New termite baiting technologies for the preservation of cultural resources:

RESULTS OF FIELD TRIALS IN THE NATIONAL PARK SYSTEM

By Mark Gilberg and Nan-Yao Su

Since 1995, the National Center for Preservation Technology and Training (NCPTT)—part of the NPS Directorate of Cultural Resource Stewardship and Partnerships—has sponsored a series of field trials to assess the efficacy and practical application of a new technology for the control of termites in historic structures and buildings. Many of these field trials have been conducted in our national parks where cultural resources are severely threatened by termite activity (fig. 1). These sites have proved ideal settings for this evaluation and for testing other new technologies. Moreover, the field trials have helped ensure the preservation of important cultural resources.

Background

Termites are a significant structural pest in the United States, costing the public nearly $1.5 billion in damage each year. The bulk of this damage can be attributed to subterranean termites. Historic buildings and structures are particularly vulnerable to subterranean termite damage, given the traditional use of wood as a building material. Termite damage to historic buildings is both costly and irreversible and can diminish the historic significance of the structure through the loss of original building fabric. Cultural landscapes are also vulnerable to termite damage. In New Orleans, many of the historic oak trees that add shelter and beauty to the city are threatened by an introduced species, the Formosan subterranean termite, *Coptotermes formosanus*.

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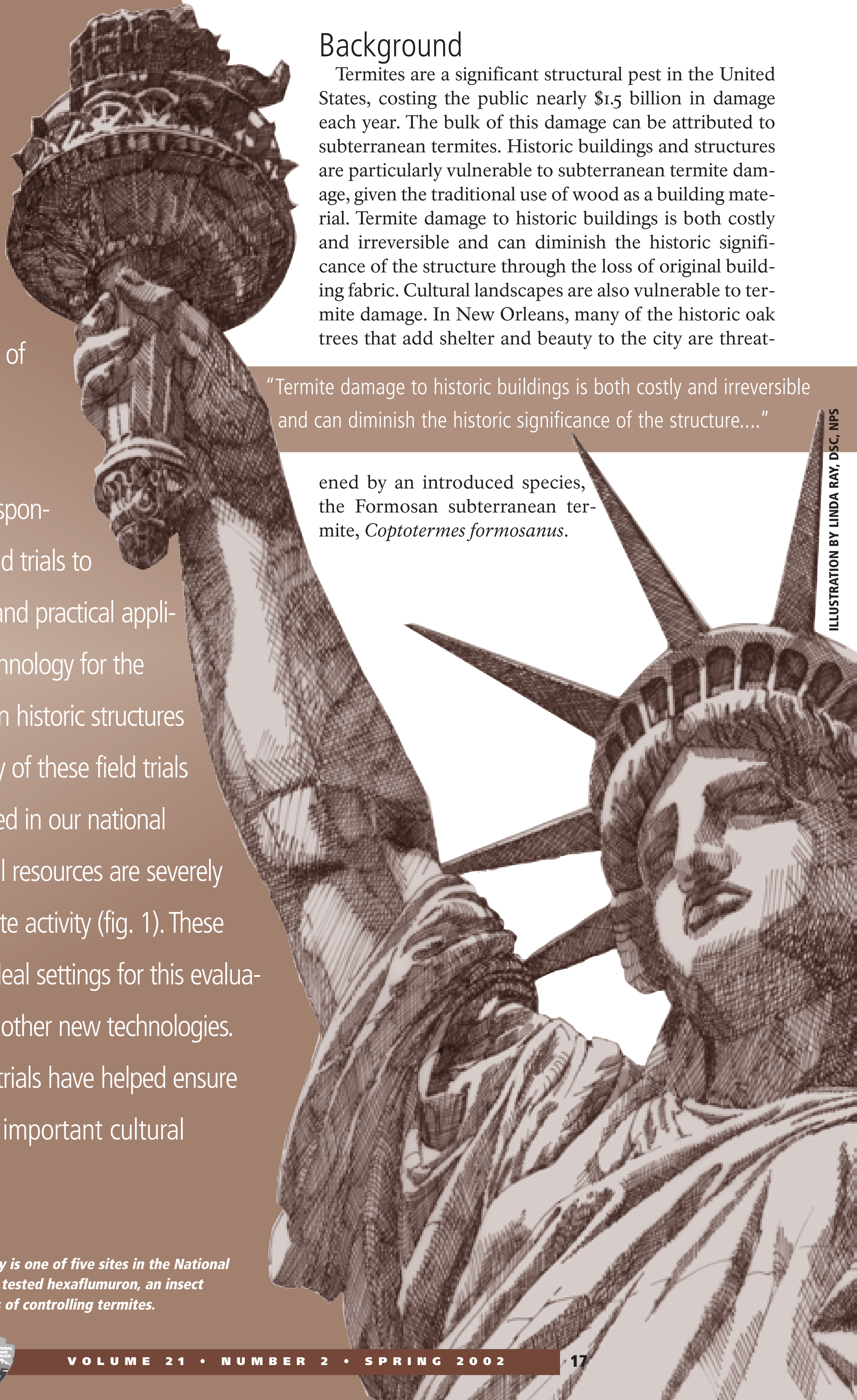

