# Karst Preserve Management and Monitoring Recommendations

U.S. Fish and Wildlife Service
Austin Ecological Services Field Office
10711 Burnet Rd. Suite #200
Austin, TX 78758

Original version: July 28, 2011

Revised on: April 8, 2014

**TABLE OF CONTENTS**

# 1.0 INTRODUCTION

The purpose of this document is to (1) provide preserve managers a reference guide to current management practices that are most conducive to protecting endangered karst invertebrates, (2) provide guidance in developing site-specific karst management plans, (3) provide recommendations for monitoring, and (4) provide adaptive management techniques that can be implemented if the goal and objectives of preserve management are not achieved. This document may be updated as new scientific information on management techniques becomes available. The U.S. Fish and Wildlife Service (Service) welcomes new information that would improve these management and monitoring recommendations. New information can be provided to the Service address on the cover of this document. We hope that you find this document useful and we appreciate your efforts to conserve these species.

## 1.1 Management Goal and Objectives

The goal of management is:

- to ensure that karst invertebrate preserves are managed in a way that is most conducive to ensuring the continued survival and recovery of the federally listed karst invertebrates in central Texas.

The following objectives will help ensure that the above goal is achieved:

- control red-imported fire ants to a level that they are not a threat to karst invertebrates or their nutrient sources (for example, cave crickets);
- protect the karst ecosystems and listed species from damage or harm that could be caused by things such as vandalism, over-visitation, and contamination of the caves and associated karst habitat;
- maintain the essential internal habitat in the caves, including a stable and mild temperature, high relative humidity, and appropriate water input;
- maintain appropriate nutrient input to caves and associated karst habitat, including cave crickets; plant detritus; root masses; and feces, eggs, and/or dead bodies of animals foraging on the surface and bringing nutrients into the cave;
- maintain or improve the condition and viability of the surface native plant community to support nutrient input and to protect the subsurface from contamination or changes in temperature and humidity; and
- undertake any other activities found to be necessary for long-term conservation of the covered species and the ecosystems upon which they depend.

# 2.0 KARST PRESERVE MANAGEMENT

## 2.1 Red-imported Fire Ants (RIFA) Control

*Purpose of RIFA control*

The purpose of RIFA control is to reduce the number of foraging RIFA to help conserve karst invertebrate species. Control of RIFA near caves is essential as RIFA pose a major threat to listed species (Service 1994, 2011b) and to cave crickets (which are important sources of nutrient input for karst invertebrates (Reddell 1993). Control efforts around caves with endangered karst invertebrates should consist of a multi-faceted approach combined with regular monitoring to assess the effectiveness of control techniques. Success of RIFA control efforts can be measured by a decline in the number of RIFA mounds or increases in cave cricket numbers. Lavoie et al. (2007) reported less competition between cave crickets and RIFA, as well as among cave crickets, near cave entrances that received boiling water treatments at Government Canyon State Natural Area.

*General aspects of RIFA control*

Red-imported fire ants (RIFA) are associated with open habitats that have been disturbed as a result of human activity (for example, lawns, roadsides, and other open, sunny habitats) and areas near moist habitats (Plowes et al. 2007). Conversely, RIFA tend to be absent or rare in late succession or climax communities such as mature forest (Tschinkel 1986). In a study conducted in Austin, Texas, Plowes et al. (2007) found RIFA in areas with open canopy and often with supplementary irrigation (for example, roadsides, apartment complexes, commercial sites, and new residential areas). The risk of RIFA infestation and RIFA densities may vary depending on where a cave entrance is in relation to moist areas.

Several native ants are known to attack and kill founding fire ant queens. These native ants are especially important in eliminating founding fire ant queens and their colonies from non-infested areas (Porter et al. 1988). This highlights the need, especially in areas with low RIFA density (for example, dense vegetative canopy cover), to take extra caution to protect the native ants that may be there.

General aspects of RIFA control include: 1) minimizing ground disturbance (for example, vehicular traffic) and 2) promoting natural landscapes (for example, native plants and high connectivity with other habitat patches) to encourage native arthropod diversity. In addition, technicians conducting RIFA surveys (as well as those conducting routine maintenance and other biological surveys) should be trained to distinguish RIFA from native ants to ensure that only RIFA are treated.

