To the Graduate Council:

I am submitting herewith a thesis written by Elizabeth Ann Long entitled "A Management Plan for the Imported Fire Ant (IFA) Migration into Gateway Communities in East Tennessee." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science in Planning, with a major in Planning.

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A Management Plan for the Imported Fire Ant (IFA) Migration into Gateway Communities in East Tennessee

A Thesis

Presented for the

Master of Science in Planning Degree

The University of Tennessee, Knoxville

Elizabeth Ann Long

December 2003

Abstract

This thesis outlines a management plan for Gateway communities to use as a preparedness guide dealing with the establishment of the hybrid species of the Imported Fire Ant (IFA). The red species of IFA, *Solenopsis invicta* Buren, and the black species of IFA, *Solenopsis richteri* Forel, are located in southern Tennessee, but it appears that it is the hybrid species of their crossbreeding that is migrating into east Tennessee. The two species of IFA and their hybrid are moving north, both by natural migration and by being brought into the east Tennessee area on landscape plant materials and by the movement of infested soil and hay.

The red and black species seem to be less cold tolerant than the IFA species hybrid. It appears that the hybrid IFA is currently migrating into the Great Smoky Mountains National Park and new IFA mounds have been found from Fort Loudon Lake eastward along the Foothills Parkway, and east and south movement into the Great Smoky Mountains National Park has been noted by the Tennessee State Department of Agriculture and Park Service personnel, primarily along power line cuts and logging roads where the natural forest vegetation has been disturbed.

Due to the economic impact on tourism and human and animal health related problems that develop after the establishment of the IFA in a community, it was determined that it would be helpful to develop a management plan based on current pest control recommendations for the IFA and also to evaluate the recommended management practices that have been helpful in other southern states that have been infested with the IFA for several years.

Recommended management practices for established populations of IFA's include cultural (physical and mechanical), biological (natural enemies), organic (natural pesticides) and chemical (synthetic pesticides) control measures. These treatment option criteria are developed for local sites such as schools and parks in the Decision Matrix.

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Part I: Introduction to the Imported Fire Ant

Chapter 1: Thesis Statement and Introduction

Thesis Statement

The purpose of this study is to develop a management plan for the exotic invasive species, the Imported Fire Ant (IFA). This management plan will be developed for a generic east Tennessee gateway community, taking into consideration the impact of IFA upon agriculture, tourism, future development, and quality of life issues.

Introduction

There are three major sections in this thesis:

PART I: Introduction to the Imported Fire Ant

In part I, the history and the biology of the IFA is discussed, how the two species of IFA became established in North America, the effect of the IFA hybrid has on the IFA, and why the IFA is considered to be an invasive species. It is important to understand the biology and what makes the IFA an invasive species to make economically feasible decisions on treatment control options for various sites in the community. In addition to biology, health effects and the interactions with native species are discussed.

PART II: Approach to Management of IFA

In part II, Integrated Pest Management (IPM) techniques are discussed, and how IPM relates to control options for the IFA. Educational resources are discussed and useful references are given with web site addresses. Tourism impacts caused by the IFA are also discussed.

PART III: Management Plan

In part III, the control choices and potential sites needing control for IFA are evaluated. The Decision Matrix is developed and the results are discussed. Implementation of the IFA Management Plan, potential problems and the importance of community involvement are considered.

Chapter 2: History of the Imported Fire Ant (IFA)

Originally from South America, the Imported Fire Ant (IFA) was evidently brought to the United States on cargo ships, probably carried in soil that was used as ballast. The first reports of IFA in the United States are from around 1918 in the Mobile, Alabama area. This first introduction was of the IFA black species, *Solenopsis richteri* Forel, and apparently remained confined in this area for about 10 years. A second introduction of IFA was of the red species, *Solenopsis invicta* Buren, which occurred at the port of Mobile, Alabama in the late 1930's (Lockley, 1996). The IFA has become invasive in the United States because it reproduces fast and can establish new colonies rapidly. Also, none of the native biological control organisms that kill the IFA in their native South American were transported along with the IFA to the United States. Therefore, with no natural enemies and an aggressive biological advantage, the IFA has become widespread in the southern United States.

The black IFA has remained in a relatively small area, including a part of northeastern Mississippi, northwestern Alabama and southern Tennessee. The red IFA, however, has spread to the limits of the IFA range in the United States, which includes all or part of thirteen states and Puerto Rico (Callcott and Collins, 1996). This dominance of the red IFA was established in 1972, when a taxonomic study by Buren (1972) showed that there were actually two different species, the red and the black (or dark) form. There is also a hybrid species, *S. invicta x S. richteri*, a cross between the red and black IFA that occurs in northeast Mississippi, northwestern Alabama and southern Tennessee where the natural range of red and black IFA merge together.

IFA have migrated much more rapidly than was once predicted, mainly due to the movement by man of plant materials and soil infested with IFA from southern infested areas to the north. Climate change (temperature and precipitation) appears to have made some difference to IFA natural migration that occurred in the 1950's and 1960's, but as more frequent movement of plants and soil has occurred, the migration of IFA would

have rapidly increased regardless of change in climate and precipitation. Local movement of soil and plant material on farm equipment and in hay and sod is becoming more and more common. As new suburban housing and commercial development have occurred with extensive non-native landscape plants, IFA mounds often develop within one to two years after establishment. Trucks and other vehicles can move the IFA if clumps of dirt or grass are attached. Widespread IFA movement also occurs if newly mated queen ants land on traveling vehicles or are wind blown long distances.

The first confirmed IFA case in Tennessee was an isolated infestation in 1948, located in Shelby County (Memphis area). This infestation was eradicated and no other finds occurred until about 20 years later (Tennessee Department of Agriculture, 2000). Hardin County, Tennessee was the first site of documented natural migration in 1987. The 2002 Tennessee IFA Quarantine map (Figure 1) shows that all of the southern tier counties of Tennessee are infested with IFA. These areas are regulated as of 6/20/02.

A 2000 map of IFA diversity in Tennessee (Figure 2) produced by Dr. Karen Vail of the University of Tennessee Agricultural Extension Service, shows the black IFA species being found from Shelby county to Giles county, with Shelby county also having the red IFA species naturally established. In Giles County there is a mix of the black and hybrid IFA species populations, then only the hybrid IFA species is found eastward along the southern Tennessee border.

While both the red species of IFA, *Solenopsis invicta* Buren and the black species of IFA, *Solenopsis richteri* Forel, are located in southern Tennessee, it appears that it is the hybrid species of their crossbreeding that is migrating into east Tennessee. The IFA hybrid is moving north by natural migration, while the red and black species of IFA continue to be brought into the east Tennessee area on landscape plant materials and by the movement of infested soil and hay. The hybrid IFA is currently migrating into the Great Smoky Mountains National Park near Fort Loudon Lake. IFA mounds have also been found along the Foothills Parkway and eastward into the Great Smoky Mountains

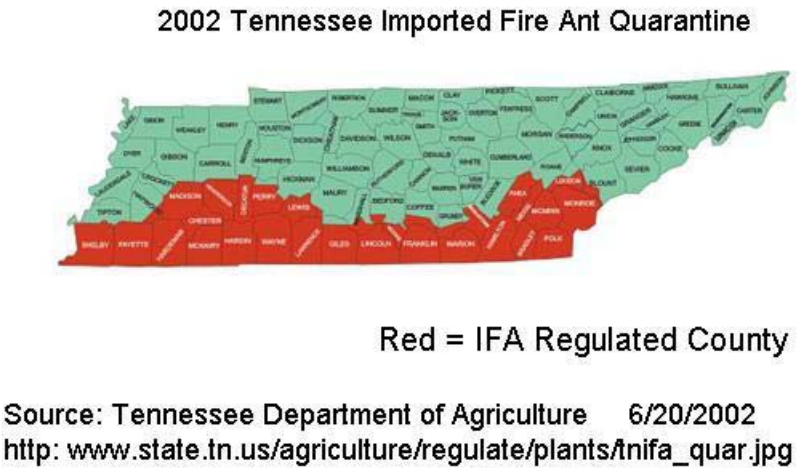


Figure 1. IFA Regulated Areas in Tennessee. Red color indicates regulated area. The current IFA Quarantine Zone became effective February 2002. Map source: Walker G. Haun, Tennessee Department of Agriculture Regulatory Services, 2003.

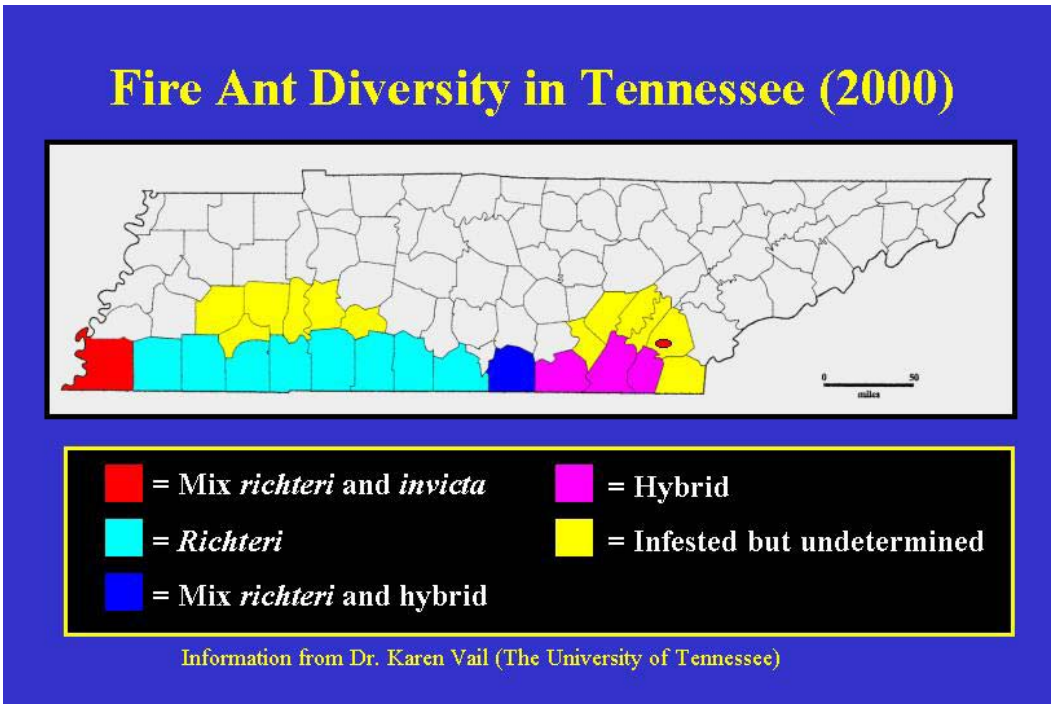


Figure 2. Fire Ant Diversity in Tennessee. Courtesy of Dr. Karen Vail, University of Tennessee Agricultural Extension Service, Department of Entomology and Plant Pathology. 2000.

National Park toward the Cades Cove area of the Great Smoky Mountains National Park. IFA mounds appear to be migrating along power line cuts and next to logging roads where the natural forest vegetation has been disturbed.

Historical data appeared to indicate that the IFA would not survive as far north as Tennessee (Diffee et al. 1997). However, with the IFA species hybridization that has occurred, a hybrid cross species has been created that appears to be more cold tolerant than either the red or black IFA. See Figure 3. This is significant because if the hybrid species of IFA is found to be more cold tolerant than either the red or black species, then the IFA may be able to survive in Tennessee and continued northern natural migration towards Kentucky may be possible. More recent modeling predictions of the expansion of the IFA taking into account the daily temperature range, the precipitation and IFA colony models show that on a global scale there is great potential for these IFA species as well as other South American fire ants to become invasive in other areas if they are accidentally introduced, especially in Europe, Asia, Africa and Australia (Morrison, et al. 2003).

Black IFA, *Solenopsis richteri*

Hybrid IFA, *S. invicta x S. richteri*

Red IFA, S*olenopsis invicta*



Figure 3. Three Species of Imported Fire Ants in Tennessee.

Photo courtesy of Dr. Karen Vail, University of Tennessee Agricultural Extension Service, Department of Entomology and Plant Pathology.