ILLUSTRATION BY LINDA RAY, DSC, NPS

Figure 1. The Statue of Liberty is one of five sites in the National Park System where scientists tested hexaflumuron, an insect growth regulator, as a means of controlling termites.

This species can construct nests within the dead heartwood of the tree eventually weakening it to the point where it is unstable and falls in bad weather.

Conventional methods for the control of subterranean termite infestations rely heavily on the use of organic (i.e., carbon-based) insecticides to provide a barrier for the exclusion of soil-borne termites from a structure. Typically, large volumes of liquid insecticide are applied to the soil beneath and surrounding an infested building. Poisoning the soil is not a sustainable practice and may contaminate groundwater as well as pose health and safety hazards. Moreover, such an approach is not altogether effective. Creating an uninterrupted barrier of treated soil beneath an existing structure is extremely difficult, and gaps in the barrier invariably allow access to the structure. Also, because the soil treatment only deters termite attack, the vast majority of subterranean termites are unaffected. Conventional soil treatments often result in physical damage to the structure; they require the drilling of often disfiguring and unsightly holes in the foundation floor before liquid insecticides are injected into the soil.

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New termite baiting technologies

In response to these concerns, a number of new baiting technologies have been developed in recent years as an alternative to conventional liquid insecticides. Of these, baits containing the insect growth regulator, hexaflumuron, have proved most promising in successfully eliminating subterranean termite populations at or near structures. Hexaflumuron inhibits the synthesis of chitin, which is essential for the formation of insect exoskeleton, but is virtually harmless to vertebrates (LD_{50}>5,000mg/kg[1]). The treatment uses a monitoring and baiting procedure, whereby hexaflumuron is delivered by foraging termites to eliminate the entire colony population. The procedure is marketed currently as the Sentricon® Termite Colony Elimination System (Dow AgroSciences, Indianapolis, Indiana) to authorized pest control operators. Studies using the Sentricon system or its commercial prototypes have confirmed that termite colonies of several million individuals can be suppressed to the point of inactivity (or observed elimination) using less than 1g of hexaflumuron. Moreover, elimination of colony populations creates a zone of termite-free soil surrounding a building for several years.

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The Sentricon system employs a cyclical process of monitoring and baiting for termite activity. Initially, a technician installs Sentricon stations containing monitoring devices in the soil surrounding a structure. When termite activity is discovered in a station, the monitoring device is replaced with bait containing 0.5% hexaflumuron (fig. 2A). Foraging termites feed upon the baits and thoroughly distribute the hexaflumuron throughout the colony population. Unlike conventional termiticides, hexaflumuron is a slow-acting toxicant that kills termites only when they molt, every 1-2 months. Thus, dead termites do not accumulate around the bait that would otherwise repel other foraging termites and prevent further uptake of the bait. Several months may be required to achieve control but the end result is complete elimination. Once the colony is eliminated, a return to monitoring continues to detect further termite activity.

