throughout the site.

Explanations for change in exotic versus native ant populations are a matter of some disagreement in the literature. On the one hand, introduced species may exhibit certain physiological traits or ecological advantages which naturally place them in a better position to compete with natives (Bruno et al. 2005). And on the other hand, successful exotics may be simply adaptive at colonizing disturbed habitat (MacDougall and Turkington 2005). While both sentiments are likely true in most cases, research concerned with the management of fire ants has implicitly taken the position of physiological/ecological superiority and prescribed the ongoing search for methods of chemical, biological and other suppressive control based purely on the assumption that fire ants are an invasive species and not the benefactors of disturbed ecosystems (Tschinkel 2006). However, the indelible relationship between “exotics” and humans is thoroughly underlined in other areas of the literature. For example, Deyrup et al. (2000) in their treatment of the exotic ants of Florida distinguish the various exotic ants by their differing types of commensalism with humans (e.g. “weedy” species are those that quickly colonize areas recently disturbed by humans, like *S. invicta*). Many introduced species tend to follow the development and movement of human ecologies in lockstep and this is especially true with ants because while they are excellent colonizers they are poor dispersers (Deyrup et al. 2000). This is even further the case with fire ants (*S. invicta* and *W. auropuncata*) because many populations are polygynous and have more than one queen in a single colony. Whether fire ants should be considered ecological “drivers” or ecological “passengers” is an important distinction to make in order to make an effective long-term management prescription for their exotic populations.

Solenopsis invicta's decline and leveling of distributions in our study is not anomalous. Several studies throughout the southeast concerning relationships between development, native and non-native ants have produced similar results with respect to changes in ant distributions. One study in the Florida Keys (Forys and Allen 2005) found that while areas of development did not significantly correlate to a loss of native ants and did correlate to an increase in non-native ants, a positive correlation was found between changes in both native and non-native ant distribution and species richness overall. Similar results were shown in a Texan study (Morrison 2002). Morrison and Porter

(2003), conducting an even broader experiment in north Florida, found a positive correlation between *S. invicta* introductions and native arthropods in general. These results suggest that population changes in both native and exotic ants are regulated by common environmental factors more than they are by the presence or absence of exotic ants.

Our study in Range VIa lacks important information in several fundamental ways. A more controlled analysis of environmental management would demand additional experimental treatments with the treatments administered in a fully crossed factorial design. Such an analysis should include the experimental treatments of reduction mowing and prescribed burning, at the least, and have control sites positioned in comparable geographic and ecological settings as the treatment sites. Baseline population assessments of each site would be required as well. However, even in its somewhat “organic” state, our study presents a useful comparison of changes in ant distribution in an environmentally sensitive locale. Comparing the results of our study to others contributes to a metric by which future predictions of environmental management can be better assessed.

A long term study (Izhaki et al. 2003) analyzing the effects of prescribed burns on an ant community in Florida found a similar immediate decrease in native ant species richness that was seen in our study. However, the native ants made a rapid (less than 18 months) recovery after the fire. Given their results the authors concluded that fires had less of an impact on ants than do changes in seasonality as indicated by unexplainable inter-annual changes in their study. Our study has less statistical spread than the Izhaki et al. study but the significant changes in abundances and distributions seen in Range VIa over the course of 9 years seems unlikely to be due purely to changes in seasonality especially considering that all of the surveys were conducted during a similar time of year (January – March).

King and Tschinkel (2008) in a fully crossed factorial study of *Solenopsis* invasions in pine flatwoods of north Florida found that mechanical disturbance (mowing and plowing), in the absence of *S. invicta*, greatly diminished native ant populations while experimental plots with only *S. invicta* diminished native ant populations to a lesser degree. Disturbed plots with both native ants and *S. invicta* experienced a leveling in both populations but not a decrease in relative abundance of *S. invicta*. The authors also noted that, on their own and in the absence of disturbance, *S. invicta* avoided the more forested habitat of native ants and were so prevalent in plowed areas that they were impossible to extricate after the study even in plots that were supposed to be plowed but free of *S. invicta*. They concluded that the perspective of *S. invicta* as an ecological "passenger" was most appropriate given their results. Another interesting result from the King and Tschinkel study that affirms this model of *S. invicta* as an ecological passenger was the spread of the native generalist *Dorymyrmex bureni* in experimentally disturbed plots. The authors grouped *D. bureni* and *S. invicta* together as "disturbance specialists" reflecting their tendency to proliferate after disturbance events. In our survey simply studying the effects of mowing *D. bureni* did experience a marked increase in abundance (from 5/88 = 6% of native ants in 2002 to 9/22 = 41% in 2012), however, given relative abundances, this increase was not statistically significant ($X^2 = 3.2$; $P < 0.25$). Often in our study multiple species were found on a single trap and it is interesting to note that *D. bureni* was the most frequently observed extra ant at traps dominated by *S. invicta*.