*Methods for RIFA control*

<u>RIFA mound counts</u> - Counts of RIFA mounds should be conducted monthly to ensure that RIFA do not exceed thresholds discussed below. The number of mounds found within 80 meters (m) (262 ft) of cave entrances should be noted (see discussion of thresholds below).

Inspections should consist of walking the entire area (within 80 m (262 ft) of cave entrances) while visually scanning for mounds and marking them with wire flags. Attention should be given to likely places for RIFA colonies such as clearings, stumps, road edges, rotting logs, and cracks in rocks. To assist with assessing the site, a line 80 m (262 ft) long should be marked from the entrance of the cave in the four cardinal directions (north, south, east, and west). The distal end of the line may be marked with flagging tape. This distance locates the radius of the area that should be monitored for RIFA. It is also the area that will be treated for RIFA at least twice annually. The time it takes to fully search a site depends on the vegetation, season, and number of searchers. For example, detectability of RIFA changes throughout the year, as colonies are more difficult to see during dry conditions. When temperatures are cool and rains return, (in spring and fall) RIFA begin rebuilding their mounds (Vinson and Sorensen 1986). Hence, they are easier to locate.

RIFA mound eradication interval – Basic RIFA eradication efforts should occur twice annually, during the spring and fall, regardless of infestation level; higher frequencies may be needed in certain circumstances. For example, the abundance and species richness of native ant species is known to decrease considerably after the initial RIFA invasion (Morrison 2002); therefore, mound eradication efforts should be greatest immediately upon RIFA's arrival into an area. When surface habitat near endangered species sites is cleared of vegetation or otherwise disturbed to a level that may encourage RIFA invasion, control efforts should be increased. This should include a regimen of two or more treatments per month. If some time has passed since the initial RIFA invasion, then control regimens can be decreased to one or fewer times per month, provided that cave cricket abundance has increased, and RIFA mounds have decreased. Once RIFA levels are below the thresholds below, RIFA control can occur twice annually.

RIFA infestation thresholds - RIFA infestation thresholds are used to determine when RIFA treatment should be increased. RIFA mounds should be counted monthly to ensure infestation levels remain under these thresholds. The RIFA infestation threshold for an area within 10 m (33 ft) of a cave entrance is one RIFA mound. Beyond the 10 m (33 ft) distance, the threshold for an area within 80 m (262 ft) of an entrance should be determined by the preserve manager and based on declines in cave cricket abundance (see section 3.2 for survey methods) or an increase in the number of RIFA mounds. We selected 80 m as a threshold distance because most (91.9 percent) cave crickets forage out to about 80 m (262 ft) (Taylor et al. 2005). We recommend this distance rather than the maximum known cave cricket foraging range (105 m (344 ft)) (Taylor et al. 2005) in an effort to balance cost and management benefits. Whenever threshold levels are reached, RIFA mounds should be treated within one week. Treating mounds with boiling water, as described below, has been shown to be effective at maintaining mound density below 80 mounds in a 50 m (164 ft) radius for 92.6 percent (64 out of 74 total sites) of all sites (Myers et al. 2005a).

Boiling water treatments - Currently, the recommended method of eradicating RIFA colonies around caves with endangered invertebrates is to drench RIFA mounds with boiling water. Extremely hot water kills ants on contact and is generated in the field using one of two methods: 1) heating metal buckets filled with water on propane-fired burners and 2) using a diesel-fired pressure washer. The former method is required in roadless areas where equipment must be backpacked into a treatment site. In this situation, on-site rain collection barrels are highly desirable to avoid the need to carry water to the site.

Boiling water treatments are most effective during early to mid-morning when the queen(s) and larvae are likely to be near the top of the mound (Vinson and Sorensen 1986). During long periods of drought or cold the queen(s) and larvae will most likely retreat deep within the mound making them more difficult to eradicate (Vinson and Sorensen 1986). Mounds should not be disturbed before treatment as this causes the ants to move the queen(s) and larvae to deeper locations within the mound or to a remote location. Ants (RIFA) that are outside of the mound may survive such treatments and attempt to re-colonize, but if the queen(s) is destroyed the reproductive capacity of the colony is neutralized.