Hexaflumuron targets only subterranean termites; drywood termites and other insect species remain unaffected. Also, it only impacts those colonies at or near the site to be protected. Hexaflumuron can not be spread over a large geographical area and thus threaten the extinction of *C. formosanus* as a species. In fact, experimental results to date suggest that re-infestation always occurs but at a slower rate than in the absence of hexaflumuron due to an overall decrease in termite population levels around the site.

Field trials

NCPTT-sponsored field trials involving the use of Sentricon have been conducted at a number of National Park System sites particularly in the Southeast and the Caribbean where subterranean termite activity is most pronounced and threatens many historically significant structures. In the greater New Orleans area the annual cost of termite damage and treatment is estimated at $300 million. The historic French Quarter is particularly threatened because of the widespread use of wood as a building material and shared-wall construction practices that make pest control difficult (Freytag et al. 2000). Much of this damage can be attributed to the Formosan subterranean termite, which was introduced from Asia after World War II. This species is characterized by extremely large colonies and, unlike other subterranean termites, is capable of forming aboveground nests.

[1] Lethal Dose, 50%, refers to the amount of insecticide that, if administered to a population, will cause 50% of the population to die. It is usually expressed in terms of milligrams of insecticide per kilogram of subject body weight.

To date, the National Center for Preservation Technology and Training has sponsored field work involving the use of Sentricon at San Juan National Historic Site, Statue of Liberty National Monument, Cane River Creole National Historical Park, Virgin Islands National Park, and New Orleans Jazz National Historical Park. These trials represent a joint effort by NCPTT and its partners—the University of Florida, the New Orleans Mosquito and Termite Control Board, and Dow AgroSciences—to advance our knowledge of subterranean termite control in historic structures. In addition to establishing the efficacy of Sentricon, these trials yielded considerable information regarding the ecology and behavior of subterranean termites. They also provided opportunities to evaluate several new technologies for detecting termite activity, including thermal imaging and acoustic emissions. We highlight below the methods used to (1) identify termite infestation, (2) measure termite activity for bait efficacy assessment, and (3) apply baits, and the results from several of these trials.

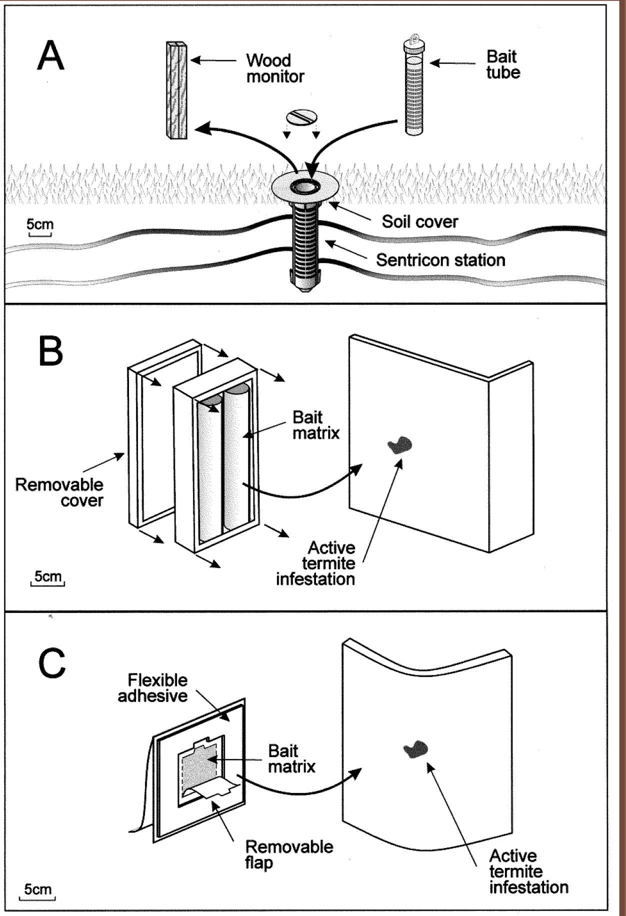

Figure 2. The field trials used three types of bait stations to deliver the hexaflumuron baits: (A) in-ground Sentricon station, (B) hard-style aboveground bait station, Recruit AG, and (C) soft-style aboveground bait station.

