Title: Invasive Species Management using Prevention and Control Technologies in the West Maui Mountains
Organization: The West Maui Mountains Watershed Partnership
Award: $27,620.00

The West Maui Mountains Watershed Partnership has completed its work for the 2009 Hawaii Invasive Species Committee Grant. The following report attempts to summarize our achievements. Although the some of the deliverables of this grant were not achieved as well as we would have liked due to technological limitations, we feel that we used the resources successfully for their best and highest use. One of the main thrusts of this grant was to use imagery from Resource Mapping Hawaii to identify priority weed species, however, since we had issues with our imagery due to poor weather and rugged terrain, our analysis and ground truthing was limited. On September 20, 2012, a total of $13,348.41 was approved for a re-budget from the categories of "image collection/ analysis, data management, and training" to a new budget category for "helicopter operations" as well as the movement of monies from the "technical report" budget category to a "weed management plan" category. With this, we were able to complete our WMMWP 5-year Weed Management Plan as well as mapping of *Macaranga tanarius* and *Toona ciliata* using helicopter surveys. We were able to purchase a new GIS workstation and have continued our participation and made significant strides within our Maui Data Hui to standardize data systems within island programs. The overarching lesson learned is that technological advances in image collection are still in development and that technology may not perform to expectations in challenging environments like those found in West Maui. We are still hopeful that new developments will make weed control easier and will continue to attempt to integrate these advances when possible.

Measures of Effectiveness

PHASE 1: Image Collection

Deliverables:

- Portable hard drive with post-processed, fully mosaiced, multi-spectral imagery at 15-20 cm resolution and natural color imager with 2cm resolution, reproducible as TIFF images or maps.
- GPS locations of target species in project area in shapefile format.
- Corresponding set of Digital Elevation Models (DEMs) for each orthoquad.

Accomplishments:
WMMWP now has in its possession 2 portable hard drives with post-processed fully-mosaiced, multi-spectral and natural color imagery. We have also obtained a set of Quickbird imagery for help with analysis as well as high-quality DEMs derived from the Quickbird imagery. Aerial photographs have been collected by Resource Mapping Hawaii for approximately 4,443 acres of the total 8,500 acres proposed. Due to difficulties flying in the extreme terrain, wind and weather near the summit of the West Maui Mountains collecting the imagery was delayed and certain proposed areas were not able to be collected. Also project areas have changed slightly due to these inabilities and now include a larger area where weeds are believed to be in higher

concentration(See Map A-1,p11.). Much of the imagery collected was un-usable (especially in the upper reaches and more extreme topography areas where we were hoping to get upper limits of these weeds).

At the time of the last communication with Resource Mapping Hawaii, we determined that the topography was too challenging to provide a credible product given the current technological platform. Possibilities for future collaboration do exist and discussions include concepts such as flying imagery transects and perhaps better capabilities with helicopter mounted versions of the imagery platform to increase the maneuverability of the aircraft and the consistency of the distance between the helicopter and the ground to improve resolution.

As of September 20, 2012, the remaining portions of this category had been re-budgeted to "helicopter operations" to help WMMWP assess priority weed ranges with traditional aerial detection methods.

PHASE 2: Data Management

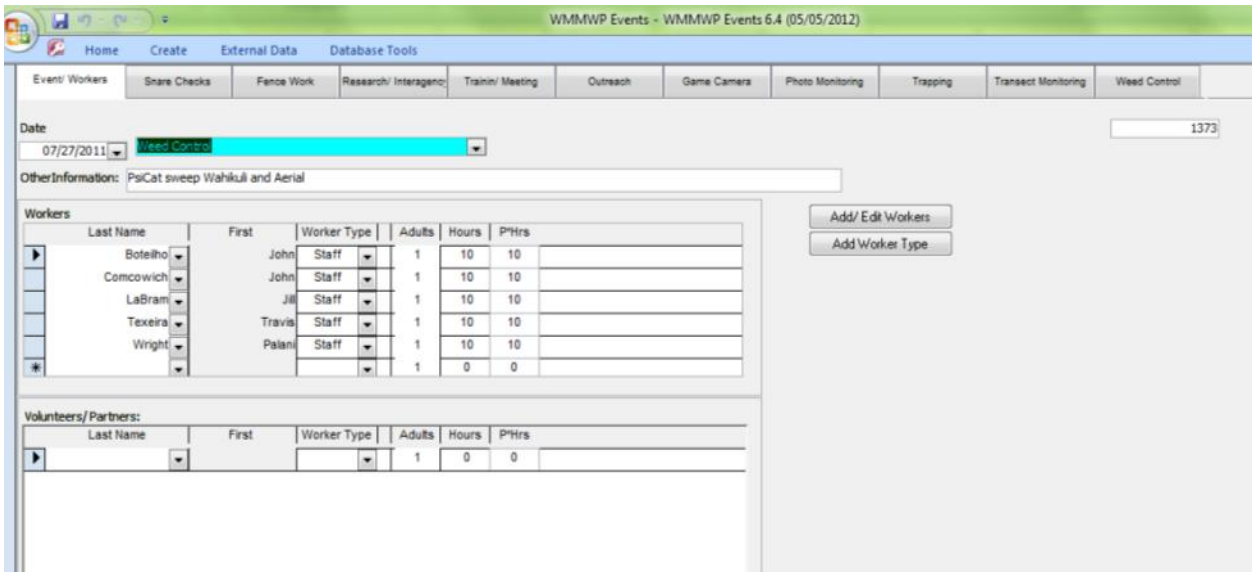
Deliverables:

- HISC compatible database structure for all conservation organizations on Maui
- Adoption of clear, similar attributes and peer-reviewed data standards
- 4 meetings attended by at least four other participating organizations

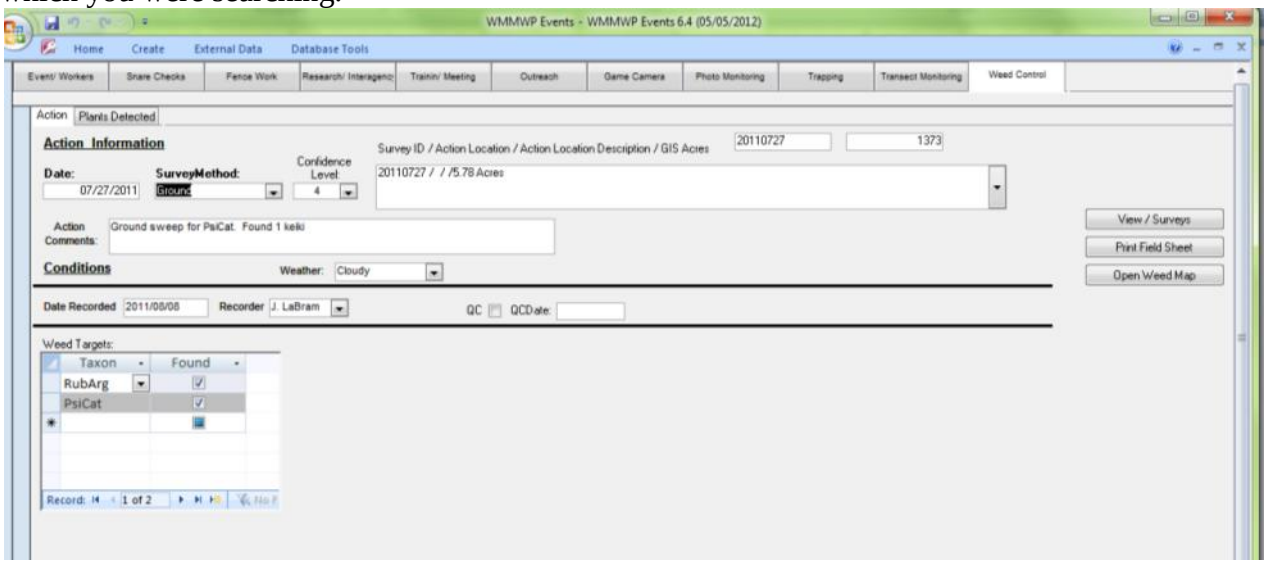
Accomplishments:
The Maui Data Hui has created weed data standards and adapted data storage attributes to on-the-ground management island-wide. Work has completed on the creation of a compatible weed database in Microsoft Access and weed collection application for use with the ArcPad software on a mobile GPS system. The following screen shots will help the reader understand the system.

Select Weed Database Screen Shots:

This shot shows all of our tabs in our database. Also shows number of hours for each staff member working.

