Eradicating *Wasmannia auropunctata* (Hymenoptera: Formicidae) from Maui, Hawaii: The Use of Combination Treatments to Control an Arboreal Invasive Ant

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Abstract. A small infestation of *Wasmannia auropunctata* (little fire ant) was discovered on the island of Maui, Hawaii in September 2009. After delimiting the infestation, we treated it on twelve occasions over the course of a year using two types of granular baits for the ground layer and a paste bait containing indoxacarb (0.18% a.i.) on the vegetation. These treatments rapidly reduced the *W. auropunctata* population with only a single ant recorded after five months treatment and none thereafter. To date, one year after initiation of treatments, no further positive detections have been observed and we tentatively report the eradication of this species from Maui. The key components of the treatment program contributing to its success to date have been the baiting of arboreal nests with a formulation designed for use on vegetation and the strategy of baiting repeatedly even after no ants could be detected with conventional survey methods. The response to the detection of this invasive species on Maui is a successful example of multi-agency collaboration and cooperation necessary for invasive species management. We recommend that future eradication and control attempts for this species include treatment of the arboreal components of infested habitats.

Key words: little fire ant, *Wasmannia auropunctata*, eradication, arboreal treatment, indoxacarb, Maui, Hawaii, invasive species

Introduction

Ants (Hymenoptera: Formicidae) are a diverse and ubiquitous group of social insects found throughout the world. Their remarkable ability to survive and thrive in almost any environment is due in no small part to their eusocial and cooperative behavior. Colonial living, division of labor amongst members, care for young, caste specialization and sophisticated chemical communication all contribute to an increased capacity for colony survival and reproduction (Holldobler and Wilson 1990, 1995). A relatively small subset of ant species has exploited these characteristics to thrive in urban environments, spreading with humans and commerce to invade new habitats. These species, often referred to as tramp ants, are moved readily by human activity, hitching rides with the movement of commodities (McGlynn 1999).

Tramp ants appear to share additional characteristics that increase their ability to invade new habitats, such as the absence of intraspecific aggression, a polydomous colony structure, tolerance of multiple queens within a nest, high interspecific aggression, reproduction by budding (Passera 1994), and often form mutualistic associations with other organisms (Way 1962, Rao et al. 1989, Reimer et al. 1990, Helms and Vinson 2002, Wetterer and Porter

2003). Tramp ants are able to invade and thrive even in locations with considerable biotic resistance provided by aggressive endemic ant communities (Majer 1994, Hoffmann 1998, Vanderwoude et al. 2000, Nattrass and Vanderwoude 2001, Hoffmann and Saul 2010). Pacific island ecosystems often lack diverse endemic ant communities (Wilson and Taylor 1967) making invasion by new ant species even more probable.

The little fire ant (LFA) (*Wasmannia auropunctata* (Hymenoptera: Formicidae)) is one of these tramp ant species, spreading throughout tropical regions over the last 100 years or so (Wetterer and Porter 2003). Their impacts are particularly broad: reducing biological diversity (Fabres and Brown jnr 1978, Clark et al. 1982, Jourdan 1997, Wetterer et al. 1999, Le Breton et al. 2003, Walsh et al. 2004, Walker 2006, Beavan et al. 2008), stinging humans and domestic animals (Theron 2005) and increasing homopteran insect populations on susceptible plants (Spencer 1941, Delabie 1988, de Souza et al. 1998, Fasi 2009). *Wasmannia auropunctata* nest in both the ground layer as well as in vegetation, forming three-dimensional supercolonies that may contain more than 200 million ants per hectare (Souza et al. 2008). They defy control by pesticides, cultural techniques and commercially available baits, which are mostly granular and therefore cannot be deployed to control arboreal nests (Delabie 1989, Abedrabbo 1994, Souza et al. 2008, Taniguchi 2008). Notable exceptions are reported by Abedrabbro (1994) and Causton and colleagues (Causton et al. 2005) who eradicated *W. auropunctata* from Santa Fe and Marchena islands in the Galapagos. To date these are the only reported instances of a successful eradication of this species.