Identifying termite infestation

The first step is to identify the whereabouts of termite activity or damage. At the Statue of Liberty National Monument, signs of termite activity such as swarming, wood damage, and mud-tubes as noticed by park personnel led us to identify three sites of live termite activity in the structure (fig. 3): boiler room (BOL), display case (DIS), and sally port (SAL). Another important tool in identifying termite activity in soil is the survey using wooden stakes (Su and Scheffrahn 1986). Researchers drove spruce stakes in soil surrounding the exterior walls of the monument to detect termite activity. The survey revealed two activity sites, one in the soil outside the boiler room and the other at the sally port exit (EXT) (fig. 3). As shown in figure 3, researchers identified four clusters or populations of the eastern subterranean termite, *Reticulitermes flavipes*, at the Statue of Liberty (Su et al. 1998).

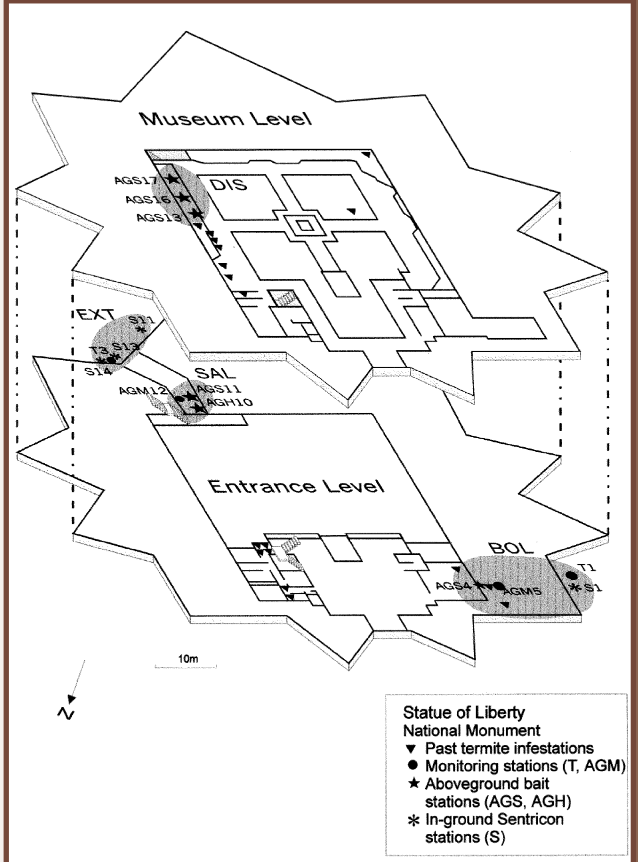

Figure 3. Site inspection and stake survey revealed four clusters of* R. flavipes *activity in the Statue of Liberty National Monument. Termite activity was measured using underground (T) and aboveground (AGM) monitoring stations. Three types of bait stations delivered hexaflumuron: in-ground Sentricon station (S), aboveground bait station Recruit AG (AGH), and soft-style aboveground bait station (AGS).

Measuring termite activity

Termite activity must be quantified before, during, and after bait application in order to properly assess the effects of the baits on the populations. Researchers used several techniques to measure termite activity.

Underground monitoring station

At some sites, researchers replaced survey stakes with underground monitoring stations composed of a plastic collar containing a feeding block (Su and Scheffrahn 1986) (fig. 4A). Termite activity is quantified by measuring the wood weight loss of the feeding block. The monitoring stations also provide opportunities to conduct a mark-recapture procedure to identify the foraging range of the termite colony. In the Creole House of the Cabildo complex in New Orleans, for example, researchers collected workers of the Formosan subterranean termite from a station in the courtyard and stained them with a blue dye before releasing them back into the same station (fig. 5). During the follow-up inspection they found blue termites in the wooden floor of the second-floor office (Su et al. 2000).