Passive management strategies to control RIFA – Passive RIFA-management strategies may be implemented to attempt to create certain microhabitat conditions where RIFA mounds are not typically found. These microhabitats are located in areas with higher vegetative canopy cover and in large undisturbed preserves. These strategies could include (1) increasing canopy cover with a diversity of native species (see our preserve design document [Service 2011a] at http://ecos.fws.gov/tess_public/ ) within at least a 20 to 25 m (66 to 85 ft) radius of the cave cricket foraging area as this would be outside the foraging range of nearby RIFA colonies (R. Plowes, University of Texas, pers. comm. 2008), (2) increasing shrub and ground cover by eliminating deer browsing through fencing, and (3) implementing feral hog control to reduce ground disturbance caused by hogs, (4) prohibiting mowing within karst preserves to enable the native plant community to provide adequate cover, and (5) diligently deterring human activity (for example, no trails or picnic tables) that may attract RIFA away from the cave cricket foraging area to avoid RIFA competition and/or predation.

## 2.2 Cave Gating and Perimeter Fencing

Gating a cave necessitates the alteration of the immediate entrance area and may affect the plant and animal community surrounding the cave entrance (Culver et al. 2000). In addition, gates may interrupt the natural flow of moisture into a cave. Therefore, cave gates should only be installed as a last resort and only for caves where there is a threat of vandalism that is both detrimental to karst invertebrates and can be prevented by gating the cave. Gating may also be appropriate where human health or safety may be at risk.

Gate designs should follow the recommendations of Bat Conservation International www.bci.org and the American Cave Conservation Association www.cavern.org to ensure that there are no inadvertent impacts to karst invertebrates or other species. Gates should have bar spacing close enough to prevent human passage, while maximizing normal passage of air, water, organic material, bats, and small terrestrial mammals such as raccoons. A gate that was improperly installed at Shelta Cave in Alabama was a contributing factor to the extirpation of some of the fauna in the cave (Culver 1999). Cave gates should not be painted to prevent paint chips from entering the karst ecosystem. Significant alteration of the cave entrance such as cementing, filling, or enlarging should also be avoided.

Certain types of vandalism, such as dumping toxic materials into a cave entrance, cannot be prevented by cave gating, which underscores the need for fencing of all karst preserves. Preserve perimeter fences may be low-security and designed to be inconspicuous. However, high-security fencing should be placed around the sensitive features of the preserve. A large enough area around the cave entrance should be fenced so that the entrance (and gate, if applicable) is not noticeable from outside the fence. Ideally the entire cave footprint and both drainage basins (surface and subsurface) should be fenced, especially if there is a history of vandalism in the area. Also, fence may need to be sturdy enough to keep deer and feral hogs out, depending on their presence/density in the preserve. The high-security fence should be at least 2 m (6.5 ft) high and of such a design that neither adults nor children could easily climb over or crawl under the fence. The fence should also be designed in a way that does not prevent or deter small to medium-sized vertebrates, which are important components of the karst ecosystem, from passing through it. This can be accomplished by leaving animals access holes, similar to those used in cave gates, at ground level for at least every 5 m (16 ft) of fence.

## 2.3 Vegetation Management

Invasive plant management should be incorporated into management plans to ensure the continued viability of the native vegetation community. Several non-native invasive plants in central Texas are more water-demanding than upland natives (for example, elephant ear plants as compared to Texas persimmons). Hence, karst features near seepages, streams, and other areas of moisture may be more prone to invasion. Mechanical control of invasive plants is preferred, and herbicides should only be used with Service approval. Once invasive plants are located, GPS points should be taken to monitor effectiveness of removal techniques.

### 2.3.1 Wildfire Vegetation Management

If karst preserves contain dead vegetation, preserve managers may need to selectively thin those areas to reduce wildfire risk. Preserve managers may also consider thinning dead vegetation on the perimeter of the preserve if it is adjacent to an urban area. Vegetation should be removed using mechanical control and care should be taken to not spill any diesel or other fuels in preserve areas. Caution should be taken to only remove vegetation that is dead to reduce potential edge effects. We encourage managers to maintain as much canopy cover as possible and to leave the preserve in a natural state.