Little fire ants were first recorded in the Hawaiian archipelago by Conant and Hirayama (2000) in 1999 at which time they were confined to the island of Hawaii. The following year a small population, linked to the movement of plant material from Hawaii Island, was discovered on Kauai. The Kauai population remains, despite concerted treatment efforts in the years following, but is limited to a single 4 hectare infestation. Since its initial discovery, *W. auropunctata* have spread rapidly and extensively through the eastern coast of Hawaii Island, and by 2010 were widely distributed from lower Puna to Laupahoehoe as well as Kailua-Kona on the west coast. In September 2009, an additional population, confined to a single property approximately 7 kilometers west of Kahului, was reported on the island of Maui.

A multi-agency response team was established by the Hawaii Department of Agriculture which included staff from the Maui Invasive Species Committee, the Pacific Cooperative Studies Unit, University of Hawaii, the County of Maui, United States Department of Agriculture, United States Geological Survey and others. This team developed a response plan which included detailed activities for a delimiting survey, movement controls, investigation into the origin of the infestation, public outreach and an operational plan for eradication. This report details the results of the eradication component of the response.

Previous attempts to control or eradicate *W. auropunctata* have been based on single or repeated applications of granular baits initially developed for control of the Imported Fire Ant (Williams and Whelan 1992, Causton et al. 2005, Souza et al. 2008, Taniguchi 2008). Other methods have also been tested including the use of pesticide sprays (Spencer 1941, Osburn 1949, Abedrabbo 1994), cultural practices such as burning and habitat removal (Abedrabbo 1994), sticky barriers (Delabie 1989) and synthetic pheromone components (Troyer et al. 2009). Baits appear to be the most effective control method at this time as they have the greatest potential to reach the queens, thus reducing or eliminating the capacity to produce new offspring. Most commercially available baits suitable for control of *W. auropunctata* are marketed primarily for control of *Solenopsis invicta*. They are manufactured by combining vegetable oil and a toxicant with defatted corn grits, a formulation largely unchanged since 1962 (Williams 1983) (although toxicants have changed since that time). These baits appear to be moderately attractive to *W. auropunctata* (Williams and Whelan

1992) and can be effective for control of nests located on the ground. Granular baits cannot be successfully applied to vegetation however, and attempts to control *W. auropunctata* in complex habitats with taller vegetation have not succeeded because the untreated arboreal nests quickly recolonize the ground layer (Souza et al. 2008). Unpublished trials of an experimental paste bait made with peanut butter as the carrier/attractant and indoxacarb 1.8 g/kg as the toxicant, yielded promising results for arboreal *W. auropunctata* colonies. This bait can be applied to vegetation up to a height of 7 meters using techniques described by Vanderwoude and Nadeau (2009).

Materials and Methods

The infested property was located on the island of Maui, Hawaii, approximately 7 kilometers west of the main city, Kahului (20°56"N; 156°31"W). The district experiences a dry tropical climate with a mean annual precipitation of 488 mm (Figure 1). Mean minimum annual temperature is 19.7°C and mean maximum annual temperature is 28.8°C (Figure 2).

The infested site was a mixed-use property containing several residential buildings, covering about 2 hectares. A wide range of agricultural crops were being cultivated on the site including banana, carambola, coconut, guava, papaya, citrus, field crops of taro, yam, sweet potato and many other vegetables. Various species of ornamental trees surrounded the houses.

A site delimiting survey using peanut butter on coffee stirrers was conducted prior to beginning treatment. This survey identified an infested area of approximately 0.5 ha. Baits were applied within the treatment area as well as a buffer area extending 20 meters beyond the infested area, resulting in a treatment zone of approximately 1 ha.

The property was treated with three different baits. Esteem™ (0.5% pyriproxyfen) was applied to the crop areas and Probait™ (0.74% hydramethylnon) was applied to turf and ornamental areas every month from October 2009 to September 2010. The experimental indoxacarb (0.18%) bait was applied to all vegetation > 1.8 meters tall every month from November 2009 to September 2010 (except August 2010). The indoxacarb treatment was applied under Hawaii Department of Agriculture Experimental Use Permit EUP09-12. Granular baits were applied with a Solo™ bait spreader and the paste bait was applied with a Texture-Pro™ pneumatic texture gun modified for this purpose (Vanderwoude and Nadeau 2009). Application rate of each bait product was approximately 2kg/ha. Baits were applied monthly, for 12 months, broadly following the guidelines for site eradication of Imported Fire Ants outlined by Drees et al. (2002).