The IFA Quarantine Zone is considered to be the area where IFA are established and therefore no regulatory action is taken in this area to suppress the IFA except by the local communities who must live with the IFA. Areas outside the Quarantine Zone that are found to be infested with IFA due to movement of soil or plant material are subject to eradication efforts by the Tennessee Department of Agriculture. Movement of all plant materials, including landscape plants, hay and soil are regulated in the Quarantine areas, and must be treated with pesticides and given a permit by the Tennessee Department of Agriculture before these items can be moved outside the IFA Quarantine Zone. (Walker G. Haun, Personal communication, 2003) The IFA Quarantine documentation can be found in the Code of Federal Regulations, Subpart, Imported Fire Ant (301.81) or located at http://www.ceris.purdue/edu/napis/pests/ifa/freg/cfrifa.txt

The current National IFA Quarantine Map is shown in Figure 4 and the current infestation of IFA is shown in Figure 5. The USDA APHIS PPQ map source for Figure 4 is located at http://www.ceris.purdue.edu/napis/pests/ifa/imap/ifareg.html and the source for Figure 5 is located at http://www.ceris/purdue.edu/napis/pests/ifa/imap/ifaall.html

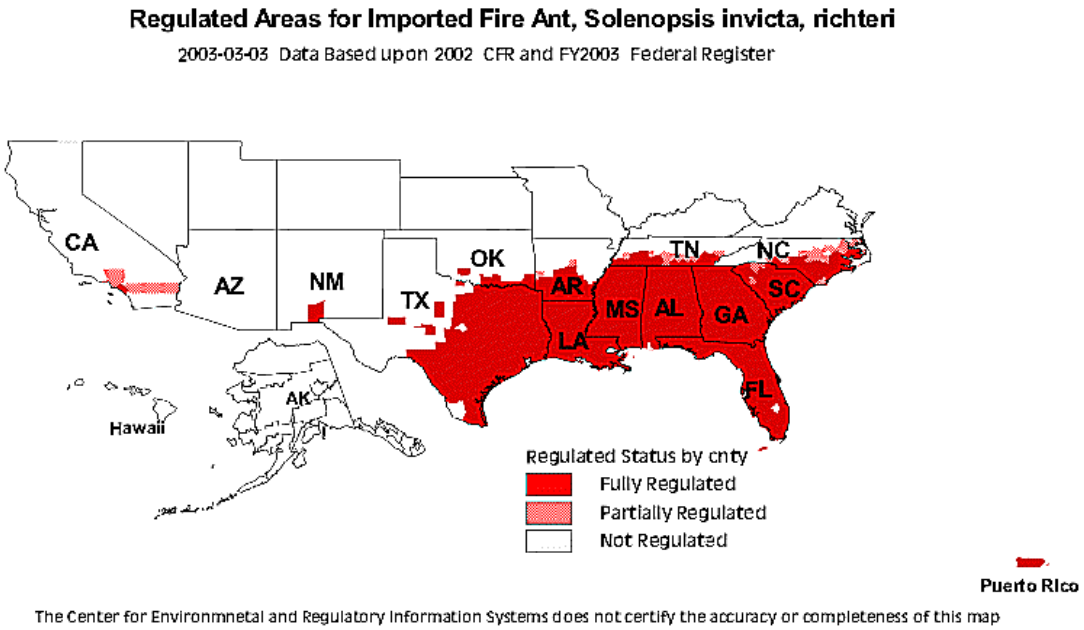


Figure 4. National IFA Quarantine Map. Source: USDA APHIS PPQ.

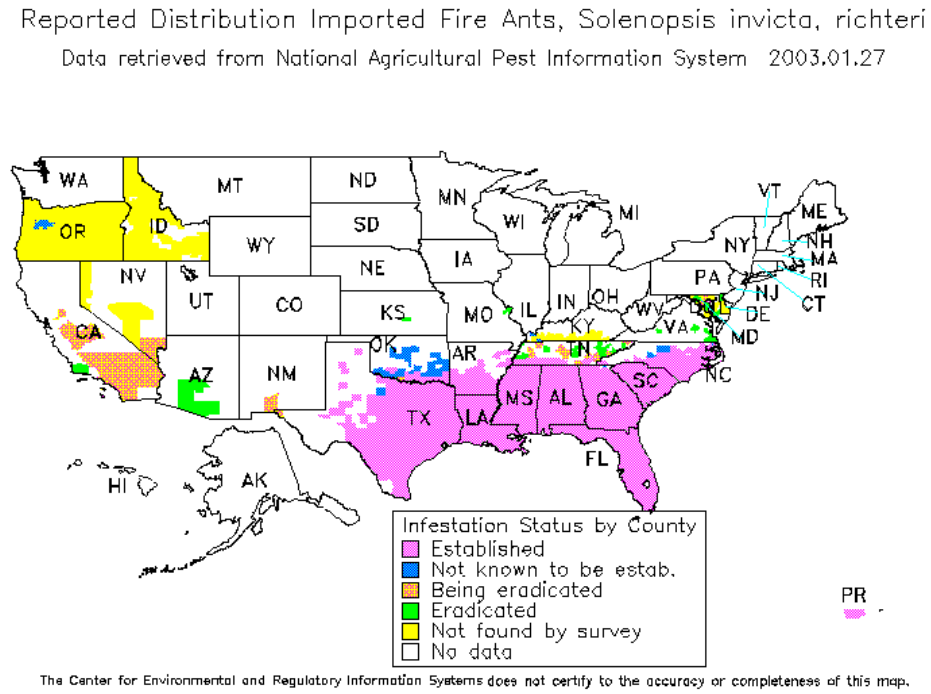


Figure 5. Current IFA Distribution Map. Source: USDA APHIS PPQ.

Chapter 3: Invasive Species Definition and the IFA

USDA Animal Plant Health Inspection Service (APHIS) defines invasive species as "… an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health. Invasive plants, animals, and aquatic organisms often reduce the economic productivity and ecological integrity of U.S. agriculture and natural resources." (USDA APHIS, April 2003)
http://www.aphis.usda.gov/oa/invasive/invasive.html

USDA APHIS estimates that one in seven introduced species will become invasive, costing $138 billion per year. Invasive species that have been brought to the United States in the last 200 years include house sparrows, European starlings, and rodents such as the roof rat, Norway rat, and house mouse. More recent invasive species that have been very destructive include European gypsy moth, zebra mussels, imported fire ants, hemlock wooly adelgid, Africanized honeybees, sudden oak death, and Asian longhorned beetles. Invasive species are a significant threat to nearly half of the native United States species that are listed under the Federal Endangered Species Act. The Endangered Species List can be found on the U.S. Fish and Wildlife Service website located at:
http://ifw2es.fws.gov/EndangeredSpecies/lists/ListSpecies.cfm

Invasive species rarely move by natural migration into the United States. Most non-native species that become established in the United States are carried either intentionally or unintentionally by humans, by movement of plants or soil, in or on food products, in ship cargo and ballast (soil or water discharge) and in or on containers or crates (discarded wood dunnage). Historically humans bring favorite plants, animals, seeds, and favorite foods with them when moving to a new location, and while many of these species cause no injury, some become invasive. Often a non-native species will cause no injury to their new environment for many years, then suddenly the populations will quickly expand in great numbers and the species will become invasive.

Invasive species often eliminate one or more native species through their feeding or reproductive habits. Since these non-native species have no natural predators that migrated with them, invasive species often reproduce in great numbers and spread rapidly. They often dominate the local habitat and cause decline or death of one or more native populations, as well as the native species that depended on the now extinct host species. Species invasions of plants (land and aquatic), animals, insects, aquatic invertebrates, and disease pathogens such as fungi, bacteria and viruses can change entire ecosystems and permanently diminish or eliminate biological diversity.

In addition to the IFA, current invasive species of concern to USDA APHIS and the Tennessee Department of Agriculture are the European gypsy moth, the hemlock woolly adelgid, and sudden oak death (Walker G. Haun, Personal communication, 2003). Each of these three invasive species will be described briefly.

The European gypsy moth (*Lymantria dispar*) is a nondescript looking moth, with a striking caterpillar stage. The female moth lays eggs on and near trees and thousands of tiny caterpillars hatch out and feed on the leaves of trees and shrubs. These insects prefer to feed on oak, alder, Douglas fir and western hemlock, but will feed on almost any type of tree or shrub, defoliating them completely. Defoliation for one or two years will not usually cause damage to otherwise healthy trees, but repeated defoliation will weaken and eventually kill mature trees.

Gypsy moth caterpillars move by 'ballooning' when they extend strands of webbing to the wind, which picks up the tiny caterpillar and carries it long distances. The gypsy moth also moves long distances when people on their household goods transport egg masses or caterpillars when they move to new areas or on cars or camping gear as they travel. A French naturalist who wanted to interbreed gypsy moths with silkworms to try to increase silk production originally moved gypsy moths to the United States.

In 1869 part of the gypsy moth population escaped from his home in Medford,

Massachusetts and became established in the local area. The gypsy moth slowly built up in population until 1889 when their numbers suddenly exploded and the expanding caterpillar population was recognized as a problem. Chemical controls were used to attempt to eliminate the population, however this was not successful due to the wide spread population and rapid reproduction rate. By 1981 the European gypsy moth caterpillars defoliated more than 12 million acres of trees in the Northeastern United States with a pocket of infestation in Michigan. By 1985 the southern front of gypsy moth spread was well into Virginia and West Virginia. (Source: USDA APHIS fact sheet http://ceris.purdue.edu/napis/pests/egm/facts.txt) Currently, the European gypsy moth is found in Tennessee in natural areas near campgrounds and in areas where household goods are moved from the northeast.

Targeted moth trapping and biological control applications are being used to eradicate local populations of gypsy moth when found in Tennessee. See Figure 6 for a current distribution map of the European gypsy moth population. Source: Purdue University, NAPIS distribution map: http://ceris.purdue.edu/napis/pests/egm/imap01/egm2001.html

The USDA Forest Service predicts that only about 20% of the healthy forest trees will be killed by repeated caterpillar feeding, and a main area of concern is the loss of oak tree species in the forest. Figure 7 shows a European gypsy moth fifth instar larvae (caterpillar). Source: USDA Forest Service http://www.fs.fed.us/ne/morgantown/4557/gmoth/

Another exotic invasive species is the hemlock woolly adelgid, Adelges tsugae, believed to be a native of Japan and China, is a serious pest of eastern hemlock and Carolina hemlock. The adelgid is a tiny insect that hides in small waxy bundles of white wool at the base of hemlock needles. These woolly bundles are most easily seen in late spring. The immature nymphs and adults damage trees by sucking sap from the base of hemlock needles. This feeding causes the tree to lose vigor, prematurely drop needles and become defoliated, which may lead to death. Uncontrolled adelgid feeding can kill a tree in a

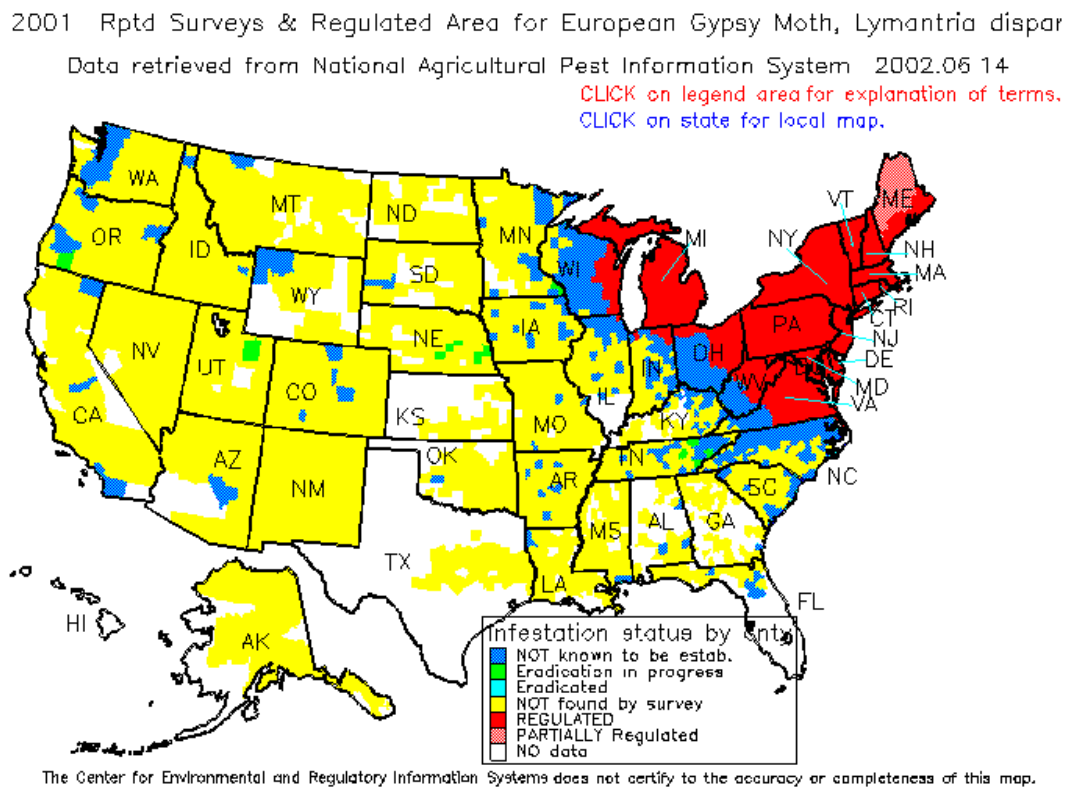


Figure 6. European Gypsy Moth Distribution in the United States (2001). Source: Purdue University, NAPIS database map located at:

http://ceris.purdue.edu/napis/pests/egm/imap01/egm2001.html

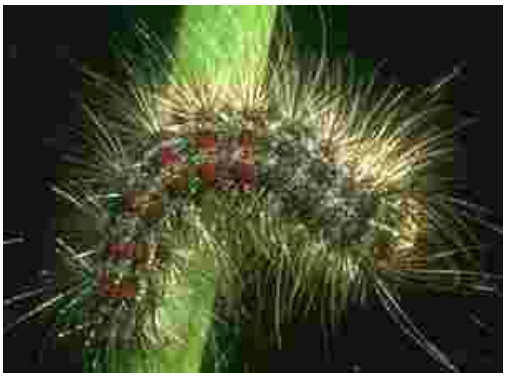


Figure 7. Fifth Instar European Gypsy Moth Larvae (Caterpillar).