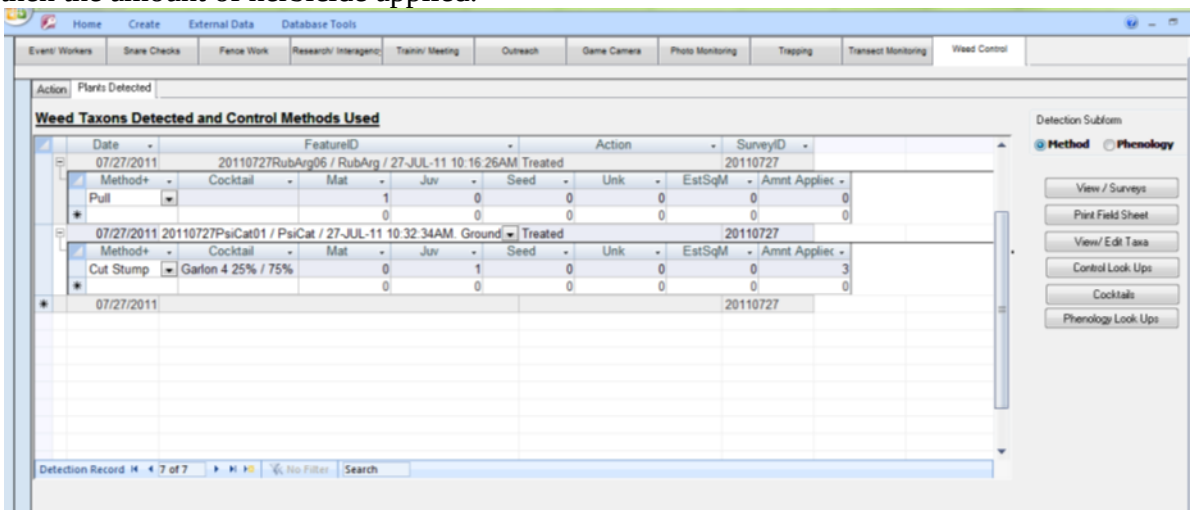


This shot shows our Weed Control Tab which consists of two parts (Action and Plants Detected). First is the Action information. The Date, Survey Method (Ground, Air, Roadside, Binocular, Remote Sensed), Survey ID (this is the unique name for the survey, usually long date). This also is directly connected to the GIS, so once you select the correct Survey ID, the GIS acres automatically come up. You can also add in Comments, the Weather, and the Weed Targets for which you were searching.

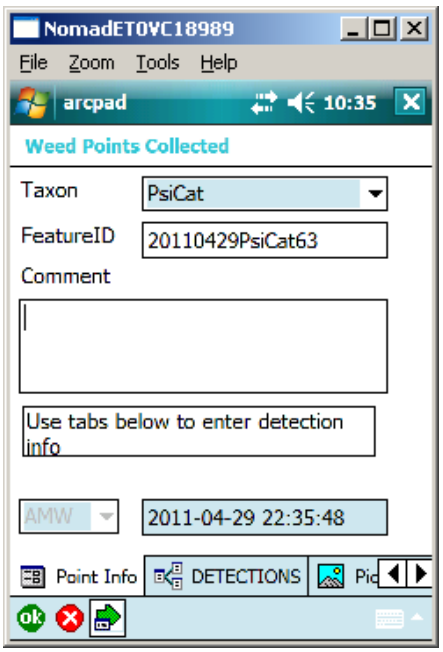


The following screen shows the Plants Detected Tab (of Weed Control) where you enter in the points controlled. These are also directly connected to our GIS geodatabase, so the FeatureID is the unique identifier for each Weed Control Point. Once you select the correct FeatureID, Action (Detected, Treated, Remote Sensed, or Misidentified), the SurveyID is automatically inserted from the previous "Action" Tab. Then you enter your Method (Observed, Pull, Cut Stump, Foliar, etc.), the name of the herbicide and % solution, number of Mature individuals, Juveniles, and Seedlings (these depend on data standards for each species). Eg. PsiCat**: Mature=>2m or flowering or fruiting, Juvenile= 0.5m-2m (not flowering or fruiting), Seedling=<0.5m (not flowering or fruiting). We do realize that based the habitat, many strawberry guavas can be mature at a small height and can enter data accordingly. You can enter

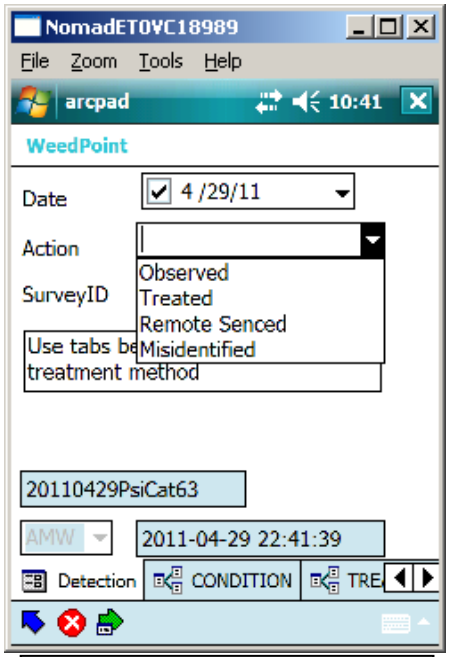
a value in EstSqM (estimated square meters) if controlling an area as opposed to individuals and then the amount of herbicide applied.