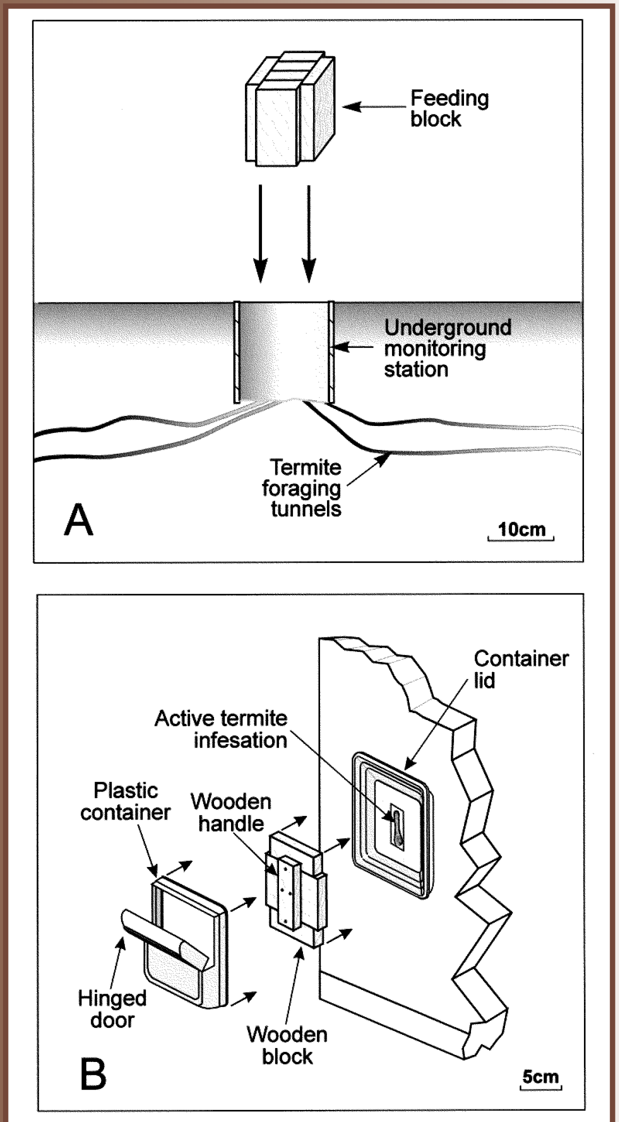

Figure 4. The field trials used underground (A) and aboveground (B) monitoring stations to measure termite activity at several historic sites.

Aboveground monitoring station

Soil was not always accessible. Therefore, researchers used an aboveground monitoring station similar to that described by Su et al. (1996) (fig. 4B) to measure the termite activity in some sites such as San Cristobal of San Juan National Historic Site.

Acoustic emission device

In addition to the monitoring stations, researchers used other methods such as acoustic emission detectors (AED) to measure termite feeding in wood (fig. 6). The detector recorded sound waves of ultrasonic frequency that were generated when termites broke wooden fibers. Researchers used the device to quantify termite activity in the wooden floor of the display case in the Statue of Liberty National Monument (Su et al. 1998), and in wooden beams of the Fort Christiansvaern of Virgin Islands National Park.

Figure 5. Termites marked with blue dye were released into a monitoring station to delineate colony foraging range.

Other methods of quantifying termite activity

At some historic sites, none of these tools could be used because of preservation concerns. For these sites, researchers counted the number of active monitoring stations and any other signs of termite activity. In Fort Christiansvaern of Virgin Islands National Park, for instance, researchers counted newly emerged foraging tubes of the subterranean termite *Heterotermes* sp. and removed them at each visit so that any new termite activity would be recorded.

Figure 6. The acoustic emission detector (AED) recorded sound waves that were generated when wooden fibers were broken by termite mandibles, and was used to measure termite feeding in wood.

