A report on Western IPM Center sponsored project:

Survey of the invasive odorous house ant, *Tapinoma sessile*, in upcountry Maui, Hawaii

USDA-NIFA-RIPM award #104564

Grzegorz Buczkowski, Ph.D.
Department of Entomology
Purdue University
765.494.6314
gbuczkow@purdue.edu

Paul Krushelnycky, Ph.D.
Department of Plant and Environmental Protection Sciences
University of Hawaii
808.956.8261
pauldk@hawaii.edu

November 30, 2010

ABSTRACT

Invasive ants are among the most damaging of Hawaii's invasive species, causing impacts to native biodiversity and becoming pests of agricultural and urban areas. A recent survey of the upper leeward slopes of Haleakala volcano, east Maui, detected the presence of the invasive odorous house ant, *Tapinoma sessile*, the first record within the state. We subsequently conducted a detailed survey covering just under 60 hectares (148 acres) surrounding the initial discovery site in June and October 2010, to determine the size of this infestation. Approximately 2,638 locations were surveyed using baited cards and visual searching, and *T. sessile* was found at 338 of these survey points. The *T. sessile* detections covered approximately 17 hectares, or 28% of the total area surveyed, indicating that the population is fairly widespread. This will make eradication of this population very challenging. The pathway by which *T. sessile* was introduced to this site is unknown, as is the likelihood that other populations exist on the island. The first steps in determining whether eradication o f the known population should be attempted are to conduct more surveys in upcountry Maui and in other parts of the island, and to determine whether *T. sessile* is naturally dispersing by short-distance budding versus mating flights. If no other populations are thought to exist on Maui, an eradication effort will likely need to develop a highly attractive bait and toxicant combination that is specific to *T. sessile*. Approval from a variety of residents in the area, engaging in a variety of land use patterns, will also need to be obtained.

INTRODUCTION

Invasive ants are among the most damaging of Hawaii's invasive species. They have caused substantial impacts to native Hawaiian biodiversity (Krushelnycky and Gillespie 2008), and are pests of agriculture and urban areas (Krushelnycky et al. 2005). In addition, recent and potential ant introductions have the ability to exert strong impacts on tourism and other sectors of the economy (Gutrich et al. 2007). A recent survey of the upper leeward slopes of Haleakala volcano, which forms east Maui, detected the presence of the invasive *Tapinoma sessile*, the first record within the state (Krushelnycky 2010). Initial observations suggested that this population may be limited in size, however the actual extent was unknown. As a result, there was an immediate need to perform a survey of the invaded area and nearby locations to delimit the distribution of this ecologically damaging invader. Early detection and a rapid response to incipient intrusions are critical for successfully eliminating potential threats to native ecosystems and forestalling new invasions of damaging pest species in Hawaii.

Tapinoma sessile, commonly known as the odorous house ant (OHA), is native to the continental US and is widespread throughout North America. It has the widest geographic range and greatest ecological tolerance of any ant in North America (Fisher and Cover 2007) and occurs in a variety of habitats. It is very opportunistic and will readily adapt to take advantage of human-modified environments. In urban areas it is considered a serious pest of homes and urban structures (Thompson 1990, Buczkowski and Bennett 2008b, Klotz et al. 2008). Recent work demonstrates that *T. sessile* is a highly plastic successional species and with a highly flexible colony and social structure (Buczkowski 2010). In its natural habitat, *T. sessile* is a subdominant species comprised of small, single-queen colonies. In invaded urban areas, OHA behaves like an invasive tramp species and shows extreme polygyny (thousands of queens), extensive polydomy (multiple nests), supercolonial colony structure, reproduction by budding, and ecological dominance over native ant species (Buczkowski and Bennett 2008a, Buczkowski 2010). Such characteristics make OHA a perfect invader, capable of colonizing areas with environmental conditions similar to its native range. Therefore, *T. sessile* could pose a substantial threat to native arthropods and could disrupt ecological processes in native biological communities in Hawaii. Further, the occurrence of *T. sessile* in temperate regions suggests that, unlike most ant species currently in Hawaii, it could be capable of invading high elevation habitats. These areas support much of the remaining intact native communities in Hawaii.

The main goal of this project was to delimit the extent of the known population located in a residential/agricultural area in the vicinity of Kula, Maui. A second objective was to survey other key nearby areas for additional populations. Biological invasions are closely tied to human activities and *T. sessile* is known for its preference for nesting in urban and disturbed areas (Buczkowski and Bennett 2006, Buczkowski 2010, Menke et al. 2010). The final objective was to develop an action plan to address the *T. sessile* invasion of Maui with a focus on controlling this invasive ant species.