## 3.0 KARST PRESERVE MONITORING

### 3.1 Karst Invertebrate Monitoring

Long-term monitoring of invertebrate populations, karst ecosystems, and the surface ecosystem is needed to determine if the management objectives identified at the beginning of this document are being met or if adaptive management is necessary. Measures to indicate success in achieving management objectives include:

- quantify numbers of listed and non-listed karst species observed in the cave;
- track visitation into the cave and quantify changes to entrances and in-cave substrates (for example, soil compaction), humidity, and air temperatures;
- quantify numbers of cave crickets to ensure adequate nutrient supply to the cave;
- record changes in surface flora and fauna (including biodiversity and canopy cover) and quantify nutrient sources in the cave (for example, cave cricket guano, leaf litter, flood debris); and
- monitor for damage or long-term effects to surface and subsurface habitat due to dumping, feral hog damage, vandalism, and damage to fences and/or gates.

Monitoring endangered invertebrate populations is difficult due to their low population levels, small size, and cryptic nature. Nevertheless, there have been several long-term monitoring efforts of the endangered invertebrates in Bexar County (SWCA 2010, Veni and Associates 2008), as well as in Travis and Williamson counties, Texas (Elliott 2000, Myers et al. 2005b). The Service provides survey requirements for determining the presence or absence of species in karst features (Service 2006). These requirements include the following: proper sampling weather conditions, sampling diligence and thoroughness, specimen collection and preservation, baiting, reporting, and observer qualifications (Service 2006). Many of these permit requirements should be applied to monitoring of known locations to measure long-term trends in karst invertebrate populations.

To effectively monitor karst invertebrates, attention should be paid to the time spent searching per survey, the number of surveys, and observations on habitat conditions and species activity. To ensure consistent survey effort, a cave should be divided into zones that are approximately 4 to 20 m (13 to 65 ft) of cave passage. Areas that have more complex substrates or that are near the entrance should comprise smaller zones. Timed visual searches are performed in each zone searching all areas in that zone, typically between 15 and 60 person-minutes. The number of surveys should be based on maximizing the ability to detect the species and declines in populations and minimizing impacts to the cave environment. Surveys within all caves with listed species should occur once every year and should be done at the same time of year (within 30 days) during the Spring (March through June) or Fall (September through December). If a listed species has not been confirmed from a cave, more surveys may be needed because research indicates that several monitoring events (10-22) are necessary to detect some karst invertebrate species with a high level of confidence (Krejca and Weckerley 2007). As stated in Service (2006), abundance and diversity of all organisms, and substrates where karst invertebrates are found (for example, on top of soil or on bare rock) should be recorded for each survey. Observations of predation, foraging, or other behaviors of troglobites or trogloxenes during in-cave surveys should be noted. Observations made of predation, competition, and foraging of cave crickets and RIFA should be made during cave cricket exit counts (discussed below). Predator-prey relationships, such as between *Rhadine* beetles and cave crickets, may be more complex than previously thought (Abrams and Ginzburg 2000). For example, we understand that *Rhadine* beetles prey on cave cricket eggs; however, we do not know how many cave cricket eggs are needed to sustain a population of *Rhadine* beetles in a given cave. Hence, any observations of interactions between these taxa should be noted.

### 3.2 Cave Cricket Monitoring

Cave crickets are possibly the most important source of nutrient input for terrestrial karst ecosystems in central Texas (Reddell 1993); therefore, their abundance should be a good indicator of the health of the karst ecosystem. Cave cricket exit counts should be part of all karst monitoring plans because without a healthy population and foraging success of cave crickets, the nutrient input they provide is reduced.

Cave cricket exit counts should be conducted for 2 hours beginning at sunset on days when surface temperatures are between 40˚F (4˚C) and 100˚F (37˚C) and relative humidity is greater than 80 percent. Cave cricket exit counts include documenting the numbers and age (for example, immature or adult) of individuals exiting per 10-minute increments to track demographics and activity peaks. Notations should be made on weather conditions including the current surface temperature and relative humidity, recent weather events in the past week (for example, rain or lack thereof, unusual temperatures) and any weather trends (for example, drought). Counts should be conducted twice a year at the same time of year (within 30 days) during the spring (March through June) and fall (September through December).

### 3.3 Vegetation Monitoring

A vegetation monitoring plan should be developed because preserve sizes are partially based on the area needed to preserve the central Texas native vegetation community (see our preserve design document for more on plant communities at http://ecos.fws.gov/tess_public/). The objective of vegetation monitoring is to assess and maintain the health of the plan community and to refine our understanding of the effects of surface vegetation on the karst ecosystem.