Source: US Forest Service http://www.fs.fed.us/ne/morgantown/4557/gmoth/

single year. Source: Virginia Cooperative Extension Service Fact Sheet http://www.ext.vt.edu/departments/entomology/factsheets/hewoadel.html

The first introduction of the hemlock woolly adelgid to the United States was in the Pacific Northwest around 1924. It was later found in eastern Virginia in the early 1950's and has continued to spread throughout the southeastern United States. Eighty percent of the hemlocks in Virginia's Shenandoah National Park are now dead. Hemlock is a main nesting site and habitat for birds, including many neotropical migrating birds. Hemlocks are a primary stream shading tree species that cool mountain stream habitat for brook trout and other aquatic species. The first find in the Great Smoky Mountains National Park was in May 2002. See Figure 8. Park personnel are trying to control the spread by the use of pesticides, insecticidal oils and soap in limited high visibility areas, and the release of a tiny non-native beetle (*Pseudoscymnus tsugae*) as a biological control agent in the forested areas. Source: USDA Forest Service fact sheets at www.savethehemlocks.net and at http://www.fs.fed.us/na/morgantown/fhp/hwa/hwasite.html



Figure 8. Hemlock Woolly Adelgid. (Insects are located in woolly bundles at the base of hemlock needles) Source: US Forest Service located at www.savethehemlocks.net

Another exotic invasive pest new to the United States is a disease that attacks oak and tanoak species, *Phytophthora ramorum*. This fungal pathogen was first reported in 1995 to cause Sudden Oak Death in central coastal California. The pathogen also causes leaf spot and twig dieback of other tree species such as huckleberry, bay laurel and California buckeye. California has lost thousands of tanoak (*Lithocarpus densiflorus*), coast live oak (*Quercus agrifolia*), California black oak (*Quercus kelloggii*), Shreve oak (*Quercus parvula var. shrevei*), and madrone (*Arbutus menziesii*), since 1995 due to this disease. The first symptoms are stem cankers formed on the trunks of trees (see Figure 9). Trees can survive with cankers for several years, but once the crown dieback begins, the leaves often turn from green to pale yellow to brown within a few weeks and the infected tree dies. Source: USDA Fact Sheet http://ceris.purdue.edu/napis/pests/sod/page1.html

Sudden Oak Death has not yet been found in the southeast; however an extensive survey is underway for 2003-2004, focusing on the nursery growing area of middle Tennessee to determine if infected nursery stock has been brought in from California. (Walker G. Haun, Tennessee Department of Agriculture, Personal communication, 2003)



Figure 9. Sudden Oak Death. A. Wilting Symptoms, B. Oozing of Canker on Trunk. Source: Purdue University fact sheet http://ceris.purdue.edu/napis/pests/sod/page1.html

As with the three invasive species described above, the IFA is considered invasive. These ants have been shown to have the ability to disrupt native species and their habitat, displace and kill native species, and can rapidly reproduce, spread large distances, and only requires one mated queen to being an entire new colony. Due to their biology and nesting habits, the IFA can cause damage to native species and the environment, and physical and economic damage to public infrastructure and to agriculture production. In addition to causing environmental and economic problems, the IFA also can cause health concerns ranging from a single sting up to and including death for humans, pets and domesticated animals. These health effects will be discussed further in Chapter 4.

Chapter 4: IFA Biology and Related Health Effects

This biology description of IFA is based upon research conducted of the red IFA only, as the literature does not document the biology of black or hybrid IFA. Therefore, these two species are assumed to have similar biology as the red IFA and general observations of the red, black and hybrid IFA seem to concur with this assumption. IFA colonies live in mounds, usually of sand or dirt, but occasionally in piles of sod, containerized plants or in wall voids of building structures. The excavated dirt and sand is piled on top of the soil, creating the typical dome shaped mound that can become up to 2 to 3 feet in height. See Figure 10.

There are multiple surface entrances and exits to the mound, plus deep tunnels that connect to water and other mounds. The colony can move up and down within the mound depending on the surface temperature. When the ground surface freezes, the colony moves the queen, eggs and larvae deeper in the nest. This movement of the colony protects the ants from cold temperatures, allowing them to survive during mild Tennessee winters that would kill exposed ants. See Figure 11.

During the spring and fall, the colony moves upward closer to the surface of the soil and is more actively foraging. This movement can make it difficult to control the IFA. While surface mound treatments kill IFA at the surface, the other IFA move down in the deeper tunnels and migrate to join other nests or start a new mound. During rainy periods, the mound may become flooded and the ants may move indoors temporarily to search for shelter and food. This can result in a temporary conflict between humans and ants from sharing the same environment.

The IFA is a tiny, very aggressive ant with foraging, protective workers that range in size from 1/10 to 1/4 of an inch in size, and are reddish brown to black in color. Confusion about IFA identification is often due to the range in size of the workers and color variation. Workers are known to attack when the nest is disturbed, swarming out by the



Figure 10. The IFA Mound. Photo images from Texas Imported Fire Ant Project. Located at: http://fireant.tamu.edu/materials/graphics/photo/index.html

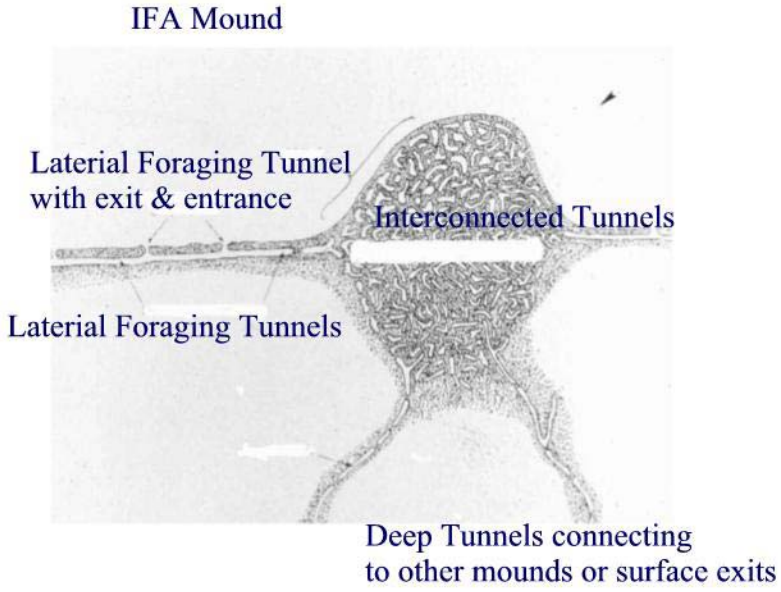


Figure 11. Details Inside the IFA Mound. Image from Texas Imported Fire Ant Project located at: http://fireant.tamu.edu/materials/graphics/photo/index.html

hundreds within seconds, and are able to inflict repeated stings. The sting of the IFA is extremely painful, with itching and burning; usually leaving a blister like pustule that develops within 8 to 24 hours, often with a white head. (California Department of Agriculture web site located at: www.cdfa.ca.gov/rifa)

The mound consists of one or more queens, plus sterile female workers and immature ants. See Figure 12. There are both single queen (monogyne) and multiple queen (polygyne) mound forms. Single queen (sQ) colony workers are territorial and do not mix with IFA workers from other mounds. Multiple queen (mQ) colony workers move freely between mounds and are not territorial, which results in many more mounds per acre (40 to 150 sQ mounds/acre vs. 200+ mQ mounds/acre) and therefore more IFA per acre (7 million sQ ants/acre vs. 40 million mQ ants/ acre). The hybrid IFA mounds found in east Tennessee have been single queen colonies as of July 2003, according to Dr. Karen Vail, University of Tennessee Agriculture Extension Service and Walker G. Haun at the Tennessee Department of Agriculture. (Personal communication, 2003)

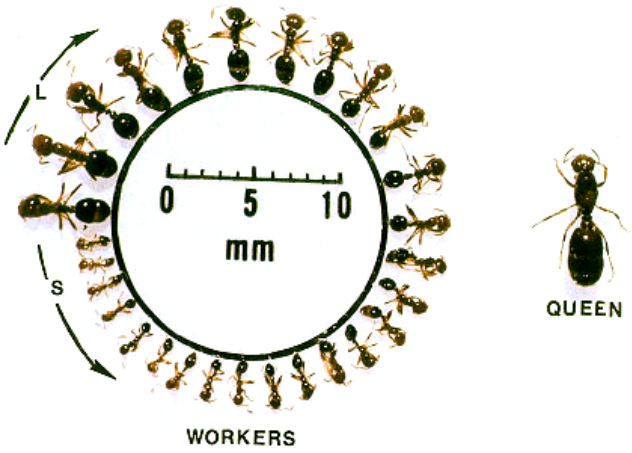


Figure 12. IFA Workers and Queen. Image from Texas Imported Fire Ant Project located at: http://fireant.tamu.edu/materials/graphics/photo/index.html

Winged reproductive ants start new IFA colonies. Winged males and females fly in large masses called swarms and mate. The winged males die, and the new queens fly up to a mile or are wind blown greater distances until a nesting site is chosen. The queen discards her wings, digs a tunnel and lays about a dozen eggs. The eggs hatch in about a week, the queen feeds them and within a month they develop into adult workers. These workers build the mound, care for and feed the queen. Mature queen IFA's can lay between 800 to 1000 eggs per day and can live for up to 7 years or more. The sterile female workers normally live 1 to 2 months. Eventually several hundred winged reproductive male and female ants are produced, mate and the new queens leave to establish new colonies. (Texas IFA Ant Facts located on the web at: http://fireant.tamu.edu/antfacts/biology.html)

While most IFA nests are established in dirt mounds, queens can nest in any dark protected area where there is sufficient moisture and food. This can include piles of laundry, manure or logs, in wall voids of buildings, under sidewalks and roads, or in automobiles, trucks or recreational vehicles. (Collins et al. 1993)

IFA are attracted to electric fields and may nest in infrastructure such as heat and air conditioning units or power utility boxes. Nesting activities may cause damage to the infrastructure and their chewing on non-insulated switches and wires can cause electrical shorts and power or traffic light outages. See Figure 13 and 14. Photo Source: Texas IFA Web Page, located at: http://fireant.tamu.edu/materials/graphics/photo/index.htm

Human and animal health can be damaged by IFA venom from stings and the resulting allergic reactions. See Figure 15. This includes the potential of humans or animals developing anaphylactic shock, which can ultimately lead to death. IFA venom is different from other stings as it is approximately 95% alkaloid with 5% soluble proteins while wasp, bee and hornet venom is composed of aqueous solutions containing proteins. Therefore, humans and animals don't always react in the same way to IFA stings as to bee or wasp stings.





Figure 13. IFA Nesting in a Utility Box. **Figure 14. IFA Nests in a Cemetery Plot.**



Figure 15. IFA Sting Pustules on a Childs Hand.

Photo Source for Figure 13, 14 and 15. Texas IFA Web Page, located at: http://fireant.tamu.edu/materials/graphics/photo/index.htm

There is no treatment or control once a person is stung by IFA, but those who become hypersensitive to IFA venom can be treated with immunotherapy. This is mainly for those who live in IFA areas and cannot avoid the potential of being repeatedly stung by IFA. The immunotherapy treatment appears to be highly, but not totally, effective. It consists of weekly low dose venom injections, increasing the serum until the maintenance dosage is reached. Then the maintenance dose is given once a month to maintain effectiveness of the treatment. (DeShazo, et al. 1990)

IFA invasion into nursing homes and school buildings can be especially dangerous for humans, as children and the elderly may be especially susceptible to IFA venom and are not able to escape the stinging ants as easily as healthy adults. Special consideration should be taken to eliminate mounds from children's play areas, including playgrounds and childcare facilities and from landscaping next to nursing homes or hospitals.

IFA are omnivorous and opportunistic, and can feed on almost any plant or animal material, including human garbage and dead animals, but seem to prefer to feed on other insects. (Lockley, 2003) They can be a problem in areas where their feeding should not occur, such as in areas where wildlife nest on the ground, in cemetery facilities or in agriculture production areas.

While foraging for food, the IFA remove plant seeds, damage developing buds and ripe fruit and vegetables and feed on plant sap flows. IFA can be beneficial when they eat cockroach eggs, flea larvae, or other harmful insects, but their feeding has a detrimental effect when IFA eliminate ground nesting wildlife, invertebrate and vertebrate eggs and young, other ant species, and agricultural food and feed production fields. The mounds in fields and pasture areas cause damage to farm equipment as well as injury to domesticated animals and pets. Figure 16 shows IFA's feeding on a caterpillar (insect larvae). Figures 17 and 18 show injury to an Irish potato crop and IFA mounds on pasture land, respectively. Photo Source: Texas IFA Web Page, located at: http://fireant.tamu.edu/materials/graphics/photo/index.htm



Figure 16. IFA's Feeding on Caterpillar.



Figure 17. IFA Damage on Irish Potato.



Figure 18. IFA Mounds in Pasture.

Photo Source of Figures 16-18. Texas IFA Web Page:
http://fireant.tamu.edu/materials/graphics/photo/index.htm

Flooding can also result in IFA related health problems for humans and animals. When IFA mounds are flooded, the ants are not drowned, but instead the entire colony emerges, forms a loose ball or mat, and will float and flow with the water. It is dangerous to contact these floating masses of IFA, as they will attach themselves to anyone or anything that might give them shelter. This could be a rowboat, rubber boots or skin. IFA's will cling to bare skin and must be rubbed off immediately as they will cling and bite, even when under water.