Monitoring of LFA activity consisted of both monthly and biannual surveys. Monthly surveys focused on high risk locations at the site. The biannual surveys involved the placement of a grid of baits covering the entire site.

Monthly LFA activity was measured in two ways: (1) Visual survey: A thorough visual inspection of likely nest locations was conducted monthly throughout the site. The presence or absence of *W. auropunctata* was recorded. Identifications were verified by observing specimens under a dissecting microscope in the field. (2) Bait survey: Immediately prior to each monthly treatment, a bait survey of banana cultivation areas was conducted. There were five separate stands of banana on the property, each with approximately 100 plants. Three of these stands were chosen for monitoring and ten evenly spaced peanut butter baits were placed in the plants every month prior to treatment. Banana leaf axils were used as survey locations due to the consistent observation of being a preferred nesting habitat for LFA. Baits composed of wooden disposable coffee stirrers smeared with a small amount of smooth peanut butter were placed in banana leaf axils at a height of 1.8 meters. These were

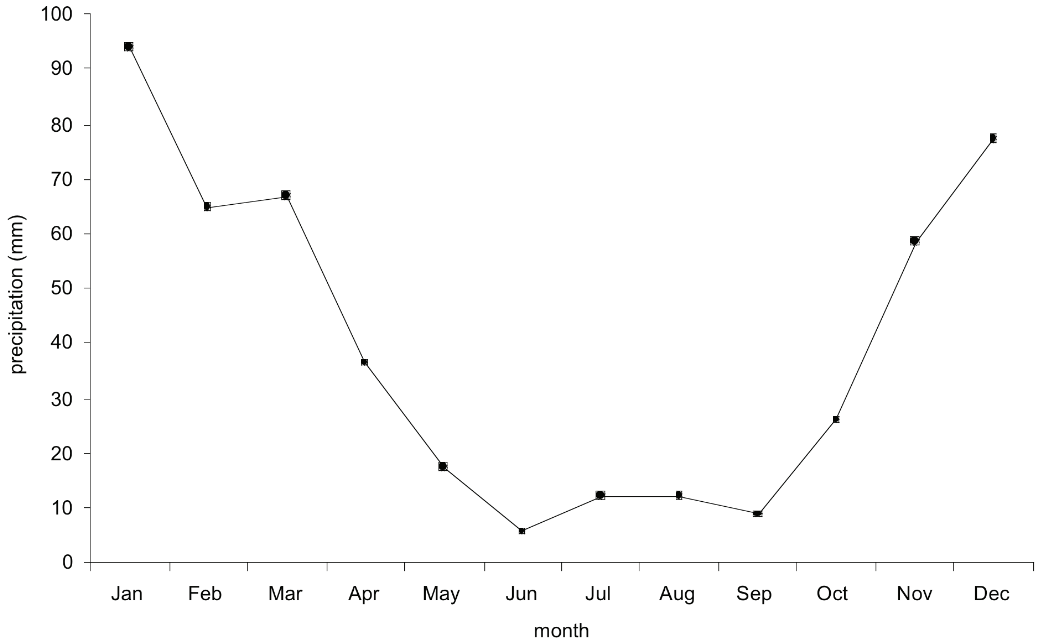

Figure 1. Mean monthly precipitation for Kahului, Maui (1954–2005).