Perhaps the most striking result in our study was the substantial increase of the little fire ant in Range VIa after 2006. *Wasmannia auropunctata* has been established in

Palm Beach County for at least three decades and may even have been present since the 1940s (Wetterer and Porter 2003). *Wasmannia auropunctata* is a highly successful generalist “tramp” ant and has invaded many tropical and subtropical sites the world over. There are several physiological/behavioral reasons for this ant's success including generalist feeding and nesting habits, superficial nests, high colony mobility, polygyny, colony budding, low intra-specific aggression, high inter-specific aggression, small size, and tending of extrafloral nectaries and Homoptera (Wetterer and Porter, 2003). In it's native range of the neotropics *W. auropunctata* populations are naturally held in check but in certain areas where it has been introduced or in areas in its native range where high levels of disturbance have occurred it can become extremely abundant. At certain sites in New Caledonia it has been documented to represent 92% of the surveyed ant fauna (Le Breton et al. 2003). Given all of this it is somewhat surprising that *W. auropunctata* has not made bigger inroads into south Florida according to the literature (Wetterer and Porter 2003).

One possible explanation for the significant spread of *Wasmannia* in Range VIa after reduction mowing may have to do with the mulch layer the mowing created. *Wasmannia auropunctata* form superficial, highly mobile colonies with little preference for quality of substrate and they commonly construct nests under rocks, logs, branches and other plant debris (Wetterer and Porter 2003). While the larger, more aggressive *Solenopsis invicta* may have been inhibited by the lack of its preferred sandy soils *W. auropunctata* would have had no such inhibition to colony formation into the interior of the site. In fact, it is possible that the act of reduction mowing itself contributed to the spread of *W. auropunctata* across the site, spreading chunks of existent colonies located inside plants across the site along with the mulch.

CONCLUSION

The leveling out in distributions of both native ants and *Solenopsis invicta* observed after the reduction mowing reflects similar results from other studies in Florida and the southeast (Morrison 2002; Izhaki et al. 2003; Morrison and Porter 2003; Forys and Allen 2005; King and Tschinkel 2008). While our results do not possess enough statistical variance or design to make a judgment call condemning reduction mowing as a form of gopher tortoise management the data do present compelling evidence of unintended change within the greenway system as a result of the practice. While the apparent decrease in *S. invicta* can be viewed as a major windfall for the tortoises of Range VIa and their various commensals the loss of natives and the rise of *Wasmannia auropunctata* is troubling at the least. It is unknown whether the current densities of *W. auropunctata* in Range VIa present a real threat to the dense population of tortoises there or not. While there is much evidence of *S. invicta* predating the eggs and neonates of terrestrial vertebrates there is little such evidence for *W. auropunctata*. The largely anecdotal tendency of *W. auropunctata* to blind certain terrestrial vertebrates has not been a problem yet observed in the tortoises of Range VIa and they have not reached anywhere near 90% of the ant fauna as they have in certain island ecosystems (Le Breton et al. 2003). However, if *W. auropunctata* abundances continue to increase there could be severe consequences for both the tortoises and their various commensals.

Whether the trends in distribution and abundance of ants discovered in this study continue depends on numerous factors. Continued study may reveal additional insights into the biogeography of fragmented land-reserves and disturbed pine flatwoods ecology. As the site continues to regrow the same problem of an over-grown understory that faced land management 7 years ago will again be revisited. Regardless of the management decision at that future date additional sampling of the ant populations will produce a greater statistical spread, thereby making long term trends regarding fire ant populations more readily accessible to Abacoa greenway management and gopher tortoise conservation efforts in the southeast as a whole.

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