When the floodwaters recede, the colony will attach itself to piles of debris or will move into a structure for shelter until the ground is dry enough for a new mound to be built. Care must be taken when cleaning up debris as IFA colonies can be found under wood, furniture or carpet, and may be either outside or inside homes and other structures. (http://fireant.tamu.edu/)

Chapter 5: Interactions of IFA with Native Species

The IFA has reduced or eliminated most other species of ants and ground inhabiting species of insects and small mammals as it has migrated north during the last 50 years. Once the IFA arrive in a new area, these aggressive ants have been shown to reduce populations of ground nesting animals at least two-fold (Allen et al. 1995). This includes damage to species of native ants, invertebrates, mice, rats, lizards, snakes, turtles, deer, quail and other ground nesting birds. See Figure 19. It is suspected that IFA prey on nests of vertebrate animals, reduce the suitability of nesting sites and alter behavior patterns. The IFA may also increase native animal species susceptibility to predation. (Holway et al. 2002) The continued northern migration of IFA may also result in ecotourism changes in the Great Smoky Mountains National Park.

IFA damage young sapling plants by girdling stems, and eat germinating seeds and new seedlings. When feeding they destroy developing buds and eat seeds, possibly reducing the plant species diversity in an area (Lockley, 2003). IFA also tunnel into rhizomes and tubers, especially during periods of drought, reducing the storage and survival structures of native and cultivated plants.

IFA have been shown to out-compete native species, in part due to their advantage of not having natural enemies to keep their colony population in check. In addition to the aggressiveness of the IFA and their venomous sting, the overwhelming numbers of ants per colony can injure and kill larger species, including young mammals such as deer. See Figures 20 and 21. Large numbers of ants per colony give the IFA a competitive advantage, rapid reproductive rates, and only one mated queen needed to establish a new colony can result in large numbers of IFA colonies per acre. A further advantage is the tendency of IFA colonies to be multiple queen, a trait that has been shown to reduce aggression between colonies and allows closer spacing of mounds. (Holway et al. 2002)



Figure 19. IFA Damage to Eggs in Ground Nest.

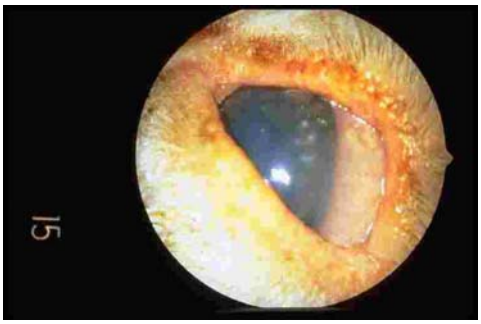


Figure 20. IFA Stings on Calf Eye



Figure 21. Scars on Fawns Face Due to IFA Stings.

Figures 19-21. Source: Texas IFA Web Page, located at:
http://fireant.tamu.edu/materials/graphics/photo/index.htm

It was confidently predicted a few years ago the IFA would never survive in Tennessee, especially not in the Great Smoky Mountains National Park. Even more recent models (Korzukhin et al. 2001) show that it is improbable that the red IFA can survive in the Great Smoky Mountains National Park and in northern Tennessee. However, in 2002, IFA mounds suspected to be of the hybrid species were found along the Foothills Parkway at the base of the Great Smoky Mountains National Park. IFA populations seem to be surviving over the winter in these areas and are continuing to spread further into the Appalachians along disturbed habitats such as open dirt roads and power line cuts through forests. While there has been some evidence of winterkill in these areas, it appears that this has occurred in mounds in open pastures, not those next to narrow disturbed areas or mounds along the north sides of gravel roads or trails along the forest edge (Stiles and Jones, 1998).

Eradication efforts during 2002 and 2003 by the Tennessee Department of Agriculture include treatment of IFA mounds in Loudon, Blount, Sevier, and Knox counties. Many of these infestations appear to be due to the movement of landscape plant material, however the populations established around the Foothills Parkway and the movement towards Cades Cove appear to be due to natural migration from established populations of the hybrid IFA in southern Tennessee. Invasive species such as the IFA have been shown to be disruptive to entire ecosystems as predator and prey balances occur and habitat resources are no longer available (Holway et al. 2002), and this is especially disturbing as the IFA continue to survive while migrating into the Great Smoky Mountains National Park.

The reasons noted above for the competitive advantage of the IFA are also traits that make the IFA difficult to control and next to impossible to eradicate once it becomes established. The IFA continues to expand its geographical range by natural migration and rapid population growth, overwhelming native species and modifying habitat as they spread. Therefore, it appears that in order to preserve ecological diversity in conservation areas, it will be necessary to rely upon introduced biological control organisms and

limited chemical treatments during critical reproductive cycles in small areas where threatened and endangered species exist.

PART II: An Approach to Management of the IFA

Chapter 6: IPM Management Techniques for IFA Control

The hybrid IFA is migrating north into east Tennessee and appears to be capable of over wintering in the Appalachians. Due to the economic value that tourism brings to the east Tennessee area, it is crucial that gateway communities understand the impact that the IFA will bring to their communities and learn to deal with the environmental and health related issues that can occur with the establishment of the IFA.

Information has been compiled in this paper from various sources to use as the basis for recommendations for east Tennessee. One primary preventative action has been noticed repeatedly – do not disturb native vegetation! When IFA migrate into a new area, these invasive ants seem to be attracted to areas where the soil has been disturbed. In east Tennessee this has been seen to be true, as IFA are moving into the Great Smoky Mountains National Park along power line cuts and along roads or trails in forested areas. Therefore, it is critical that native habitat not be disturbed in order to minimize IFA infestations.

Cultural landscape elements and suggested practices to minimize IFA are included in the Texas Red IFA Plan web site located at http://fireant.tamu.edu If it is not possible to leave the soil or natural vegetation undisturbed, there are some courses of action currently under trial that can be attempted. Use shade as an IFA deterrent and plant more trees in the landscape as IFA have been shown to prefer to nest in open, sunny areas. Maintain plant habitat diversity to encourage competitor ant species. Do not use chemical bait treatments when low populations of IFA exist, especially when IFA colonies are first migrating into a new area. Baits will kill the competitor ant species as well as IFA, and the reproductive rates of the IFA will allow them to rapidly colonize the area that was treated, and this may eliminate the beneficial competitor ants. Plant and maintain pest free native plants in the landscape, which may provide less food sources (such as caterpillars and aphids) for IFA colonies.

Good sanitation around homes will also provide less food sources for IFA, such as outside bowls of pet food and water, loose garbage, pet manure, and excessive decaying plant litter. Landscape materials such as concrete slabs, landscape timbers, and mulch often attract IFA as they provide for colony structure, hold moisture in the soil and moderate temperature fluxuations. Disturbing IFA colonies with frequent mowing or digging around the mounds may cause IFA to move to less disturbed areas, such as along fence and hedgerows. When this frequent disturbance ends IFA colonies tend to rapidly reinvade the area. Be aware that cultural practices alone will not eliminate IFA colonies; however these techniques may reduce IFA infestations and reduce dependence on insecticide treatments.

When eradication or suppression control is necessary for IFA nests, IPM management techniques have been used successfully in other southern states. Information from other communities that have learned to deal with the presence of IFA should be able to be used in east Tennessee to help control and minimize the establishment of these alien invaders in various land use situations. Fact sheets are available from the University of Tennessee Agricultural Extension Service (http://www.utextension.utk.edu/publications/) and from several governmental agencies that can be provided to residents and visitors to help them learn to deal with the potential health hazards that can develop when stung by the IFA.

Integrated Pest Management (IPM) is a systems approach to manage insect, disease, weed or other pests. The goal is to use a combination of ecologically sound pest control tactics to suppress pest populations and keep them below levels that cause economic or health problems. There are usually a number of combined approaches used in IPM, such as biological, cultural, organic and chemical control methods in order to provide effective and economic while doing the least harm to the environment. Since there is no way to totally eliminate IFA colonies, an IPM systems approach for IFA control is the best way to suppress the pest population without excessive expense or using excessive chemicals that could damage the environment and impact water quality.

The first step for any IPM program is to correctly identify the pest problem. This is especially true in areas where the IFA is becoming established, as these ants can easily be confused with other mound-building ants. To confirm the identity of ants suspected to be IFA, collect ants in a jar or other small container by putting a small amount of peanut butter or jam in the bottom of the jar and place it near the ants. Once 15-20 ants are feeding in the jar, carefully pick up the jar with kitchen tongs or while wearing gloves and put the lid on the jar. This may require leaving the jar out for several hours or overnight. The ants can then be killed by putting the jar in the freezer. The ant sample should be submitted to the local county Extension agent for identification. A list of Tennessee county Extension offices is located on the web at: http://www.utextension.utk.edu/offices/default.asp

If the ants are identified as IFA and the mound is located outside the IFA quarantine area, a local Tennessee Department of Agriculture (TDA) plant inspector may visit to determine if the IFA mound requires treatment by their agency. Otherwise, the responsibility for ant control is with the individual landowner. If IFA are present in very low numbers or are in a location that does not pose a health problem to humans or animals or detract from the appearance of a landscape, chemical control measures may not be necessary.

Most IPM techniques work best in areas where the IFA is widely established and a community wide approach is taken. Most management programs will require repeated treatments over a period of time to maintain suppression of the IFA, and this will require a commitment to the labor and expense of continued treatments. Once the IFA are established in an area, the public will need to be alerted to help control the spread of IFA to uninfested areas of the state.

The USDA Imported Fire Ant Quarantine is administered by the Tennessee Department of Agriculture and requires the inspection of hay, sod, soil, plants or any equipment that could be contaminated with soil from IFA infested areas. This agency must be notified

before items are moved to uninfested areas in order to be sure that the IFA's are not moved to an area that is not already infested. To determine if an area in east Tennessee is considered infested with IFA, contact the Tennessee Department of Agriculture Knoxville office (865-594-6098).

Part III of this paper has a discussion of chemical and non-chemical treatment choices, criteria for treatment and management suggestions for various scenarios, such as homes, schools, commercial landscapes, etc. When using any pesticide, care must be taken to prevent contamination of water resources with pesticides and to use all pesticides in a safe and responsible manner.

Before buying or using any pesticide product, read the pesticide label thoroughly to be sure it can be used in the desired location and applied to the targeted pest. Most pesticides for control of IFA only have a limited shelf life; so only buy the amount of pesticide that is going to be applied within 6 months time. Never dump excess pesticides down the drain or into a ditch, as this can lead to ground water contamination and injure wildlife and other non-target species.

Also be aware that the air temperature can change the effectiveness of the pesticide product. At temperatures below 75 degrees F, IFA workers become uninterested in feeding on the oil (pesticide) that is part of the bait. Therefore, contact insecticides such as individual mound drenches are more effective than baits at cooler temperatures.

Chapter 7: Educational Resources Relating to the IFA

A holistic IFA Management Plan for a generic east Tennessee gateway community has been developed in this paper, taking into consideration the impact of IFA upon agriculture, tourism, future development, and quality of life issues. This Management Plan is based upon what has worked for other communities in the southeastern United States, primarily Texas, Florida, Mississippi and Louisiana. Much of this information is located on the web, and web sites have been provided in the text as a reference for most of the recommended control options.

The Texas Cooperative Extension Service has coordinated a regional control plan for both urban and rural areas with participation from nine states in the southeast region of the United States, including Alabama, Arkansas, Florida, Georgia, Louisiana, Oklahoma, South Carolina, Tennessee and Texas. More information is available at: http://fireant.tamu.edu/materials/

The Texas Red Imported Fire Ant Project web site (http://fireant.tamu.edu) has many links to IFA resources, and also has a community-wide IFA management kit with a sample informational letter to be sent to the community, sample interest and satisfaction surveys about a community-wide IFA management effort, and educational support materials, such as fliers.

There are also IFA fact sheets on IPM in the schools, nursing home and day care center information, and infrastructure management and control information. A fact sheet is also available on protection of people and animals from IFA during floods. This topic is a critical one since entire IFA colonies will form a loose ball and float during floods until they come to rest on a debris pile or other shelter, even inside a house or other structure.