MATERIALS AND METHODS

T. sessile was first detected in Hawaii in June 2009 during a survey for other invasive ants performed on the upper leeward slopes of Haleakala volcano on the island of Maui, immediately west of Haleakala National Park (Figure 1). The ants were found foraging alongside a rural road (Waipoli Rd.). The initial infestation site was located in a residential/agricultural setting, an area dominated by small vegetable and flower farms, pastures, forest patches, and sparse residential housing. Initial observations suggested that the population might be limited in size; however, the actual extent was unknown. As invasive ant species are often spread by human-mediated, long-distance jump dispersal (Suarez et al. 2001) surveying efforts concentrated along roads that might act as avenues for *T. sessile* dispersal (Figure 2). This included surveying along Kekaulike Avenue, a major road connecting Kula Highway and Crater Road (main road leading to Haleakala National Park), Waipoli Road, and nearby residential streets. To obtain fine-scale distributional information, a detailed survey of lower Waipoli Road was performed (20.74031° N – 20.73079° N to 156.33003° W – 156.31701° W; Figure 3), the location where *T. sessile* was originally detected. A roughly circular area radiating approximately 350 to 1000 m from the point where *T. sessile* were originally discovered was exhaustively sampled. A combination of baiting and visual searching was used at all locations. Note cards baited with a blend of canned tuna and corn syrup were placed on the ground at approximately 10 to 25 m intervals along numerous transects throughout the search site. The bait cards were collected 1 hr later, the presence of *T. sessile* was recorded using a GPS, and species identity of other ants present on the baits was recorded at a subset of the bait card survey points. In addition to baiting, likely nesting locations were searched for *T. sessile* nests throughout the site. This involved turning over rocks, inspecting debris on the ground (logs, piles of leaves), inspecting vegetation for ants that might be feeding on hemipteran honeydew, and looking for signs of ant activity on the ground (trails). All surveying was performed over a period of 20 days, during June 13-22 and October 5-15.

RESULTS

The results of this project are presented in Figures 1-3 below. Figure 1 shows the upper leeward slopes of Haleakala volcano surveyed during 2008-2009 (blue dots) which initially detected the presence of *T. sessile* on Maui. Overlaid on this earlier survey are the 2010 survey points (green dots), with *T. sessile* presence indicated in red. The total area surveyed for *T. sessile* in 2010, which was directed at characterizing the extent of *T. sessile* presence in the vicinity of the initial detection, is shown in Figure 2. Over the course of 20 days an area totaling just under 60 hectares (148 acres) was surveyed using approximately 2,638 baited cards and visual inspections (Figure 2, red dots indicate *T. sessile* presence, green dots indicate all survey locations where *T. sessile* was not detected). Of the 60 hectares surveyed, *T. sessile* was detected at 338 locations in an area totaling approximately 17 hectares, or 28% of the total area. This calculated invaded area does not take into account slope and topography, so the actual area is slightly larger. A close-up of the area surveyed in 2010 is shown in Figure 3. The black polygon indicates the approximate boundary of the locations where *T. sessile* was detected.

Of the 2,638 locations surveyed for ants in 2010, ant species identity was recorded at 1,230 of the survey points. This subset was chosen haphazardly, and should be unbiased with respect to location and microhabitat. Within this subset of survey points, we detected seven ant species in addition to *T. sessile*. Of these 1,230 survey points, 448 (36%) had *Pheidole megacephala*, 338 (27%) had *Tapinoma sessile*, 98 (8%) had *Linepithema humile*, 28 (2%) had *Tetramorium caldarium*, 24 (2%) had *Ochetellus glaber*, 8 (1%) had *Cardiocondyla kagutsuchi*, 7 (1%) had *Plagiolepis alluaudi*, 7 (1%) had *Solenopsis papuana*, and 272 (22%) had no ants.

DISCUSSION

Colonies of *T. sessile* were detected in an area totaling approximately 17 hectares, an area much larger than we had initially anticipated. This infestation forms a relatively continuous aggregation of nests in a single discrete area, located mainly between lower Waipoli Rd. and Kawehi Pl. in upcountry Maui. Close inspection of several colonies revealed that all were highly polygynous and consisted of thousands of workers and brood, and preliminary aggression tests revealed lack of aggression or only low, non-injurious interactions between workers from different nests. This suggests that this population of colonies may exist as a single large supercolony spanning the entire survey area. On the US mainland, *T. sessile* supercolonies may cover an area of approximately 3 ha in urban areas (Buczkowski and Bennett 2008a), and could potentially reach a larger size in invaded natural areas with suitable feeding and nesting resources.