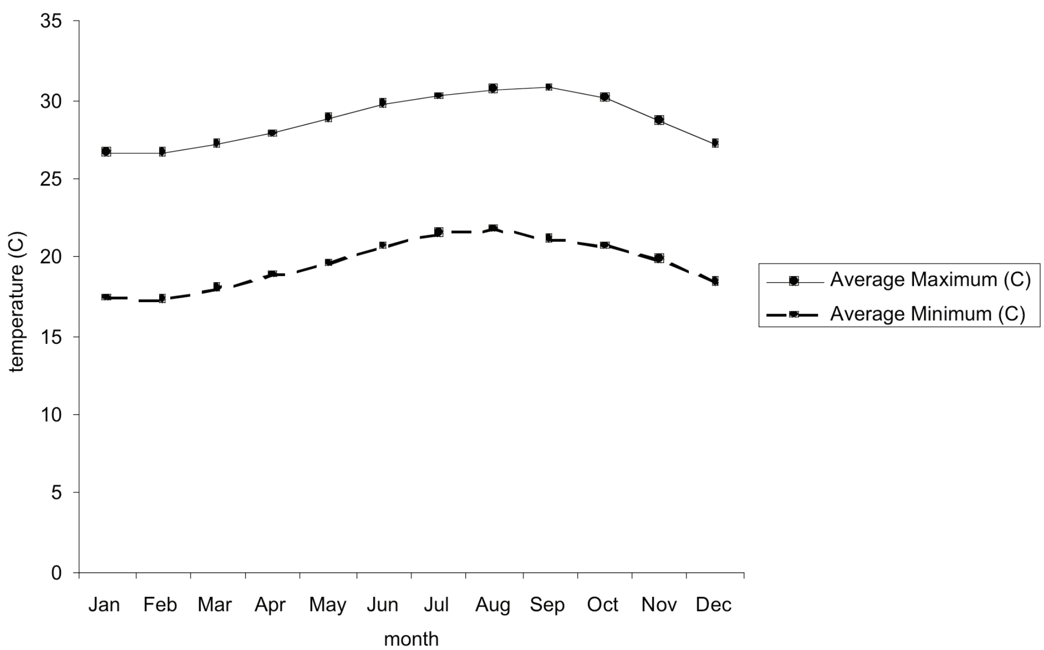

Figure 2. Mean monthly average maximum and minimum temperatures (C) for Kahului, Maui (1954–2005).

photographed one hour after deployment with a digital camera (Canon S3 is Powershot™) set on macro at maximum resolution. Ants present at bait sticks were counted from the digital images. The upper limit of counted ants was set at 50, as we considered this level of recruitment to indicate the presence of a strong viable nest nearby.

Pre treatment monitoring was limited to the initial delimiting survey. At this time, foraging workers were very abundant throughout the infested area and were readily observed by visual means. Due to the urgency of responding to this incursion, no further pre-treatment measures of abundance were conducted. Biannual monitoring for the presence of *W. auropunctata* was conducted in February and September of 2010, 6 and 12 months after the commencement of treatments. On these dates the entire site, including a 20 meter extension boundary beyond the treatment area, was baited on a grid at 5 meter intervals using approximately 200 survey baits composed of wooden disposable coffee stirrers smeared with a small amount of smooth peanut butter. These were collected approximately one hour after deployment. All specimens were identified under a dissecting microscope.

Results

Monthly visual surveys. In October and November 2009, *W. auropunctata* were present in large numbers and could be readily observed foraging within all shaded parts of the infested area. In December 2009, two months following the first treatment, *W. auropunctata* were still present over much of the property but confined to the most favorable habitats – moist heavily shaded micro-sites, under rocks and paving stones. From January 2010 until the completion of the treatment regime, twelve months following the first treatment, no *W. auropunctata* were found by visual means.

Monthly baited surveys. In November 2009, we observed ants at 94% of baits placed in banana leaf axils. At 50% of baits, recruitment exceeded the 50 worker thresh-hold we believed would indicate the presence of a strong viable nest nearby. In December, this dropped to 43% and 4%, respectively (Figure 3). The mean number of ants present at baits in November 2009 was 30.8 and this dropped to 3.9 in December 2009 (Figure 4). No *W. auropunctata* were observed at baits in banana plants in subsequent months.

Biannual bait surveys. Two site surveys were conducted with baited coffee stirrers. In February 2010 the entire site was baited on a grid at 5 meter intervals using approximately 200 baits. Open spaces without shade or devoid of suitable habitat were sampled at a lower density. During this survey, a single *W. auropunctata* specimen was observed at one bait. In September 2010, this survey was repeated at a closer spacing of baits and extending to cover the entire 2 ha property. A total of 633 baits were deployed over the infested area and the surrounding area. Additional careful visual searching of likely nest locations was also conducted by experienced surveyors. No *W. auropunctata* were observed via either method.