Additional web resources with information on IFA's include the following:

Alabama Cooperative Extension Service
http://www.aces.edu/dept/fireants

Alabama Cooperative Extension Service
http://www.aces.edu/department/extcomm/publication/

APHIS, USDA Pest Fact Sheets, Purdue University
http://ceris.purdue.edu/napis/pests/

APHIS, USDA
http://www.aphis.usda.gov/ppq/ep/pestdetection/plthlthcon.pdf

Appropriate Technology Transfer for Rural Areas (ATTRA)
htpp://www.attra.org/attra-pub/fireant.html

Arkansas Fire Ant Advisory Board
http://www.aragriculture.org/pestmanagement/fireants/board.asp

Auburn University
http://www.ag.auburn.edu/dept/entplp/FireAnts/

Beaufort, SC (Hilton Head Area), USA
http://www.beaufortusa.com/fireants.htm

California Department of Food and Agriculture
http://www.cdfa.ca.gov/phpps/pdep/rifa/

Clemson Extension Fire Ant Program
http://entweb.clemson.edu/fireant/

Coachella Valley California Red Imported Fire Ant (RIFA) Program
http://www.cvrifa.org/

Fire Ant Spatial Information Management System
http://fasims.tamu.edu/

FORMIS: A Master Bibliography of Ant Literature
http://cmave.usda.ufl.edu/~formis/

IPM Network for IFA
http://ipmworld.umn.edu/chapters/lockley.htm

Louisiana State University AgCenter
http://www.lsu.edu/ants

Mississippi State University Extension Service
http://msucares.com/insects/fireants/

Nevada Department of Agriculture
http://www.unlv.edu/faculty/wagner/RIFA.html

New Mexico State University
http://cahe.nmsu.edu/pubs/_g/G-319.html

North Carolina State University
http://www.turffiles.ncsu.edu/pubs/insects/ag486.html

North Carolina Department of Agriculture & Consumer Services
http://www.ces.ncsu.edu/depts/ent/notes/Urban/ifa-affect.htm

Oklahoma State University
http://www.ento.okstate.edu/fireants/fireants.html

Orange County California Fire Ant Authority
http://www.ocfireant.com/

Oregon Department of Agriculture
http://www.oda.state.or.us/plant/pdd/ent/rifa.html

Purdue University IFA Fact Sheet
http://ceris.purdue.edu/napis/pest/ifa/facts.txt

Queensland (Australia) Department of Industries
http://www.windvallshs.qld.edu.au/curriculum/fireants/links.html

Tennessee Department of Agriculture Regulatory Division
http://www.state.tn.us.agriculture/regulate/plants/ifa.html

Texas A&M University, Department of Entomology
http://fireant.tamu.edu/faars/index.html

Texas Red Imported Fire Ant Project
http://fireant.tamu.edu

Texas Tech University
http://ecologia.uta.mx/biotam/v5n2/art1.html

University of Arkansas
http://www2.uaex.edu/

University of Georgia Agriculture and Environmental Sciences
http://www.ces.uga.edu/pubcd/B1191.htm

University of Minnesota
http://ipmworld.umn.edu/chapters/lockley.htm

University of Tennessee Agricultural Extension Service
http://www.utextension.utk.edu/publications/

US. Department of Agriculture - Agricultural Research Service
http://www.ars.usda.gov/fireant/

USDA Forest Service
http://www.fs.fed.us/na/morgantown/fhp/hwa/hwasite/html

USDA NAPIS System
http://ceris.purdue.edu/napis/pests/ifa/index.html

Chapter 8: Possible IFA Tourism Impacts in East Tennessee

Tourism promotion of an area usually depends upon publicity, word of mouth recommendations from satisfied tourists and repeat vacation travel. IFA has the potential to negatively impact the tourism experience to the Great Smoky Mountains National Park and the associated gateway communities of east Tennessee. It is critical that the impacts of IFA populations be planned for and managed before negative experiences and an associated negative reputation develops for this region. Not only may there be negative personal experiences, but there is the potential for lawsuits associated with injuries due to IFA stings.

Tourism health and safety concerns need to be concentrated in public use recreational areas, such as: playgrounds; campgrounds; hiking trails; fishing, swimming and boating areas; and trails and dirt roads where horseback riding occurs. Many public use areas are highly desirable for IFA mounds as open sunny areas and cuts in forested areas such as dirt trails and roads are preferred locations for mound building. These areas must be monitored often for the presence of IFA mounds and directed control treatments will probably be required to minimize the numbers of ants in these high use areas.

Another concern is the potential decline in the natural environment of the Appalachian region and loss of richness of diversity of plant, insect and animal species due to the IFA. Many tourists come to the Great Smoky Mountains National Park to view the natural environment and this enjoyment has already been impacted by the death of trees in the higher elevations of the park by several new invasive species and by acid rain and pollution problems. Concerns for personal health and the health of domestic pets due to IFA stings while visiting the Great Smoky Mountains National Park and nearby recreational areas may drive away repeat tourism business. Tourists who enjoy the recreational facilities and panoramic views provided in the Great Smoky Mountains National Park may also consider retirement options in the east Tennessee area. These potential investors in the community may be driven away by personal injuries or negative

publicity regarding IFA.

Gateway communities also need to be aware of the potential damage and associated costs related to infrastructure because of the IFA. As discussed earlier, heat and air conditioning units, electrical boxes, traffic light switches, and other infrastructure are susceptible to invasion and colonization by IFA. In addition to actual physical damage to infrastructure there may be additional costs to gateway communities due to IFA pest control costs, employee training costs, extra on the job stress due to extra vigilance for IFA's, worker injury claims, and additional environmental impacts upon the east Tennessee region, such as water quality concerns due to increased pesticide use.

An invasion of IFA into a gateway community can be managed; however the attractiveness of certain types of microclimates to the IFA must be taken into consideration when designing public infrastructure and monitoring recreational areas for IFA's. Education about IFA and awareness training must be conducted to minimize the danger to animals and humans in the community, and allow tourists to enjoy the rural beauty of Tennessee without becoming injured by the IFA while out on trails or horseback riding.

The agriculture industry will also need training and assistance in providing protection to livestock and crops that can be damaged by the IFA. Education for the public on how IFA's spread is also needed to minimize the movement of IFA into uninfested areas. The community and general public also need to be educated on the current location of the IFA Quarantine Zones and regulations, and the consequences of moving IFA infested plants to a non-infested area.

PART III: Management Plan

Chapter 9: Community Types That Need IFA Management

There are various communities and land use sites that are present in east Tennessee. The physical places that gateway communities need to take into account for the effects of IFA are broken down into the urban community areas, and the rural areas. There are also different living communities that need to be considered and protected; such as humans, domesticated pets and livestock, and native ground nesting wildlife, especially threatened and endangered species.

Physical urban areas include public government buildings and grounds, schools and playgrounds, urban infrastructure such as telephone, electric utilities, power transformer boxes, heat and air conditioning units, and traffic light boxes; semi-public buildings such as churches, nursing homes and hospitals; commercial businesses and associated landscaping; suburban housing and yards; and athletic fields and urban park areas.

Rural areas include agriculture (farms, crop production fields, pastures, forested/logged areas), forested/wilderness, rural housing and yards, campgrounds, picnic areas, logging roads, hiking and horseback riding trails, natural areas such as parks, and recreational areas. Some physical areas of concern apply to both urban and rural areas, such as water wells, streams, ponds, and lakes, power line cuts.

Each of the above site scenarios will be evaluated through the Decision Matrix for the types of management techniques that will be feasible to control the IFA. The evaluation will be based upon information from a variety of fact sheets and publications, many of which are summarized in the southern Regional 2002 Texas Publication B-6043, 'Managing Imported Fire Ants in Urban Areas'.

For the Decision Matrix that follows, these scenarios will be grouped into the following types of sites:

Public Buildings

Infrastructure such as Power Boxes and Heat & Air Conditioning Units

Medical Buildings and Nursing Homes

Commercial Buildings

Housing Structures (both Rural and Urban)

Housing (Yard and Gardens)

Urban Parks and Recreational Areas

Agriculture such as Pastures, Field Crops, Managed Forest for Harvest

Picnic Areas and Campgrounds

Logging Roads, Hiking and Horseback Riding Trails, Power Line Cuts

Rural Forest and Wilderness Areas

Water Features such as Wells, Streams, Ponds, Lakes

Human Safety

Domesticated Animals and Pets

Wildlife

Threatened and Endangered Species

Chapter 10: IFA Control Options

Treatment option criteria for the control of IFA will be evaluated though the Decision Matrix to determine one or more potential control measures that will be feasible for each type of site.

IFA control choices have been compiled from various fact sheets, web sites, and Extension publications to be considered for use in the following Decision Matrix. There are four basic types of control options: cultural, biological, organic and chemical. Of course, there is also the option to do nothing and allow invasive species to do a certain amount of damage or cause environmental change. This 'do nothing' option is most feasible in a forest or wilderness area. Management and control options for IFA may be necessary for human safety and animal health reasons and to protect infrastructure in urban areas, however IFA control may only be necessary or economically feasible to a limited extent in rural areas, such as for agricultural production areas, protection of endangered wildlife habitat, or in high public use recreational areas. Descriptions of possible control options for IFA are described below.

1. Cultural Control Options (physical and mechanical)

a. Do not disturb soil or native vegetation. This will mean no clear cutting along logging roads, power line cuts, etc. Housing and other future building sites will need to be constructed in such as way to limit soil and native plant disturbance. The more soil and native plants are disturbed, moved or removed, the more likely it is that IFA mounds will become established in the area.

b. IFA mounds near a structure, or in the yard or garden may be controlled by applying 3 gallons of nearly boiling hot water as a drench upon the mound. This has been found to eliminate about 60% of IFA mounds. Shoveling out or disturbing the mound repeatedly has been found to encourage IFA to move nearby. These methods can be very dangerous and great care must be taken if they

are used. Keep hot water off desirable plants and grass.

c. Seal all electrical components inside traffic boxes, heat and air systems, and other equipment housing that are not insulated. Plastic housings should contain all contact points of switches, relays and circuit breakers. Keep all plant debris, mulch and soil away from equipment housing to discourage nesting of IFA. It may require pesticide treatments to keep mounds away from equipment housing.

d. Use exclusion practices around buildings and homes, including practices such as weatherproofing, sealing all openings around pipes, windows and doors. This method helps with controlling many types of pest invasions, but as the IFA are very small ants, total pest exclusion will be difficult to achieve. Do not mulch or have loose dirt around buildings as this may encourage IFA mounds to become established. When installing new landscaping, do not purchase plants from IFA infested areas, which could bring IFA into the landscape along with the plants, soil or sod. The use of native plants that are adapted to the area will reduce the amount of watering and extra care needed once the plants are established. Native plants will also be less likely to decline or die, thus requiring replanting or new landscaping in the area.

2. Biological Control Options (natural enemies)

The IFA spreads rapidly for several reasons, one of which is the fact that none of the natural enemies of the IFA were moved to North America along with the IFA. Therefore, there is great potential for control if several of the natural enemies of the IFA from South America can be released into new areas where the IFA have become established. Care must be taken, however, to evaluate these natural enemies to be sure that these biological agents do not become pests when released into new areas. After careful evaluation, a number of natural enemies have been tested and released, and others are under evaluation for possible release. It must be noted that none of these natural enemies will provide complete control (eradication) of the IFA, but the release of multiple types of natural

enemies will help suppress populations of IFA. Currently there are four types of biological control agents being used by State University and USDA researchers to provide partial control of the IFA in Florida, Texas, Oklahoma, South Carolina, Mississippi and Tennessee. These biological control agents include: phorid flies, parasitic ants, microsporidia and fungi. Bacteria and viruses with pathogenic properties have not yet been isolated from IFA bodies or mounds, but work is underway by USDA researchers to find additional naturally occurring agents that can be used for IFA control. (http://cmauve.usda.ufl.edu/ifahi/areawide_home.html)

a. Phorid decapitating flies are found in the genus Pseudacteon, and include *P. tricuspis*, which has been released at a number of sites in the southeastern United States. It has become established and is showing potential for partial control of IFA species. (http://cmauv.usda.ufl.edu/ifahi/phoridflies.html) The USDA ARS web site has videos of Phorid flies attacking IFA's and other fly life cycle information, located at: http://www.ars.usda.gov/fireant/news1.htm

b. Solenopsis (Labauchena) daguerrei (Santschi) is a parasitic ant of both the red and black fire ants in South America. It causes stress upon the IFA colony, which must feed and maintain the brood of S. daguerrei. Mound densities of IFA colonies have been reduced by 33% and the number of IFA queens was reduced by 47% in parasitized colonies. (http://cmauve.usda.ufl.edu/ifahi/parasiticants.html)

c. There are two microsporidia (protozoan) pathogens that are currently being evaluated as biological control agents; Thelohania solenoopsae and Vairimorpha invictae. T. solenopsae has been found infecting IFA colonies in Florida, Mississippi and Texas, where it causes the IFA colonies to slowly die. When both of these microsporidia are combined in laboratory tests, the IFA colonies die more rapidly. (http://cmauve.usda.ufl.edu/ifahi/microsporidia.html)

d. Entomopathogenic fungi have been seen to infect IFA colonies in their native South America. The spores infect the ant, the fungus germinates, grows and reproduces in the ant body, and then new spores are released to infect healthy ants. Infected ants usually die within 3-5 days. There are a number of fungi being studied for use in IFA control, including Metarhizium anisopliae, Beauveria bassiana and an Aspergillus species. (http://cmauve.usda.ufl.edu/ifahi/fungi.html)

3. Organic Control Options (natural pesticides)

Organic is a term used to describe naturally occurring products that act as a pesticide. State and Federal agencies have standards that are used to certify crops that have been treated by products that are on a list of standard materials that are approved for use by farmers that want to be certified as producing organic crops. These products are not necessarily better than conventional synthetic pesticides, and the cost of the product or application cost is usually not reduced. However, for farmers that are producing crops for the organic market, these natural products offer an insecticide alternative while controlling the IFA. An organic Two-Step Method for IFA Control (nicknamed the Texas Two-Step) is a method that uses a sequential approach with a broadcast application of an organic bait followed by selective treatment of individual mounds (Drees, June 2002). A description of this Two-Step Method is located at http://fireant.tamu.edu

4. Chemical Control Options (synthetic pesticides)

a. Direct contact (kill) treatments. Includes Dusts (Acephate, Deltamethrin), Granulars (Chlorpyrifos, Diazinon, Deltamethrin) and Drenches (Chlorpyrifos, Diazinon, Permethrin, Citrus oil, Esfenvalerate). The pesticide is applied directly to the mound, reducing the cost and the impact upon the environment. Areas near (but not on) wellheads, ponds and streams may be treated with care using some direct contact products. Check with the pesticide label for each products use limitations. These treatments must be repeated every year for continuous control.

b. Indirect contact treatments. Baits such as Hydramethylnon, Methoprene,

Fenozycard, Pyriproxyfen and Spinosad. Pesticide is mixed with oil and applied to a granule that is then broadcast over a large area. IFA carry the bait to the mound, feed on the oil from the granule, and pass the insecticide along to others in the mound. Baits can be a slow acting toxicant that kills the entire mound or a growth regulator that will either sterilize or stop the ants from maturing. The population of affected ants will die, but the effect of baits is often short lived (normally from 6-18 months) as nearby colonies can eventually move into areas where ant populations have died out.