As can be seen in Figure 3, there are large and small pockets within the 17 ha population where *T. sessile* appears to be absent. This absence could be due to competition from the existing ant community at this locality, due to abiotic unsuitability of these microsites, or a combination of the two. Seven species make up the ant community that *T. sessile* is invading in this area, with the big-headed ant (*Pheidole megacephala*) the most common by far. The second most common species in the area is the Argentine ant (*Linepithema humile*). Both the big-headed ant and the Argentine ant are dominant, aggressive invasive species, and typically are capable of displacing most other ant species in the areas they invade (Holway et al. 2002, Krushelnycky et al. 2010). These species, and perhaps some of the others (like *Ochetellus glaber*), may be preventing colonization of some of the microsites within the invaded area, and may also be slowing the outward spread of the *T. sessile* population in some directions. Indeed, previous studies of *T. sessile* within its native range have found it to be a subdominant species, often losing battles with other ant species (including the Argentine ant), especially at the colony level (Fellers 1987; Holway 1999; Buczkowski and Bennett 2008b). When it invades mainland urban areas, however, it frequently becomes much more dominant and forms large, high density supercolonies (Buczkowski 2010). In an analogous development, *T. sessile* has become established, spread and has achieved high densities at this Maui site in spite of competition from other dominant invasive ants, exhibiting behavior comparable to that of some of the world's worst known invasive ant species. This supports the presumption that *T. sessile* could eventually have some of the same devastating ecological impacts in Hawaii commonly attributed to species such as the big-headed ant and the Argentine ant (Krushelnycky et al. 2005).

The main abiotic factors that appear to be limiting *T. sessile* spread at the local scale are the conditions prevalent within closed canopy forest, although open, sun-baked dirt-covered agricultural fields also appear to be unsuitable. Patches of black wattle (*Acacia mearnsii*) and *Eucalyptus* forest occur around the periphery of the *T. sessile* population, and these were always free of *T. sessile* and the other ant species that occur at the site. For example, closed canopy forest patches abut most of the areas where the *T. sessile* distribution reaches the edge of the survey points in Figure 3, leading us to conclude with fairly high confidence that the polygon in that figure does represent the approximate current boundaries of the *T. sessile* population at the site, and that *T. sessile* will not spread into heavily forested areas in this climatic zone. We surmise that relatively cold ground temperatures are the main factor responsible for the unsuitability of thick forests at this elevation (approx. 1200 m) for all of the ant species at this locality. However, in early succession areas sparsely wooded with black wattle, extrafloral nectaries on the wattle saplings may provide an abundant food source for *T. sessile*; for example we commonly observed *P. megacephala* workers visiting these nectaries. The majority of *T. sessile* colonies discovered within the search area were found nesting under kikuyu grass (*Pennisetum clandestinum*), which forms thick, dense mats over the ground in pastures, roadsides and abandoned agricultural plots. Additional colonies were found in pastures nesting inside of dry cow dung, as well as in and around several residential buildings. On the mainland, *T. sessile* is a major urban nuisance pest (Thompson 1990, Buczkowski 2010), and it will likely also become a serious urban pest in Hawaii if it spreads among the islands and invades larger urban areas.

Although we were able to delimit the known *T. sessile* population with fairly high resolution, the distribution of *T. sessile* on the remainder of the island is still unknown. We surveyed along part of Kekaulike Rd., which bisects much of upcountry east Maui, as well as throughout Kula Botanical Garden, but most of the residential/agricultural areas of this part of the island remain unsurveyed, as do all other parts of the island. Additional populations are a distinct possibility, for several reasons. Although the rate of outward spread of the Waipoli Rd. population is unknown, its relatively large size suggests that it has been present at this location for some time, probably five years at a minimum. One resident located at the edge of the current population reported first seeing *T. sessile* in his house approximately one to two years ago. The Waipoli Rd. population has therefore served as a potential source pool for additional populations on the island for at least several years, either through movement of infested material from the area by people, or by natural dispersal.