Discussion

The little fire ant has proven to be a formidable foe worldwide, resisting most attempts to eradicate it, even where infestations occupy only small areas. This is due in no small part to its cryptic nature during the initial "beach-head" phase of its invasion (Moller 1996), use of both ground and arboreal niches for nesting and foraging (Wetterer and Porter 2003) and the survival behaviors exhibited by tramp ants generally. We employed a "combination-treatment" approach using three different bait types and continued to treat well after the ant population was below our ability to detect it. Monitoring for possible recovery of *W. auropunctata* will continue for at least two years to ensure no nests have escaped treatment.

Although *W. auropunctata* will forage more than 6 meters from their parent nest (Fernald 1947), at least some arboreal nests may forage exclusively above the ground (Wetterer and Porter 2003) and are therefore not susceptible to baits deployed on the ground. A vital component of our approach has been to treat the arboreal layer with a bait appropriate for deployment in vegetation. Previous recorded attempts at eradicating this species have not utilized this approach, and it may have been the cause of at least some past failures. Souza et al. (2008) treated a site repeatedly with granular baits and observed a rapid return of

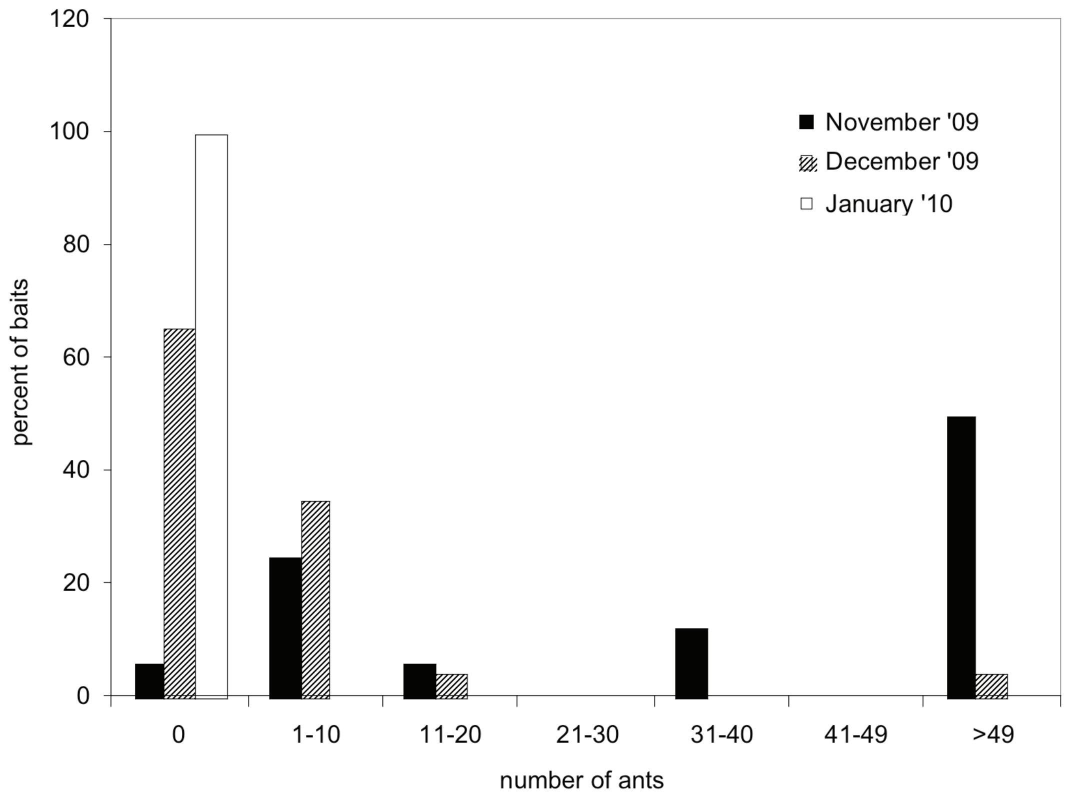

Figure 3. Ant counts at baits placed in banana plants in November 2009, December 2009, and January 2010.

ground-nesting W. *auropunctata* once treatment ceased. This they attributed to recolonization from arboreal nests within the treatment sites, demonstrating the need to consider treating three-dimensionally for this species.