Chapter 11: Decision Matrix for Sites and Control Choices

An evaluation matrix will need to be developed by each gateway community to determine which local land use sites require management choices and to rate the treatment option criteria for control of the IFA. The development of this matrix should provide east Tennessee communities with a number of specific treatment options that will assist in future development decisions and changes needed in public land management in order to increase safety in IFA infested areas. These criteria may also be useful in the middle Tennessee area as the soil and climate conditions are similar to east Tennessee.

A generic Decision Matrix is shown in Table 1, with scenarios chosen that apply to many east Tennessee gateway communities. The control options are grouped into the four basic types of treatments plus the no control option. Specific treatments under each control option are discussed in Chapter 10, but the specific treatments may change over time. New chemicals and organic controls may be developed and registered for use, and new cultural and biological control options become available as technology advances. Note that organic and chemical control treatment rates, pesticide use options and safety requirements may differ according to pesticide brand name and product application type. Always read and follow the pesticide label on the product chosen.

IFA control will probably require a combination of control options, and treatments may need to be repeated. IFA are never going to be completely eliminated, only managed in order to keep IFA mounds away from high use areas or keep the IFA populations low enough to allow for use of specific sites. Some sites can tolerate more IFA mounds, such as in remote forested or wilderness areas which may not require treatment at all, while some sites may require multiple treatments at certain times of the year, such as during ground nesting season for a threatened or endangered species. Still other sites, such as children's playgrounds or high use public areas, may require year-round repeated treatments in order to eliminate IFA mounds in a limited area.

Table 1. Decision Matrix (Scenarios vs. Control Options).

	Cultural	Biological	Organic	Chemical	No Control
Public Buildings	X		X	X	
Infrastructure: Power Boxes, Heat/Air Units	X		X	X	
Medical Buildings & Nursing Homes	X		X	X	
Commercial Buildings	X		X	X	
Housing Structure (Rural & Urban)	X		X	X	
Housing (Yard & Garden)	X	X	X	X	
Urban Parks & Recreation Areas	X	X	X	X	
Agriculture: Pasture, Field Crops, Forest	X	X	X	X	
Picnic Areas & Campgrounds	X	X	X	X	
Logging Roads & Hiking Trails	X	X	X	X	
Rural Forest & Wilderness Areas					X
Water Features (Wells, Streams)	X	X		4a only	
Human Safety	X	X	X	X	
Domesticated Animals & Pets	X	X	X	X	
Wildlife	X	X			
Threatened & Endangered Species	X	X	X limited	X limited	

Chapter 12: Discussion of Decision Matrix Results

Each of the scenarios used in the Decision Matrix will be looked at individually and the Control Option results for IFA in Table 1 will be briefly discussed. It must be noted that before any control options are considered, suspect ants must be positively identified. There are a number of similar looking ants, and the size of the IFA workers can vary. The University of Tennessee Agricultural Extension Service County Extension agents or Tennessee Department of Agriculture personnel can assist in identification of ants. Once the ants are confirmed to be IFA, and the ant colony is determined to be located inside the IFA Quarantine area, then one or more of the following control options may be considered.

The first five scenario results were the same, and will be discussed together. This includes public buildings, infrastructure such as power boxes, traffic lights and heat/air units, medical buildings and nursing homes, commercial buildings, and urban and rural housing structures. The IFA control choices include cultural, organic and chemical control options.

Biological control is not a choice since there is little tolerance for any IFA to be present in buildings, facilities such as hospitals or nursing homes, or in infrastructure such as traffic light and power boxes. IFA damage to these facilities can be costly, both in repairs and in terms of human safety. A combination of all options should be used for the most effective IFA control.

1. Cultural Options. Do not disturb the soil and native plantings, especially close to structures. IFA mounds near structures may result in ants foraging indoors for food, especially when soil is flooded or during hot, dry periods when ants search for moisture. IFA colonies have been found nesting in wall voids or in attics. In these situations, IFA can be a health threat as they can injure sleeping or bed-ridden individuals. Follow trails of foraging ants to locate nests, and use baits or

contact insecticides injected into the next. Vacuuming or treating only the ant trails will not eliminate the IFA colony.

Use native landscape plants and move (transplant) plants as little as possible. Keep overhanging plants trimmed away from buildings to limit access of ants to the structures. Limit use of mulch around structures. Caulk and seal openings around buildings and infrastructure, and use plastic housings to seal all circuits and switches that are not insulated. If IFA are found in power boxes, or similar infrastructure with electricity, an electrician or licensed pest control operator should treat the nest.

2. Organic Options. Natural pesticide choices are available for ant control. Most schools require an IPM approach to pest control, including parent notification before pest controls are applied.

3. Chemical Options. Synthetic pesticide choices are available and may be necessary for extended control of IFA. Specific products are labeled for use inside electric power boxes, such as pest control strips. Long residual contact insecticides should be used around the outside of power boxes and/or to the mounting pad to prevent reinfestation. On school grounds, baits are a safer method of control.

The next two scenario results were the same, and will be discussed together. This includes Housing (Yards and Gardens) and Urban Parks and Recreational Areas. IFA control choices include cultural, biological, organic and chemical control options.

1. Cultural Options. Do not disturb the soil and native plantings, especially close to any structures. Use native landscape plants and move (transplant) plants as little as possible. Limit use of mulch as IFA are attracted to compost piles and mulch for warmth and moisture.

Garden plants can be damaged by IFA, especially tuberous plants in the soil, or on okra buds and developing pods. Most damage occurs during hot, dry weather as ants forage for food and moisture. IFA can be beneficial as they prey on pests such as caterpillars, but they also protect and tend pests such as aphids. IFA mounds can be shoveled out of the yard and garden or may be treated with very hot water. However, these are dangerous methods that must be done with care.

2. Biological Options. These options are best used on a widespread or community basis. Often these biological controls will spread naturally from one area to another, resulting in partial control of IFA. Additional options can be used, depending on the amount of IFA control needed in the particular situation.

3. Organic Options. Natural pesticide choices are available for ant control. The Texas Two-Step Method is only recommended for areas with large numbers of IFA mounds and few native competitor ants.

4. Chemical Options. Synthetic pesticide choices are available and may be necessary for extended control of IFA. Recreational areas that cannot tolerate any IFA mounds (such as ball fields) must be aggressively treated to eliminate all ants at least 6-8 weeks before athletic events are scheduled. On school grounds, baits are a safer method of control.

The next three scenario results were the same, and will be discussed together. They include agriculture, managed forests, picnic areas and campgrounds, rural areas such as logging roads, hiking and horseback riding trails, and power line cuts. IFA control choices include cultural, biological, organic and chemical control options.

1. Cultural Options. Do not disturb the soil or native plantings. Use native landscape plants and move (transplant) plants as little as possible. This is especially important in areas where people and their animals frequent. Disturbed

areas along logging roads, hiking and horseback riding trails and power line cuts are very attractive to IFA, and the microclimate near these disturbed trails and roads seem to allow better survival of IFA than in open fields and pasture. IFA along the Foothills Parkway appear to be using these trails, gravel or dirt roads and power line cuts to move up into the Great Smoky Mountains National Park. Reducing the width of clear cutting along these trails and power lines or eliminating the clear-cutting entirely may help prevent movement of the IFA into wilderness areas.

2. Biological Options. These options are best used on a widespread or community basis. Often these biological controls will spread naturally from one area to another, resulting in partial control of IFA. Additional options can be used, depending on the amount of IFA control needed in the particular situation.

3. Organic Options. Natural pesticide choices are available for ant control. The Texas Two-Step Method is only recommended for areas with large numbers of IFA mounds and few native competitor ants.

4. Chemical Options. Synthetic pesticide choices are available and may be necessary for extended control of IFA. Pasture and cropland are often difficult and expensive areas for IFA control. Large acreages are necessary for domestic animal grazing, yet can be very hazardous to animals and field machinery if large numbers of IFA mounds are present. Broadcast bait treatments, applied once or twice a year, will often suppress ants about 90% when properly applied. In many agriculture situations, this type of treatment is sufficient.

The next scenario is for rural forest and wilderness areas. Because of the large acreage involved, there is normally no control that is economically feasible. Biological treatments in adjacent areas may assist in control if natural spread of agents occurs. Selective treatment may be necessary for high use areas as noted above, or for periodic control

around threatened and endangered species, especially during nesting season.

The next scenario is for water features such as wells, streams, ponds, and lakes. Cultural and Biological options for control are possible, plus a limited type of Pesticide option (Direct Contact only). Care must be taken not to contaminate water sources with pesticides. Pyrethrins and rotenone products should not be used, as they are highly toxic to fish.

1. Cultural Options. Do not disturb the soil or native plantings. Use native landscape plants and move (transplant) plants as little as possible. This is especially important in high traffic areas where people and domestic animals frequent.

2. Biological Options. These options are best used on a widespread or community basis. Often these biological controls will spread naturally from one area to another, resulting in partial control of IFA. Additional options can be used, depending on the amount of IFA control needed in the particular situation.

3. Chemical Control Options. (synthetic pesticides) Direct contact (kill) treatments. Includes Dusts (Acephate, Deltamethrin), Granulars (Chlorpyrifos, Diazinon, Deltamethrin) and Drenches (Chlorpyrifos, Diazinon, Permethrin, Citrus oil, Esfenvalerate). The pesticide is applied directly to the mound, reducing the cost and the impact upon the environment. Areas near (but not on) wellheads, ponds and streams may be treated with care using some direct contact products. Check with the pesticide label for each products use limitations. These treatments must be repeated every year for continuous control.

The next two scenario results were the same, and will be discussed together. This includes human safety and domesticated animals and pets.

IFA control choices include cultural, biological, organic and chemical control options. Since humans and their domesticated animals may be found in a wide range of situations, proper control options may be found in the appropriate site situation listed above. However, some individuals and animals are extremely sensitive to IFA stings and may require use of all control measures available. Short of moving out of IFA territory, humans and animals must learn to live with IFA, becoming extremely vigilant and aware of potential IFA habitat. Wearing sox, shoes and long pants year round may be necessary. Ants tend to hide under sandal straps and between toes, crawling up legs and arms for some time before ants bite to secure a hold on the human or animal, and then they begin to sting. It is very difficult to remove these ants and hundreds of stings may be received before all ants are dislodged. Small animals and children or adults with a compromised immune system may be stung enough to cause severe illness or death.

The last two scenario results were the same, and will be discussed together. This includes wildlife and threatened and endangered species. IFA control choices include cultural, biological, and limited organic and chemical control options.

As with domesticated animals and pets noted in the above scenario, wildlife may be assisted with some cultural techniques and biological controls in agriculture and urban forest areas. However, organic and chemical control options are not practical or economical on a wide spread basis in rural areas. The exception is for ground nesting species that may be on the Threatened or Endangered species list. IFA forage and kill most species of ground nesting animals, so protection may be necessary during the limited periods of nesting. Limited baits or localized mound treatments may be possible during these periods to protect selected areas that are at high risk.

Chapter 13: Implementation of a Management Plan for IFA

As IFA colonies become established in new areas in Tennessee, local communities will need to adjust their landscaping procedures and improve pest control activities around public infrastructure and recreational facilities in order to provide a safe and healthy environment for tourists and residents. Gateway communities will need to take steps to educate visitors and monitor for IFA's along hiking and horseback riding trails, campgrounds and recreational facilities to maintain a safe and healthy environment for the tourists that come to enjoy the rural Tennessee area.

A management plan should be developed based upon the information in this document and utilizing other references that have been provided in Chapter 7. The gateway communities that appear to be most vulnerable to the impacts of IFA upon tourism opportunities in and around the Great Smoky Mountains National Park in the east Tennessee area are Townsend, Wear's Valley, Gatlinburg, and possibly Pigeon Forge, Sevierville, Cosby and Maryville. See Figure 22. Map Source: All the Smokies.com located at: http://www.allthesmokies.com/maps.html Additional maps are available from the National Park Service website at: http://www.nps.gov/grsm/pphtml/maps.html



Figure 22. Map of the East Tennessee Area.

Map Source: All the Smokies.com at: http://www.allthesmokies.com/maps.html

Communities can assess the potential for IFA invasion in their area by going to the Tennessee Department of Agriculture web site that shows the current infestation status of IFA. (http://www.state.tn.us/agriculture/regulate/plants/ifa.html) This web site also shows the area of Tennessee that is under IFA Quarantine, discusses the current IFA regulations, and offers contact information for nursery and landscape professionals who need a permit for movement of plants or hay. Information is also provided about how to contact local Tennessee Department of Agriculture offices and University of Tennessee Extension Service county personnel. Keeping in contact with local Tennessee Department of Agriculture and University of Tennessee Extension personnel is the best way to be kept informed about the current status of IFA movement in east Tennessee.