Bait application

In some places where soil access was limited, researchers used aboveground stations (Recruit®AG), which consisted of a plastic box containing hexaflumuron bait (fig. 2B, page 19). Researchers attached the open-side of the Recruit AG bait box over an active infestation so that the bait was accessible to foraging termites. Researchers also experimentally constructed another type of aboveground bait station, the soft-style station, for use in several historic sites. This station consisted of a flexible plastic pouch containing hexaflumuron bait (fig. 2C, page 19) and, on its back side, a removable flap surrounded by flexible adhesive. Soft stations were attached over active infestations and the removable flap was pulled to expose the bait. Because of its flexibility, the soft station was adaptable to flat, curved, or contoured surfaces.

Effects of hexaflumuron baits on termite populations

Researchers measured termite activity at the Statue of Liberty National Monument (see fig. 3) using underground (T) and aboveground (AGM) monitoring stations. Additionally, they used three types of bait stations to deliver baits to termite populations, including the in-ground Sentricon station (S), the aboveground bait station, Recruit AG, (AGH), and the soft-style aboveground bait station (AGS). Termites fed on hexaflumuron baits as soon as researchers placed a bait station inside the display case in August 1996 (fig. 7, DIS). The acoustic emission device detected 20–30 feeding episodes per minute from the wooden floor of the display case through fall 1996 to spring 1997, during which *R. flavipes* continued to feed on the baits. By March 1997, no termites were found in the bait station, and the feeding activity in the nearby wooden floor also ceased.

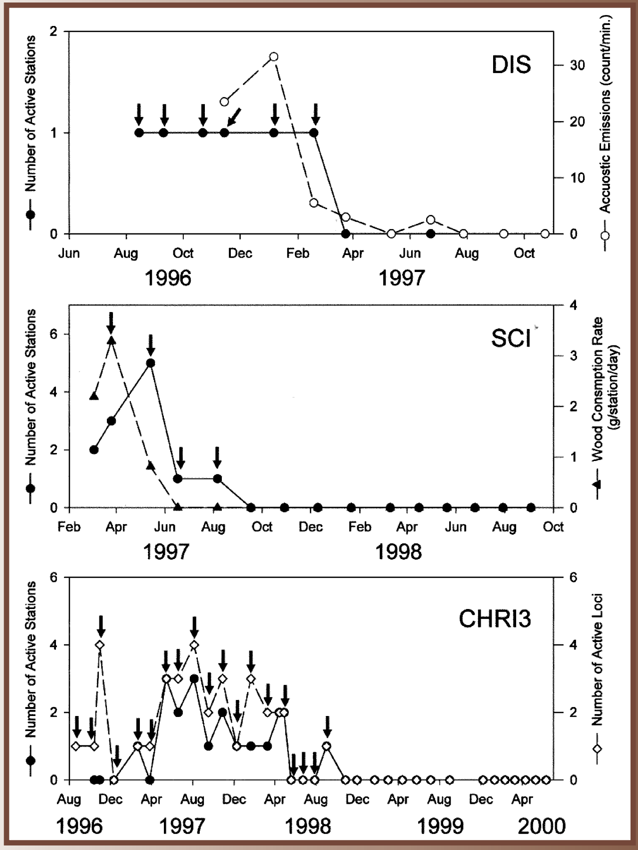

Figure 7. The researchers quantified termite activity as the acoustic emission count (per minute) in the display case of the Statue of Liberty National Monument (DIS), wood consumption rate (g wood per station per day) in the utility room of San Cristobal of San Juan National Historic Site (SCI), and number of active sites such as newly emerged foraging tubes of* Heterotermes *sp. in a storage room of Fort Christiansvaern, Christianstead National Historic Site (CHRI3). Arrows depict applications of hexaflumuron baits. Number of active stations was also included to measure the overall termite activity during and after bait applications.

In March 1997, the subterranean termite *Coptotermes havilandi* fed extensively on wooden blocks in two monitoring stations in the utility room of San Cristobal (fig. 7, SCI). In April, researchers applied hexaflumuron baits to these stations, and after one month, *C. havilandi* activity had declined significantly. By July no termites were found in the monitoring station. Slight feeding on hexaflumuron baits continued in July and August. During this time researchers found *C. havilandi* individuals in the bait station that exhibited apparent symptoms of hexaflumuron effects such as marbled coloration on the worker's abdomen. Since September 1997, no termite has been found in this location.