Regarding the first possibility, we spoke with landowners and tenants on all of the infested properties in the Waipoli Rd. area in an attempt to ascertain the pathway of introduction to the site. At the same time, we were able to assess the likelihood that propagules were being moved from the site. Unfortunately, none of the residents of the area were able to remember any obvious events or infested materials by which *T. sessile* may have been introduced. Moreover, despite the agricultural activities that take place on some of the infested properties, all residents stated that they do not normally import potted plants or other media that could be likely sources of incoming propagules. Based on their stated activities, there are also currently no obvious, regular high-risk export pathways of propagules to other parts of the island, or to other islands. One possible exception is a cut-flower business located on an infested property, which regularly imports cut flowers from other parts of the island (Haiku and Hana), arranges the flowers with cut proteas grown on the property, and exports the arrangements to hotels and other sites on the island. However, the imported cut flowers and the business' processing area appeared quite clean, and all exported cut flower arrangements are treated with pesticides, reducing the chances that *T. sessile* is being imported to or exported from this property. Despite the lack of obvious regular export pathways of *T. sessile* from the area, infrequent high-risk export activities that were not reported or that have been forgotten are always a possibility. Initiation of other populations that originated through infrequent dispersal events from the Waipoli Rd. population should therefore not be discounted. An additional caveat is that agricultural activity at the site was considerably higher in recent years, including cultivation of fields located at the center of the present infestation, where *T. sessile* densities are currently high. Many of these fields are now abandoned, but former agricultural work may have included high-risk import and/or export activities. Finally, because the original pathway of introduction to the Waipoli Rd. site is still unknown, it is impossible to judge the probability that other populations have established on the island through the same pathway.

The probability that additional colonies and populations have established through natural dispersal is also unknown at this point. On the mainland, small monogynous colonies of *T. sessile* in natural areas are believed to disperse through mating flights, like most ant species. However, it is unknown whether the large polygynous supercolonies in urban areas also disperse through mating flights, or instead through contiguous short-distance budding like most other supercolonial invasive ant species, or possibly through both mechanisms. The more or less contiguous infestation of the Waiopoli Rd. population suggests either budding dispersal or only short-distance mating flights at this site, although this is completely uninvestigated. If this is the case, it would signify that additional distant colonies are unlikely to have established through natural dispersal. If on the other hand long-distance mating flights are common in the Waipoli Rd. population, the chances that numerous additional distant colonies exist on Maui are greatly increased.

Further surveys to determine whether other colonies or populations exist on Maui, and research to investigate the mode of natural dispersal of *T. sessile* on Maui, are the most important first steps in deciding how best to address this invasion. If the Waipoli Rd. population appears to be the only infestation on the island, an attempt to eradicate it could be considered. At roughly 17 ha in size, this population would present serious challenges, but is similar in size to at least some previous examples of successful ant eradications. For example, the little fire ant (*Wasmannia auropunctata*) has been eradicated from two areas in the Galapagos Islands whose areas were 3 and 21 ha (Abedrabbo 1994, Causton et al. 2005); numerous populations of the big-headed ant (*P. megacephala*) have been eradicated, including one covering 3.85 ha on an offshore islet off Oahu (Plentovich et al. 2010) and multiple populations covering a total area of approximately 30 ha in Kakadu National Park, Australia (Hoffmann and O'Connor 2004); and a roughly 11 ha population of Argentine ants (*L. humile*) has nearly been eradicated from Tiritiri Matangi Island in New Zealand (C. Green pers. comm). One advantage of the Waipoli Rd. *T. sessile* population is that the terrain is all accessible by foot, and in most places is fairly open and easy to traverse. Furthermore, the site itself is not remote, precluding any serious logistical difficulties. Several major challenges exist, however, and these are discussed below.

The first challenge is finding a bait that is sufficiently effective against *T. sessile*. Although this species is frequently the target of control in urban settings, to our knowledge it has not previously been targeted for eradication in a field setting such as the one that exists on Maui. We did perform an informal test using one product that works well for controlling *T. sessile* around buildings and other urban areas. Thirteen nests were sprayed with Arilon™ insecticide donated by DuPont Professional Products. Eleven of these 13 nests appeared to be dead or inactive after one day, and all 13 were dead or inactive after one week. Arilon also gave excellent long-term control with all 13 sites remaining ant free at 15 weeks after the treatment despite heavy re-infestation pressure from nearby untreated sites. While these results show that Arilon is effective against *T. sessile*, using a direct contact spray alone is not a realistic approach for attempting eradication over a 17 ha area. Instead, a highly attractive bait (formulated with an effective toxicant) is the only practical primary tool for large scale ant eradication, and baiting is the method that has been used in all previous successful ant eradications in similar field settings. Unfortunately, we do not believe that a commercially produced ant bait that is sufficiently attractive to *T. sessile* and therefore effective enough to achieve eradication is currently available in the US. One of us (PDK) has tested a large variety of commercial ant baits against the Argentine ant on Maui, a species that appears to be very similar in biology and feeding behavior to *T. sessile*, and none of these baits have been effective enough to warrant attempts at field eradication (Krushelnycky and Reimer 1998, P. Krushelnycky unpubl. data). We think that it is likely that a bait would have to be specially formulated to achieve the level of attractiveness necessary for eradication across a fairly large scale. This approach has been successful in other situations (e.g. Vanderwoude et al. 2011), and would incorporate a food known to be highly attractive to *T. sessile*, for example the tuna and corn syrup mixture that we used for monitoring *T. sessile* on Maui that always elicited very heavy worker recruitment. This type of approach would need to proceed under an experimental use permit.