Once an IFA Management Plan has been developed for an individual community, it will be necessary to inform and educate the public and the community government of the steps necessary to implement the plan. Having a plan for IFA Management will be of no help to the community if it is developed and then sits on the shelf unused. There must be commitment from community leaders and the tourism industry to be proactive in managing IFA colonies when they arrive by natural migration, so that steps can be taken early in the IFA establishment process to minimize the economic and environmental impact upon the east Tennessee region. The goal is not to create fear of fire ants, but to inform the local community so that appropriate actions can be taken to provide for human, pets, and domestic animal safety and protection of the community infrastructure and natural resources. A proactive approach to IFA management will demonstrate the cultural pride and environmental awareness of the community.

It is understandable that communities will not want to advertise the fact that IFA's are migrating into their community, however, tourism will be hurt if visitors stay away from the community due to developing an image problem because of having uncontrolled IFA mounds in the area. The private camping community will be especially vulnerable to the negative image of IFA's, therefore these stakeholders will have a vested interest in early detection and monitoring for IFA, so the appropriate control measures can be taken

immediately to keep visitors safe. The culture and heritage of the gateway communities is part of the attraction to visitors and environmental awareness and concern for the environment will project a positive image to tourists and other visitors. Since disturbance of natural areas appears to be the most common reason that various invasive species become established, it will be very important to educate the residents, community leaders and visitors that natural areas need to be left alone and valued for their undisturbed habitat. This ethic should be promoted to help cultivate cultural pride in the community.

The Decision Matrix that was developed in this document will assist communities to decide upon local priorities in order to determine where efforts and funding will need to be committed. Areas such as high use public buildings including schools and playgrounds, sports fields, hospitals and nursing homes need to be monitored for IFA and protected by control measures when IFA are found. Public infrasture and water sources must also be protected from IFA. High use recreational areas, urban parks and public landscaped areas may also be determined to be high priority by the community. A series of meetings for public input on deciding local priorities should be conducted. These meetings may also be the best way to develop committed neighborhood groups for IFA control efforts and to educate the public about the need for comprehensive IFA control.

A part of any IFA Management Plan must be to provide education and training for IFA detection, monitoring and pest control efforts. This training should include the general public, landscapers and greenhouse operators, infrastructure service workers, visitors and tourism service providers (such as privately owned campgrounds or horse rental operators), local pest control operators, farmers and local park personnel. In this way, all parties will be working together with the same goal and everyone will understand the need to manage IFA in order to minimize health and environmental concerns. Again, a series of meetings targeted at each audience listed above may be the best educational approach to both educate and develop commitment for an IFA Management Plan.

It is critical that homeowner groups participate in managing IFA colonies. Conducting a

survey about current IFA problems will be beneficial to the community to determine the extent of establishment, and the survey information will assist in educating the public and recruiting homeowners to create a community wide effort to manage IFA in a large area. Educational fliers and meeting invitations could be sent to homeowners with the survey results to help inform the public of upcoming IFA educational meetings that will help determine the priorities of the community. Homeowner education about the need to treat a large area of IFA infested land at the same time during spring and fall; with the same selected insecticide product to provide for better IFA control may be done with the survey and again during the neighborhood meetings. It has been shown that large-scale consistent treatments will reduce the IFA population and will lower reinfestation rates.

A concerted community wide effort will mean that the need for using pesticides will be reduced dramatically. Most reinfestations occur when only some homeowners treat IFA mounds; therefore yards with mounds that are not treated are a source of new IFA infestations in the community. Homeowner groups can determine if they wish to contract with a pest control company to do the treatments or if each homeowner will be responsible to do the twice-yearly treatments. The Texas Red Imported Fire Ant Project (RIFA) web site (http://fireant.tamu.edu) provides guidelines for selecting pest control companies to do area wide treatments for a community, as well as sample notification letters and survey questionnaires.

There is a great economic and environmental benefit to using a systematic approach with an IFA Management Plan to develop preventative maintenance and control measures on a community wide scale. This holistic approach has been used in communities and regions in areas where Red IFA have been established for some time. Web sites with examples of community programs include the Arkansas Fire Ant Advisory Board (http://www.aragriculture.org/pestmanagement/fireants/board.asp), Beaufort, South Carolina (Hilton Head Area), USA (http://www.beaufortusa.com/fireants.htm), the California Department of Food and Agriculture (http://www.cdfa.ca.gov/phpps/pdep/rifa/), Coachella Valley California Red Imported

Fire Ant Program (http://www.cvrifa.org/), and the Orange County California Fire Ant Authority community program (http://www.ocfireant.com/). Another good example of an existing community wide IFA management and public education plan is located on the Texas Red Imported Fire Ant Project web site (http://fireant.tamu.edu).

There are great financial repercussions of doing nothing until after the IFA are established and causing physical damage to community infrastructure. Eradicating IFA from power and traffic boxes requires both electricians to fix and replace switches and damaged power lines, and also certified pest control personnel to eradicate the IFA colony from the infrastructure units. There is the cost of having power and traffic light outages within the community and resulting issues with public safety. Legal issues and potential lawsuits with having public facilities where children, older adults and domestic animals may be stung and injured by IFA also need to be considered. Without education on proper and effective IFA control, homeowners may try to use old fashioned methods of IFA mound control, such as using gasoline to try to destroy the ant mounds, which may result in injury to the homeowner, ecological injury to plants and animals, and environmental damage to the water quality of the local area.

Invasion of IFA into a gateway community in east Tennessee has the potential to be managed without excessive negative publicity or health problems; however the attractiveness of certain types of microclimates to the IFA must be taken into consideration when designing and managing public infrastructure, landscaping and recreational areas. Education for the general public and tourists about IFA must be conducted to minimize the danger to animals and humans in the community. Commitment of the public and economic investment from gateway communities and the Great Smoky Mountains National Park will be required to implement a comprehensive plan to minimize the impacts of IFA. The use of a management plan based upon the outline in this document should assist in this process.

Implementation of an IFA management plan should allow residents and tourists to enjoy

the rural beauty of east Tennessee without becoming injured by IFA. It will also promote the wide diversity of native species to survive and thrive in the Great Smoky Mountains National Park, so that there will continue to be a reason for tourists to vacation in east Tennessee.

Bibliography

Bibliography

Alabama Cooperative Extension System (2000). *Biological Control of Imported Fire Ants*. Retrieved May 13, 2003, from the Alabama Cooperative Extension System Web site: http://www.aces.edu/department/extcomm/publication/anr/anr-1149.html

Allen, C., Rice, K., & Wojcik, D (1997). Effect of Red Imported Fire Ant Envenomization on Neonatal American Alligators. *Journal of Shorter Communications, 31*, 318-321.

Allen, C., R. Lutz, S. Demarais (1995) . Red Imported Fire Ants Impacts On Northern Bobwhite Populations. *Journal of Ecological Applications*, 5:3, 632-637.

Anderson, Alan (1997). Functional groups and patterns of organization in North American ant communities: a comparison with Australia." *Journal of Biogeography*, 24, 433-460.

APHIS, USDA (1993) Fact Sheet Number 20-45-001. *Gypsy Moth: A Pest of Trees.* Retrieved on July 20, 2003 from the Purdue University NAPIS web site: http://ceris.purdue.edu/napis/pests/egm/facts.txt

APHIS, USDA (2000). *Plant Protection and Quarantine- Pest Detection & Detecting And Monitoring of Invasive Species: Plant Health Conference 2000.* Retrieved on May 22, 2003, from the aphis.usda.gov Web site: http://www.aphis.usda.gov/ppq/ep/pestdetection/plthlthcon.pdf

Apperson, C. S., Garcia, L., Waldvogel, M. (1995). *Control of the Red Imported Fire Ant.* Retrieved on May 20, 2003, from the North Carolina Cooperative Extension Service Web site: http://www.turffiles.ncsu.edu/pubs/insects/ag486.html

Appropriate Technology Transfer for Rural Areas (ATTRA). *Sustainable Fire Ant Control*. Retrieved on July 22, 2002, from Appropriate Technology Transfer for Rural Areas (ATTRA) Web site: htpp://www.attra.org/attra-pub/fireant.html

Barber, J.T., Ellgaard, E.G., Thein, L.B., & Stack, A.E. (1989). The Use of Tools for Food Transportation by the Imported Fire Ant, Solenopsis invicta. *Journal of Animal Behavior, 38:3*, 550-551.

Beaufort, USA. (1999). *Fire Ants and fire ant info for the Beaufort, SC and Hilton Head Island Area.* Retrieved on May 29, 2003, from Beaufort, USA Web site: http://www.beaufortusa.com/fireants.htm

Bhatkar, A., Whitcomb, W.H., Buren, W.F., Callahan, P., and Carlysly T (1972). Confrontation behavior between Lasius niger (Hymenoptera: Formicidae) and the imported fire ant. *Journal of Environmental Entomology, 1:3*, 274-279.

Boman, B.J., Bullock, R.C., Parsons, M.L. (1995). Ant Damage to Microsprinkler Pulsator Assemblies. *Journal of Applied Engineering in Agriculture*, 835-836.

Briano, J.A., Calcaterra, L.A., Wojcik, D.P., Williams, D.F., Banks, W.A., &Patterson R.S. (1997). Abundance of the Parasitic Ant Solenopsis daguerrei (Hymenoptera: Formicidae) In South America, a Potential Candidate for the Biological Control of the Red Imported Fire Ant in the United States. *Journal of Environmental Entomology, 26:5*, 1143-1148.

Briano, J.A., Patterson R.S., & Cordo H.A. (1995). Colony Movement of the Black Imported Fire Ant (Hymenoptera: Formicidae) in Argentia. *Journal of Environmental Entomology, 24:5*, 1131-1134.

Briano, J.A., Patterson R.S., & Cordo H.A. (1995). Long-term Studies of the Black Imported Fire Ant (Hymenoptera: Formicidae) Infected with a Microsporidium. *Journal of Environmental Entomology, 24:5*, 1328-1332.

Brinkley, C.K., Ervin, R.T., & Sterling, W.L. (1991). Potential Beneficial Impact of Red Imported Fire Ant to Texas Cotton Production. *Journal of Biological Agriculture and Horticulture, 8*, 145-152.

Brinkman, M., Gardner, W., & Buntin, W. (2001). Effect of Red Fire Ant (Hymenoptera: Formicidae) on Rhinocyllus conicus (Coleptera: Curculionidea), a Biological Control Agent of Musk Thistle. *Journal of Environmental Entomology, 30:3*, 612-616.

Brinkman, M., and Gardner, W. (2001). Use of Diatomaceous Earth and Entomopathogen Combinations Against The Red Imported Fire Ant (Hymenoptera: Formicidae). *Journal of Florida Entomologist*, 740-637.

Brown, W.L. & E.O. Wilson. (1956). Character Displacement. *Journal of Systematic Zoology, 5*, 49-64.

Buren, W.F. (1972). Revisionary studies on the taxonomy of the imported fire ants. *Journal of the Georgia Entomological Society*, 7:1-25.

Bui-Hooper, L.M. (2001). *Fire Ant Control in Urban Areas.* Retrieved on May 29, 2003, Louisiana Agriculture Web site: http://www.agctr.lsu.edu/Communications/LouisianaAgriculture/agmag/44_2_articles/fire

Caldwell, S.T., Schuman, S.H., & Simpson, W.M. (1999). Fire Ants: A Continuing Community Health Treat in South Carolina. *Journal of the South Carolina Medical Association, 95*, 231-235.

California Department of Food and Agriculture (1999). *Red Imported Fire Ants*. Retrieved May 20, 2003, from the California Department of Food and Agriculture Web site: http://www.fireant.ca.gov/htlm/english/facts/facts.html

Callcott, A.M. and Collins,H. (1996). Invasion and Range of Imported Fire Ants in North America. *Journal of Florida Entomologist, 79:2,* 240-251.

Callcott, A.M., Oi, D.H., Collins, H., Williams, D.F., & Lockley, T.C. (2000). Seasonal Studies of an Isolated Red Imported Fire Ant (Hymenoptera: Formicidae) Population in Eastern Tennessee. *Journal of Environmental Entomology*, 29:4, 788-794.

Callcott, A.M., and Collins, H. (1996). Invasion and Range expansion of IFA in North America. *Journal of Florida Entomologist, 79:2*, 241-251.

Calcaterra, L.A., Briano, J.A., &Williams, D.F. (1999). Field studies of the Parasitic Ant Solenopsis daguerrei (Hymenoptera: Formicidae) on Fire Ants in Argentina. *Journal of Environmental Entomology, 28:1,* 88-95.

Carruthers, R.I. (online, 2003). Invasive species research in the United States Department of Agriculture – Agricultural Research Service. *Pest Management Science, 59*, 827-834.

Case, T.J. and Gilpin, M.E. (1974). Interference Competition and Niche Theory Proceedings of the National Academy of Science, 71:8, 3073-3077.

Cherry, R.H. and Nuessly, G.S. (1992). Distribution and Abundance of Imported Fire Ants (Hymenopter: Formicidae) in Florida Sugarcane Fields. *Journal of Environmental Entomology*, *21:4*, 767-770.

Clark, B.R. & Faeth, S.H. (1997). The consequences of larval aggregation in the butterfly Chlosyne lacinia. *Journal of Ecological Entomology 22*, 408-415.

Connell, Joseph. (1983). On the Prevalence and Relative Importance of the Interspecific Competition: Evidence from Field Experience. *Journal of The American Naturalist 122:5*, 661-691.

Cox, G., Mills, J., & Ellis, B. (1992). Fire Ants as Major Agents of Landscape Development. *Journal of Environmental Entomology, 21:2*, 281-286.