Unlike *Coptotermes* sp. that is more susceptible to hexaflumuron, the response of *Heterotermes* sp. in Fort Christiansvaern of the Virgin Islands National Park was more erratic. After the initial baiting in a storage room in August 1996, termite activity started to decline in December, but new activity emerged in spring 1997 (fig. 7, CHRI3). Despite repeated applications of baits throughout 1997, termites continued to feed on baits and new foraging tubes kept appearing. Our persistent efforts seemed to pay off when this second wave of termite activity ceased in spring 1998. The cessation lasted for three months, but in October 1998 termites reappeared in one bait station. This third wave of light activity, however, did not last as long as before. Researchers have found no termites or additional foraging tubes in this room since December 1998, two months after termites began feeding on hexaflumuron baits. The repeated cycles of activity during bait application appeared to be common for *Heterotermes* sp., which tend to have many small colonies in one area.

Monitoring and inspection

After successfully eliminating termite populations at a historic site, resource managers must establish a monitoring program to continue protecting the site from further termite infestation. At the Statue of Liberty National Monument, for example, Sentricon stations installed in soil surrounding the exterior wall of the monument have been monitored quarterly since 1998, and no termites have been found on Liberty Island. Termites are abundant in the tropics and subtropics. Even after successfully eliminating all detectable populations of *Heterotermes* sp. at Fort Christiansvaern, Virgin Islands National Park, re-infestation by neighboring populations is likely. To date, the routine inspections by Park Service personnel have not detected any new termite activity. If any sign of a new infestation is detected, the baiting program will resume to eliminate the new population before severe damage occurs.

Conclusions

National Park System sites and monuments are ideal environments for evaluating many new technologies for the preservation of cultural resources. Recent studies involving the use of baits containing the insect growth regulator, hexaflumuron, have demonstrated that they are safe and effective in protecting historic buildings and structures against subterranean termites with no adverse effect upon the cultural or surrounding natural resources. Moreover, the introduction of baits did not interfere with visitor services or the quality of the visitor experience at the sites or monuments. PS

References

Freytag, E. D., M. K. Carroll, and E. S. Bordes. 2000. Control of Formosan subterranean termites in Perserverance Hall in New Orleans, Louisiana. APT Bulletin XXXI:71–75.

Scheffrahn, R. H., W. P. Robbins, P. Busey, N.-Y. Su, and R. K. Mueller. 1993. Evaluation of a novel, hand-held, acoustic emissions detector to monitor termites (Isoptera: Kalotermitidae, Rhinotermitidae) in wood. Journal of Economic Entomology 86:1720–29.

Su, N.-Y., and R. H. Scheffrahn. 1986. A method to access, trap, and monitor field populations of the Formosan subterranean termite (Isoptera: Rhinotermitidae) in the urban environment. Sociobiology 12:299–304.

Su, N.-Y, P. M. Ban, and R. H. Scheffrahn. 1996. An aboveground station for monitoring structure-infesting populations of the Formosan subterranean termite (Isoptera: Rhinotermitidae). Sociobiology 27:39–45.

Su, N.-Y., and R. Scheffrahn. 1998. A review of subterranean termite control practices and prospects for integrated pest management programs. Integrated Pest Management Review 3:1–13.

Su, N.-Y., J. D. Thomas, and R. Scheffrahn. 1998. Elimination of subterranean termite populations from the Statue of Liberty National Monument using a bait matrix containing an insect growth regulator, hexaflumuron. Journal of the American Institute for Conservation 37:282–92.

Su, N.-Y., E. Freytag, E. Bordes, and R. Dicus. 2000. Control of the Formosan subterranean termite infestations in historic Presbytere and the Creole House of the Cabildo, French Quarter, New Orleans, using baits containing an insect growth regulator, hexaflumuron. Studies in Conservation 45:30–38

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