A second important component of our approach has been to treat repeatedly, well beyond our capacity to detect any nests that may have remained. This approach has been suggested for small-scale eradications of *Solenopsis invicta* (Buren) (Imported Fire Ants) by Drees et al. (2002), and has formed the basis of several eradication strategies for this species worldwide (eg. (Vanderwoude et al. 2004, Christian et al. 2010). We have modified this approach by increasing treatment frequency to account for the tropical climate in Hawaii which undoubtedly supports year-round LFA colony growth. The passage of time and continued monitoring of the study site will reveal whether this approach has ultimately been successful.

Hawaii experiences the highest rate of invasions by alien species in the USA with an introduction rate approximately 50,000 times the national average (Kraus and Duffy 2010). Once established, eradicating an invasive species is notoriously difficult and successful eradications are rare (Mack et al. 2000). In Hawaii, like many other jurisdictions, invasive species management may fall between the cracks, with no single agency mandated with responsibility. In addition, many agencies have experienced downsizing in personnel and other resources, decreasing their capacity to adequately respond to and control new invasive species. As a consequence, alternative models for invasive species management have been adopted, using informal multi-agency and NGO collaborations (Kraus and Duffy 2010), and this project is an example of this approach. While the Hawaii Department of Agriculture is the lead agency

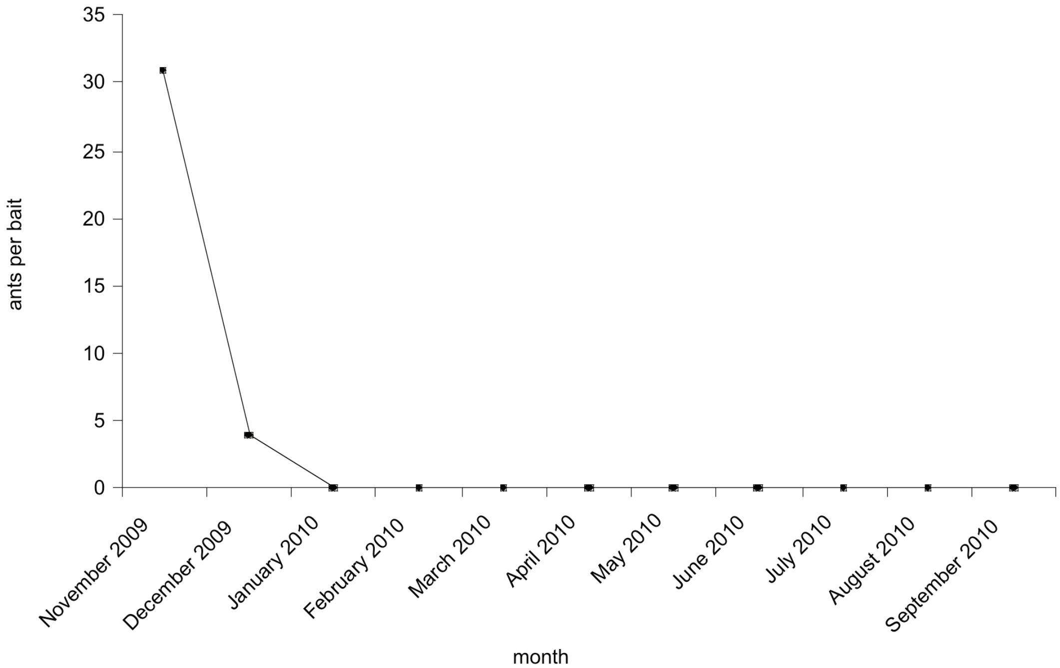

Figure 4. Mean number of ants at baits placed in banana leaf axils between November 2009 and September 2010.

for responses to invasive ants, many other agencies have been involved – each contributing to the success of this program to date. At various times, staff from The Pacific Cooperative Studies Unit, Maui Invasive Species Committee, Maui County, United States Department of Agriculture and the United States Geological Survey have allocated resources and participated in this project. They are all still actively working on the broader operational plan which includes public outreach, further delimiting surveys and quarantine activities.

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