A second major challenge to an eradication attempt concerns the large variety of land owners and land use types within the Waipoli Rd. infestation. The entire population is located on private land, and includes residential properties, vegetable and flower farms and horse and cow pastures. An organic farm is located very near, but currently outside, the infestation. It will be difficult to find an insecticidal ant bait that is permissible for all of these use patterns, although an experimental use permit may provide an exemption for this particular situation. Obtaining permission and access from all of the residents in the area may also be challenging.

If these primary challenges can be overcome, an eradication attempt will require the collaborative efforts of multiple agencies and resource management groups. The project would be fairly labor intensive, would require a commitment to conduct follow-up monitoring and spot treatment for at least several years, and would therefore be an expensive undertaking. Under the right circumstances, however, we feel that such an attempt would be justified, because it could potentially completely eradicate *T. sessile* from the island of Maui and thus avoid indefinite financial and environmental costs down the road.

Figure 1. Upper leeward slopes of Haleakala volcano on the island of Maui, Hawaii showing areas surveyed during 2008-2009 (blue dots) which detected the presence of *T. sessile*. Areas sampled in 2010 are indicated in green and *T. sessile* presence is in red. The inset map shows the area of Maui enlarged in the main figure.

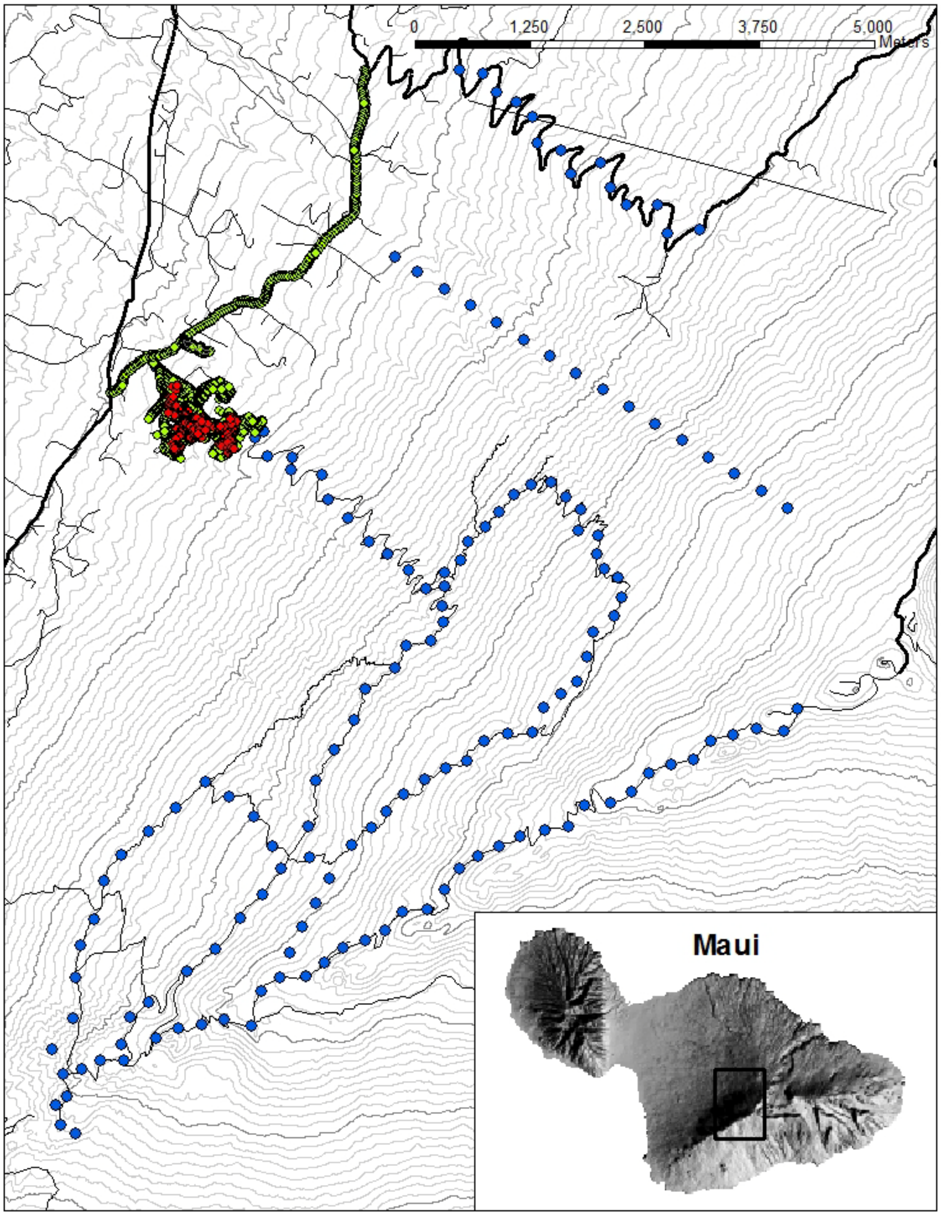


Figure 2. Areas surveyed for *T. sessile* in 2010. Green dots indicate locations with *T. sessile* absent, red dots locations with *T. sessile* present. Also shown are major and minor roads in the vicinity, and 100 and 1000 ft elevation contours.

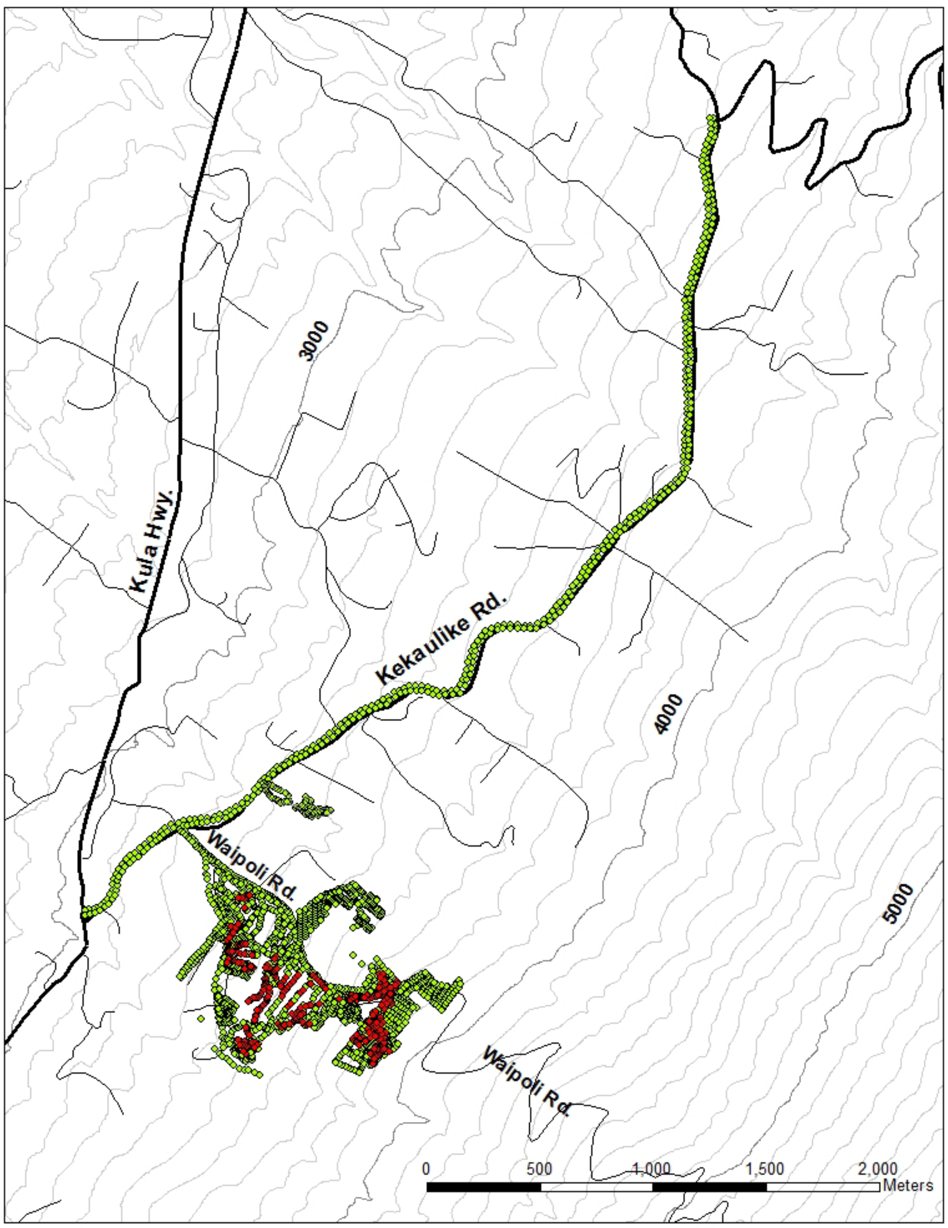
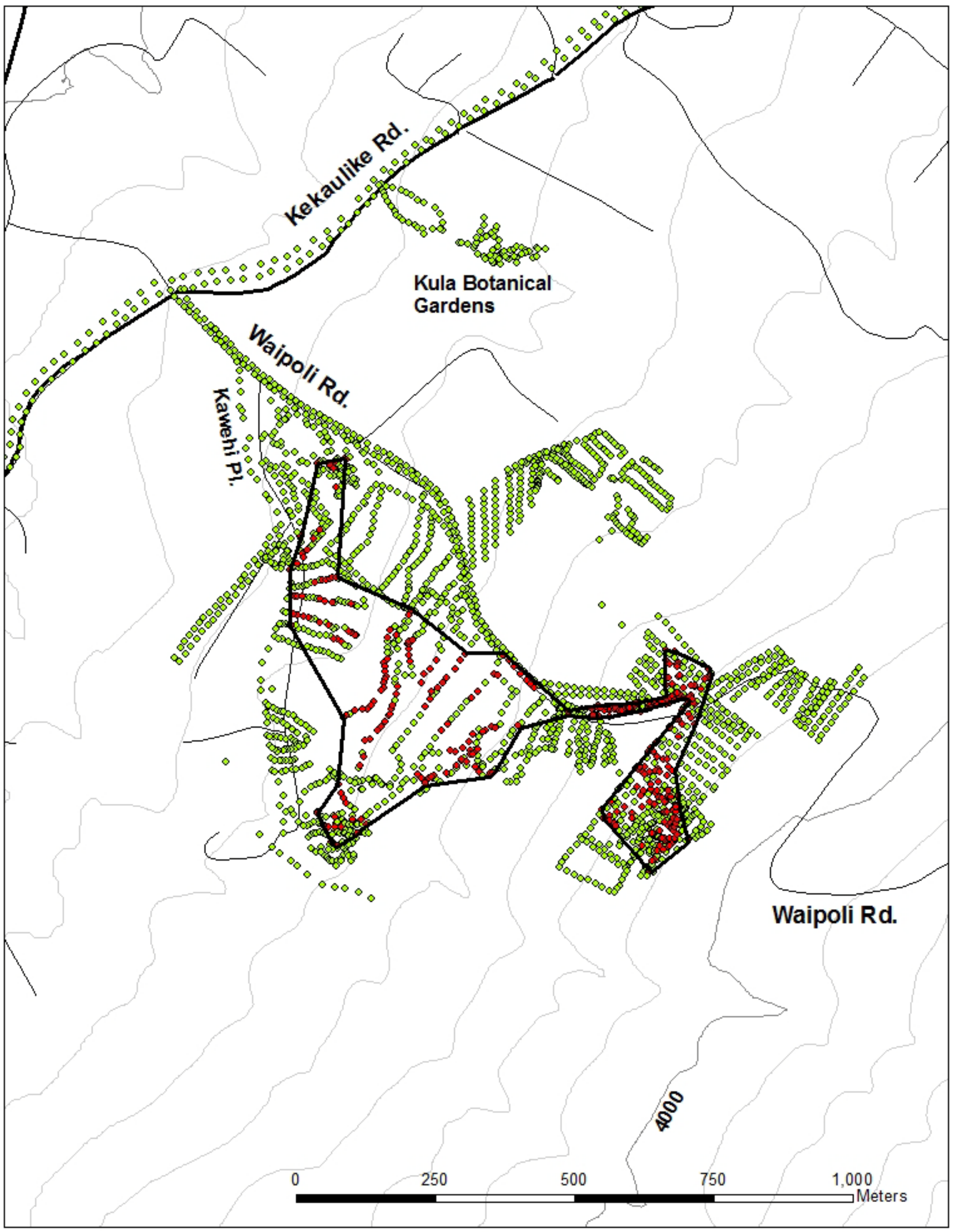