A baseline vegetation survey should be conducted upon preserve acquisition using a quantitative method to appraise the current condition of the preserve. Specific techniques for this may include: 1) pilot nested-plot techniques [using randomly located (and permanently marked) plots that are 1,000$m^2$ for woodlands and 10$m^2$ for grasslands], 2) add-on sample area techniques, or 3) comparable techniques to construct and examine species-area curves (a relationship between an area of habitat and the number of species in that area) to determine vegetation sampling intensity. Data collected for woodland areas should include species composition, density, dominance, importance to overall vegetation community, reproductive profile (size classes; for example, seedling or mature), and amount of canopy cover (using Daubenmire cover classes). In grassland areas, the following should be measured: species composition, relative species dominance and importance to overall vegetation community, percent of total cover, percent of bare ground, and rockiness. This baseline information can be used to determine the need for vegetation restoration to maintain a viable native plant community.

### 3.4 Routine Inspections

We recommend that preserve managers conduct routine preserve inspections to determine whether impacts are occurring that need to be addressed. These inspections should include looking for signs of vandalism and unauthorized entry; damage to cave gates, fencing, and/or signs; damage to vegetation; presence of red-imported fire ants (*Solenopsis invicta*) (RIFA) or other non-native species; dumping; and any other conditions that could impact the listed species or the karst ecosystem. All gates should be checked to ensure that they are functioning correctly, are not blocked by debris, and are equipped with locks that are regularly lubricated.

## 4.0 ADAPTIVE MANAGEMENT

If during surveys/site inspections or monitoring, a determination is made that the management objectives of the preserve are not being met or management activities are determined not to be effective in conserving karst invertebrates, then adjustments to the management program may be needed. Management funding should be designed to provide for adaptive management when necessary. Management adjustments may, for example, be in response to the following:

- destruction or deterioration of subterranean habitat (which could be due to a number of factors including, but not limited to, drying, loss of water input, or point-source and non-point source pollution);
- a single drastic or consistent gradual decline in the number of observed native karst invertebrate species that normally inhabit the caves;
- declines in relative humidity, increased variation in temperature, or shifts from suitable temperatures;
- new information on the biology of karst invertebrates;
- evidence of loss of structural integrity of one or more caves, such as collapse or large breakdown in the cave interior or entrance;
- reduction in cave crickets populations; or
- impacts from climate change.

Adaptive management options to be considered may include, but are not limited to, the following:

- replacement or modification of the karst preserve perimeter fence and/or installation of interior cave security fencing around specific caves;
- installation, replacement, or repair of cave gates;
- restriction, removal, or control of feral hogs and deer;
- restrict human access if soil compaction is occurring inside caves or if trails are developing on the surface;
- irrigation or vegetation management to preserve humidity levels in caves;
- vegetation control or plantings to achieve trespass deterrence, runoff control, improved nutrient input, re-establishment of native plant species, reduced RIFA densities, or cave temperature and moisture regulation – planting more native vegetation to increase overall plant diversity could benefit cave crickets because they are opportunistic scavengers (Taylor et al. 2007);
- vegetation management activities, such as control of invasive plant species and oak wilt;
- vegetation restoration activities, including replanting native species to increase diversity and other suitable restoration activities to enhance plant communities and increase canopy or ground cover;
- investigations to address root causes of poor reproduction of the plant community or survivorship (such as control of seed predators, browsers, disease, etc);
- remediation after a chemical contamination event;
- modifications to RIFA treatments (for example, increasing the frequency of boiling water treatments); and

- physical reinforcement of a cave(s) or cave entrance(s).

More frequent management could increase disturbance to preserves, so managers should consider the benefit to karst invertebrates before they conduct increased management activities.

## 5.0 LITERATURE CITED


Abrams, P.A. and L.R. Ginzburg. 2000. The nature of predation: Prey dependence, ratio dependence or neither? Trends in Ecology and Evolution 15(8): 337-341.

American Cave Conservancy. 2011. Cave gate design. Available from: www.cavern.org

Bat Conservation International. 2011. Cave gate design. Available from: www.bci.org

Culver, D.C. 1999. A history of the management of biological resources of Shelta Cave, Alabama, USA. Pages 130-132 *in* Proceedings of the meeting on caves of natural origin under cities and urban areas. Hungarian Speleological Society, Budapest, Hungary.

Culver, D.C., L.L. Master, M.C. Christman, and H.H. Hobbs III. 2000. Obligate cave fauna of the 48 contiguous United States. Conservation Biology 14(2): 386-401.