DeShazo, R.D, Butcher, B.T., & Banks, W.A. (1990). Reactions to the Stings of the Imported Fire Ant. *The New England Journal of Medicine*, 462-466.

Davis, Tim. *Fire Ant Home Page*. Retrieved on May 13, 2003, from Clemson Extension Fire Ant Web Site: http://entweb.clemson.edu/fireant/

Diffie, S.K., Bass, S.M., & Bondari, K. (1997). Winter survival of *Solenopsis invicta* and the *Solenopsis* hybrid (Hymenopteria: Formicidae) in Georgia. *Journal of Agricultural Entomology*, 14:93-101.

Elton, C.S. (1958). Ecology of Invasions. John Wiley and Sons, Inc., New York.

Fellers, J.H. (1987). Interference and Exploitation in a Guild of Woodland Ants. *Journal of Ecology, 68:5,* 1466-1478.

Fire Ant Spatial Information Management System (FASIMS). *The Fire Ant Spatial Information Management System.* Retrieved on May 20, 2003, from Fire Ant Spatial Information Management System Web site: http://fasims.tamu.edu/

Forys, E., Quistorff, A., & Allen, C. (2001). Potential Fire Ant (Hymenoptera: Formicidae) Impact on the Endangered Schaus Swallowtail (Lepidoptera: Papilionidae). *Journal of Florida Entomologist,* 254-258.

Fraelich, B.A. (1991). Interspecific Competition for Food between the Red Imported Fire Ant, Solenopsis invicta, and Native Floridian Ant Species in Pastures. Thesis, University of Florida.

Georgia Ag and Environmental Sciences. *Managing Imported Fire Ants in Urban Areas*. Retrieved on July 22, 2002, from University of Georgia Ag and Environmental Sciences Web site: http://www.ces.uga.edu/pubcd/B1191.htm

Hardin, G. (1960). The Competitive Exclusion Principle. *Journal of Science, 131*, 1292-1297.

Haun, Walker G. Tennessee Department of Agriculture Regulatory Services, Personal Communication, 2003

Helms, K. and Vinson, S. (2001). Coexistence of Native Ants with the Red Imported Fire Ant, Solenopsis Invicta. *Journal of The Southwestern Naturalists, 46:5,* 396-399.

Holldobler, B. and Wilson, E.O. (1990). The Ants. Belknap Press, Cambridge, Massachusetts, USA.

Holway, D.A. (1999). Competitive Mechanisms Underlying the Displacement of Native Ants by the Invasive Argentine Ant. *Journal of Ecology, 80:1*, 238-251.

Holway, D.A., Lach, L, Suarez, A.V., Tsutsui, N.D. & Case, T.J. (2002). The Causes and Consequences of Ant Invasions. *Annual Review of Ecological Systems*, 33:181-233.

Hu, G.Y. and Frank, J.H. (1996). Effect of the Red Imported Fire Ant On Dung-Inhabiting Arthropods in Florida. *Journal of Environmental Entomology, 25:5*, 1290-1296.

Human, K.G. and Gordon, D.M. (1996). Exploitation and Interference Competition Between the Invasive Argentine Ant, Linepithema Humile, and Native Ant Species. *Journal of Oecologia, 105:3*, 405-412.

James, S., Pereira, R., Vail, K., & Ownley, B. (2001). Survival of Imported Fire Ant (Hymenoptera: Formicidea) Species Subjected to Freezing and Near-Freezing Temperatures. *Journal of Environmental Entomology, 31:1,* 127-133.

Jouvenaz, D.P., Lofgren, C.S., & Banks, W.A. (1981). Biological Control of Imported Fire Ants: A Review of Current Knowledge. *Journal of Entomological Society of America, 27:3,* 203-208.

Kaspari, M. (2000) Do Imported Fire Ants Impact Canopy Arthropods? Evidence from Simple Arboreal Pitfall Traps. *Journal of The Southwestern Naturalist, 45:2,* 118-122.

Killion, M., Grant, W., & Vinson, S. (1995). Response of Baiomys Tayori to Changes in Density of Imported Fire Ants. *Journal of Mammalogy, 76:21*, 141-147.

Kopachena, Buckley, J., & A., Potts, G. (2000). Effects of the Red Imported Fire Ant (Solenopsis Invicta) on Reproductive Success of Barn Swallows (Hirundo Rustic) in Northeast Texas. *Journal of The Southwest Naturalists, 45:4*, 447-482.

Korzukhin, Michael D., Porter, S., Thompson, L., & Wiley, S. (2001). Modeling Temperature-Dependent Range Limits for the Fire Ant Solenopsis invicta (Hymenoptera: Formicidae) in the United States. *Journal of Environmental Entomology, 30:4*, 646-655.

Lockley, Timothy C. *Imported Fire Ants*. (2003). Book Chapter in IPM World. University of Minnesota. Retrieved on May 20, 2003, from the University of Minnesota Web site: http://ipmworld.umn.edu/chapters/lockley.htm

Lockley, Timothy C. (1995). Observation of Predation on Alate Queens of the Red Imported Fire Ant (Hymenoptera: Formicidae) by the Black and Yellow Garden Spider (Araneae: Araneidae). *Journal of Florida Entomologist, 78:4*, 609-610.

Lofgren, C.S., Banks, W.A., & Glancey, B.M. (1975). Biology and Control of Imported Fire Ants." *The Annual Review of Entomology, 20,* 1-30.

Loftin, K., Shanklin, D., & Blackburn, D. (1999). The Federal Imported Fire Ant Quarantine. University of Arkansas Division of Agriculture.

Mackay, W., Vinson, B., Irving, J., Majdi, S., & Messer, C. (1992). Effect of Electric Fields on the Red Imported Fire Ant (Hymenoptera: Formicidae). *Journal of Environmental Entomology, 21:4*, 865-870.

Minor, E. (2002). *Fire Ants Adapt to Cold Weather*. Retrieved on May 20, 2003, from Sunherald Web site: http://sunheral.com/mil/sunherald/news/3603722.htm

Morrison, L. (1999). Indirect Effects of Phorid Fly Parasitoids on the Mechanisms of the Interspecific Competition Among Ants. *Journal of Oecologia, 121*, 113-122.

Morrison, L.W. and Gilbert, L.E. (1999). Host Specificity in Two Additional Pseudacteon Spp. (Diptera: Phorida), Parasitoids of Solenopsis Fire Ants (Hymenthoptera: Formicidae). *Journal of Florida Entomologists, 82:3*, 404-409.

Mississippi State University (2000). *The Imported Fire Ant and Its Control.* Retrieved on May 29, 2003, from: http://msucares.com/pubs/publications/pub1833.htm

Mississippi State University (2000). *Impact of Imported Fire Ants on Mississippi Soil.* Retrieved on May 20, 2003, from Mississippi Agriculture and Forestry Experiment Station Web site: http://msucares.com/pubs/techbullentins/tb223.htm

Nevada Department of Agriculture. Red Imported Fire Ants. Retrieved May 29, 2003, From the Nevada Department of Agriculture Web site: http://www.unlv.edu/faculty/wagner/RIFA.html

North Carolina Department of Agriculture & Consumer Services. *Red Imported Fire Ant.* Retrieved on May 29, 2003, from the North Carolina Department of Agriculture & Consumer Services Web site: http://www.ces.ncsu.edu/depts/ent/notes/Urban/ifa-affect.htm

Orange County, California Vector Control District. Pest Control Bulletin No. 45. " Red Imported Fire Ants."

Oregon Department of Agriculture. *Imported Fire Ants.* Retrieved on May 29, 2003, from*:* http://www.oda.state.or.us/plant/pdd/ent/rifa.html

Orr, M., Seike, S., Gilbert, L. (1997). Foraging ecology and patterns of diversification in dipteran parasitoids of fire ants in South Brazil. *Journal of Ecological Entomology, 22*, 305-314.

Pennisi, E. (2000). When Fire Ants Move In, Others Leave. *Journal of Science*, *289*, 231.

Perfecto, J. and Vanderdermeer, J. (1996). Microclimatic changes and the indirect loss of ant diversity in a tropical agroecosystem. *Journal of Oecologia, 108*, 577-582.

Petren, K. and Case, T. (1996). An experimental demonstration of exploitation competition in an ongoing invasion. *Journal of Ecology,* 77:1, 118-132.

Phillips, S.A., Justino-Atresino, R., & Throrviilson, H.G. (1996). Desiccation Resistance in Populations of the Red Imported Fire Ant (Hymenoptera: Formicidae). *Journal of Physiological and Chemical Ecology, 25:2*, 460-464.

Phillips, S.A., and Thorvilson, H.G. The Red Imported Fire Ant: Prospect for the Invasion of Mexico. Retrieved from the Department of Plant and Soil Sciences, Texas Tech University Web site: http://ecologia.uta.mx/biotam/v5n2/art1.html

Porter, S.D. and Savignano, D.A. (1990). Invasion of polygyne fire ants decimates native ants and disrupts arthropod community. *Journal of Ecology, 71:6*, 2095-2106.

Porter, S. and Tschinkel, W. (1993). Fire ants thermal preferences: behavioral control of growth and metabolism. *Journal of Behavioral Ecology and Socibiology, 32*, 321-329.

Porter, S., Williams, D., Patterson, R., & Fowler, H. (1997). Intercontinental Differences in the Abundance of Solenopsis Fire Ants (Hymenoptera: Formicidae): Escape from Natural Enemies. *Journal of Environmental Entomologist, 26:2,* 373-384.

Purdue University. (1993). *Fact Sheet-Made Available through the CAPS programs.* Retrieved on May 13, 2003 from: http://ceris.purdue.edu/napis/pest/ifa/facts.txt

Ready, C. & Vinson, B. (1995). Seed Selection by the Red Imported Fire Ant (Hymenoptera: Formicidae) in the Laboratory. *Journal of Entomological Society of America,* 1422-1431.

Russell, S., Thorvilson, H., & Phillips, S. (2000). Red Imported Fire Ant (Hymenoptera: Formicidae) Populations in Texas Highway Right-of-Way and Adjacent Pastures. *Journal of Environmental Entomology, 30:2*, 267-273.

Schuman, S., Banov, C., Levy, A., & W. Simpson. (2000). Prevention of Fire Ants Anaphylaxis in South Carolina: Improving Patient Referrals, 1989-1999. *The Journal of the South Carolina Medical Association, 96:9,* 373-377.

Stiles, S. & Jones, R. (1998). Distribution of the red imported fire ant, Solenopsis invicta, in road and powerline habitats. *Journal of Landscape Ecology, 1998*, 335-346.

Stiles, J & Jones, R. (2001). Top-down Control by the Red Imported Fire Ants (*Solenopsis invicta*). *Journal of the American Midland Naturalist, 146:1*, 171-185.

Stoker, R.L., Grant, W.E., & Vinson, B. (1995). Solenopsis invicta (Hymenoptera: Formicidea) Effects on Invertebrate Decomposers of Carrion in Central Texas. *Journal of Environmental Entomology, 24:4,* 818-822.

Tennessee Department of Agriculture. *Imported Fire Ants.* Retrieved on May 29, 2003, from: http://www.state.tn.us.agriculture/regulate/plants/ifa.html

Texas A& M University, Department of Entomology. (2003). *Texas Imported Fire Ants Research and Management.* Retrieved on May 20, 2003, from Texas A&M University, Department of Entomology Web site: http://fireant.tamu.edu/faars/index.html

Texas A& M University, Texas Cooperative Extension. (2002). *Managing Imported Fire Ants in Urban Areas. A Regional Publication Developed for: Alabama, Arkansas, Florida, Georgia, Louisiana, Oklahoma, South Carolina, Tennessee, Texas.* Publication number B-6043

Thorvilson, J., Cokendolpher, J., & Phillips, S., Jr. (1992). Survival of the Red Imported Fire Ant (Hymenoptera Formicidae) on the Texas High Plains. *Journal of Environmental Entomology, 21:5,* 964-968.

Vogt, J., Grantham, R., Smith, R., & Arnold, D. (2000). Prey of the Red Imported Fire Ant (Hymenoptera: Formicidae in Oklahoma Peanuts. *Journal of Environmental Entomology, 30:1,* 123-128.

Wells, J.D. & Henderson, G. (1993). Fire ant predation on native and introduced subterranean termites in the laboratory: effect the number in Coptotermes formosanus. *Journal of Ecological Entomology, 18*, 270-274.

White, Peter. (2002). An Introduction to the St. Louis Declaration and the Codes of Conduct. *Journal of Wildland Weeds*, 4-6.

Wiens, J.A. (1977). On Competition and Variable Environment. *Journal of the American Scientist,* 65, 590-597.

Williams, David. (2003). *Imported fire Ants and Household Insects*. Retrieved on February 12, 2003, from the U.S. Department of Agriculture- Agricultural Research Service Web site: http://cmave.usda.ufl.edu/ifahi/ifarange_us.html

Williamson, M. (1996). Biological invasions. Chapman and Hall, London, England.
Wilson, E.O. (1950). Variation and adaptation in the imported fire ant. *Evolution, 5,* 68-79.

Wilson, E.O. 1971. The insect societies. Belknap Press, Cambridge, Massachusetts, USA.

Winn, Judy. (1999). Managing Red Imported Fire Ants in Agriculture. Agricultural Communication, Texas A&M.

USDA Forest Service, Forest Health Protection, *Hemlock Woolly Adelgid*. Retrieved on June 10, 2003, from the USDA Forest Service web site: http://www.fs.fed.us/na/morgantown/fhp/hwa/hwasite/html

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