Figure 3. Close up of areas surveyed for *T. sessile* in 2010. Green dots indicate locations with *T. sessile* absent, red dots locations with *T. sessile* present. The black polygon shows the boundary of the known area occupied by *T. sessile*.



Acknowledgements

We thank numerous farm and home owners for permission to work at their properties. We also thank Forest Starr, Kim Starr, and Cas Vanderwoude for assistance in the field. This project was made possible though a grant from the USDA (NIFA-RIPM award #104564 to GB and PK), a travel grant from DuPont Professional Products (GB), and the Industrial Affiliates Program at Purdue University.

REFERENCES

Abedrabbo S (1994) Control of the Little Fire Ant, *Wasmannia auropunctata*, on Santa Fe Island in the Galapagos Islands, pp. 63-72. *In* D. F. Williams [ed.], Exotic Ants. Biology impact and control of introduced species. Westview Press, Boulder Colorado.

Buczkowski G, Bennett GW (2006) Dispersed central-place foraging in the polydomous odorous house ant, *Tapinoma sessile* as revealed by a protein marker. *Insectes Sociaux*, 53: 282–290.

Buczkowski G, Bennett GW (2008a) Seasonal polydomy in a polygynous supercolony of the odorous house ant, *Tapinoma sessile*. *Ecological Entomology*, 33:780–788.

Buczkowski G, Bennett GW (2008b) Aggressive interactions between the introduced Argentine ant, *Linepithema humile* and the native odorous house ant, *Tapinoma sessile*. *Biological Invasions*, 10:1001–1011.

Buczkowski G (2010) Extreme life history plasticity and the evolution of invasive characteristics in a native ant. *Biological Invasions*, 12: 3343–3349.

Causton CE, Sevilla CR, and Porter SD (2005) Eradication of the Little Fire Ant *Wasmannia auropunctata*, (Hymeoptera: Formicidae) from Marchena Island, Galapagos: on the edge of success? *The Florida Entomologist*, 88:159–168.

Fisher BL, Cover SP (2007) Taxonomic descriptions. In: Fisher BL, Cover SP (eds), Ants of North America: a guide to the genera. University of California Press, pp. 145–146.

Gutrich JJ, VanGelder E, and L Loope (2007) Potential economic impact of introduction and spread of the red imported fire ant, *Solenopsis invicta*, in Hawaii. *Environmental Science and Policy*, 10: 685–696.

Hoffmann BD and O’Connor S (2004) Eradication of two exotic ants from Kakadu National Park. *Ecological Management and Restoration*, 5:98–105.

Holway DA, Lach L, Suarez AV, Tsutsui ND, and Case TJ (2002) The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics*, 33: 181-233.

Klotz J, Hansen L, Pospischil R, and M Rust (2008) Urban ants of North America and Europe: identification, biology, and management. Cornel University Press, Ithaca, NY.

Krushelnycky PD and Reimer NJ (1998) Efficacy of Maxforce bait for control of the Argentine ant (Hymenoptera: Formicidae) in Haleakala National Park, Hawaii. *Environmental Entomology*, 27:1473–1481.

Krushelnycky PD (2010) Invasive ant control for native ecosystem preservation and restoration in Hawaii: a test of Advion Insect Granule Bait on Argentine ants at Haleakala National Park, and survey of ant distributions in leeward Haleakala watershed and restoration lands. Report to the Hawaii Invasive Species Council, 28 pp.

Krushelnycky PD and Gillespie RG (2008) Compositional and functional stability of arthropod communities in the face of ant invasions. *Ecological Applications* 18: 1547-1562.

Krushelnycky PD, Loope LL, and Reimer NJ (2005) The ecology, policy, and management of ants in Hawaii. *Proceedings of the Hawaiian Entomological Society*, 37: 1–25.

Krushelnycky PD, Holway DA and LeBrun EG (2010) Invasion processes and causes of success. Pp. 245-260. *In*: L. Lach, C. Parr, K. Abbott (eds.), *Ant Ecology*, Oxford University Press, Oxford.

Menke SB, Booth W, Dunn RR, Schal C, Vargo EL, et al. (2010) Is it easy to be urban? Convergent success in urban habitats among lineages of a widespread native ant. PLoS ONE, 5:e9194. doi:10.1371/journal.pone.0009194.

Plentovich S, Eijzenga J, Eijzenga H and Smith D (2010) Indirect effects of ant eradication efforts on offshore islets in the Hawaiian Archipelago. *Biological Invasions*, DOI 10.1007/s10530-010-9848-y.

Suarez AV, Holway DA, and Case TJ (2001) Patterns of spread in biological invasions dominated by long-distance jump dispersal: Insights from Argentine ants. *Proceedings of the National Academy of Sciences, U.S.A.* 98:1095–1100.

Thompson RC (1990) Applied Myrmecology: In: Vander Meer RK, Jaffe K, Cedeno A (eds), A World Perspective. Westview Press, Boulder, Colorado, pp. 51–67.

Tsutsui, ND, Suarez AV, Holway DA, and Case TJ (2000) Reduced genetic variation and the success of an invasive species. *Proceedings of the National Academy of Science, U.S.A.*, 97: 5948–5953.

Vanderwoude C, Onuma K and Reimer N (2011) Eradicating *Wasmannia auropunctata* (Hymenoptera: Formicidae) from Maui, Hawaii: the use of combination treatments to control an arboreal invasive ant. *Proceedings of the Hawaiian Entomological Society*, in press.