Elliott, W.R. 2000. Community ecology of three caves in Williamson County, Texas: 1991-1999. Annual Report submitted to Texas Parks and Wildlife Department.

Krejca, J.K. and F.W. Weckerly. 2007. Detection probabilities of karst invertebrates. Report prepared for Texas Parks and Wildlife Department and U.S. Fish and Wildlife Service.

Lavoie, K.H., K.L. Helf, and T.L. Poulson. 2007. The biology and ecology of North American cave crickets. Journal of Cave and Karst Studies 69: 114-134.

Morrison, L.W. 2002. Long-term impacts of an arthropod-community invasion by the imported fire ant, *Solenopsis invicta*. Ecology 83(8): 2337-2345.

Myers, G.R. III, J. Krejca, and P. Sprouse. 2005a. Cave management at Camp Bullis 22 September 2003-21 March 2004. Report Prepared for Directorate of Safety, Environment, and Fire, Natural and Cultural Resource Branch, Fort Sam Houston, Texas.

Myers, G.R. III, P. Sprouse, and J. Krejca. 2005b. Community ecology of three caves in Williamson County, Texas: 2000-2003. Unpublished Report for the Texas Cave Management Association.

Porter, S.D., B. Van Eimeren, and L.E. Gilbert. 1988. Invasion of red imported fire ants (Hymenoptera: Formicidae): microgeography of competitive replacement. Annals of the Entomological Society of America 81: 913-918.

Plowes, R.M., J.G. Dunn, and L.E. Gilbert. 2007. The urban fire ant paradox: native fire ants persist in an urban refuge while invasive fire ants dominate natural habitats. Biological Invasions 9: 825-836.

Plowes, R.M. 2008. Email dated July 14, 2008 to Cyndee Watson and Alisa Shull regarding the draft Bexar County Recovery Plan.

Reddell, J.R. 1993. The status and range of endemic arthropods from caves in Bexar County, Texas. A report on a study for the U.S. Fish and Wildlife Service and Texas Parks and Wildlife Department.

Service (U.S. Fish and Wildlife Service). 1994. Recovery plan for endangered karst invertebrates in Travis and Williamson Counties. Austin, Texas.

Service (U.S. Fish and Wildlife Service). 2006. Service Section 10(a)(1)(A) Scientific Permit Requirements for Conducting Presence/Absence Surveys for Endangered Karst Invertebrates in Central Texas.

Service (U.S. Fish and Wildlife Service). 2011a. Karst preserve design recommendations. Fish and Wildlife Service. http://ecos.fws.gov/tess_public/

Service (U.S. Fish and Wildlife Service). 2011b. Bexar County karst invertebrates recovery plan. Fish and Wildlife Service. http://ecos.fws.gov/tess_public/

SWCA Environmental Consultants. 2010. Annual report 2009 management and maintenance activities on the seven La Cantera preserves, January 2009-December 2009. SWCA Environmental Consultants. Unpublished Report.

Tschinkel, W.R. 1986. Distribution of fire ants *Solenopsis invicta* and *S. Geminata* (Hymenoptera: Formicidae) in northern Florida in relation to habitat and disturbance. Annals of the Entomological Society of America. 81(1): 76-81.

Taylor, S.J., J. Krejca, and M.L. Denight. 2005. Foraging range and habitat use of *Ceuthophilus secretus* (Orthoptera: Rhaphidophoridae), a key trogloxene in central Texas cave communities. American Midland Naturalist 154: 97-114.

Taylor, S.J., J.K. Krejca, and K. Hackley. 2007. Examining possible foraging distances in urban and rural cave cricket populations: carbon and nitrogen isotope ratios ($\delta^{13}C$, $\delta^{15}N$) as indicators of trophic level. Illinois Natural History Survey Technical Report 2007(59): 1- 97.

Veni, G. and Associates. 2008. Hydrogeological, biological, archeological, and paleontological karst investigations, Camp Bullis, Texas, 1993-2007. Report for Natural and Cultural Resources, Environmental Division, Fort Sam Houston, Texas, George Veni and Associates, San Antonio, Texas, 2,621 pp.

Vinson, S.B. and A.A. Sorenson. 1986. Imported fire ants: life history and impact. Texas Deptartment of Agriculture.