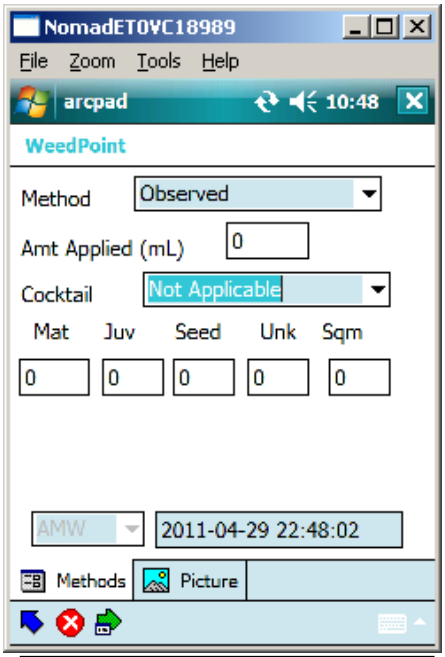
Select Weed Screen Shots for the Nomad data logger with ArcPad: All of this information can be uploaded straight into the database…



A FeatureID is generated with the date and Taxon. You can enter Comments..



Once you detect a weed, you check the date and then enter the Survey Action.



Then you select your Control Method, amount of herbicide applied and type. Enter number of individuals in the appropriate categories.

The weed related fields and data standards were largely adopted from the Maui Invasive Species Committee (MISC) and integrated into the WMMWP data management system. Strawberry Guava was used as the example species upon which definitions were discussed in terms of plant age class and definitions of individuals.

In total, we have held seven Maui Data Hui meetings since the beginning of this grant. These meetings have enabled data managers to get together to discuss recent data accomplishments within all of the different organizations as well as setting data standards. In addition to the weed standards, we have also created standards for similar attributes for island-wide fences, while trails and landing zones are in progress which is important to weed management for the purposes of weed control infrastructure and orientation. This is particularly important to collaborative efforts to manage areas by multiple organizations. For example, MISC may utilize the camps, trials, LZ's and fence lines to access its target weeds within a WMMWP management unit or WMMWP could provide MISC with similar locations on State land.

Participants included representation from the East Maui Watershed Partnership (EMWP), The Nature Conservancy (TNC), Leeward Haleakala Watershed Restoration Partnership (LHWRP), Maui Land and Pineapple (Pu'u Kukui Preserve, (PKW), Maui Invasive Species Committee (MISC), Plant Extinction Prevention Program (PEPP), Natural Resource Data Solutions (NRDS), Pacific Basin Information Node (PBIN), and Kaheawa Wind Farm.

- Meeting held on November 18, 2010: We reviewed the Hui goals and objectives, and continued work on updating the data standards for both weeds and fences (in particular, standards for Strawberry Guava data collection). We also completed a round robin of current projects that groups were doing in order to stay up to date with on-going progress in various groups.
- Meeting held on August 10, 2011: Stephanie Tom from The Nature Conservancy on Oahu participated in this meeting and talked about current TNC projects and the uses of ArcGIS online. We discussed the possibility of offering data over the internet in real time but realize our limitations to this tool.
- Meeting held on February 16, 2012: Updates of each organization. Trying to create a server for all fences to be able to share data. Maui Invasive Species Committee representative showed their analysis of weed control sweep lines.
- Meeting held on May 29, 2012: Updates of each organization; started to create standards for trails layers.
- Meeting held on July 17, 2012: Updates of each organization; continued discussion of standards for trails and also LZ layers; Sam Aruch with NRDS (Natural Resource Data Solutions) showed his presentation for the HCA conference. This sparked discussion about presenting more real life examples of data hui accomplishments, and to continue these types of presentations showing the utility of groups such as the Maui Data Hui.

As of September 20, 2012, a small remaining portion of this category had been re-budgeted to "helicopter operations."

PHASE 3: Analysis
Deliverables:

- GPS locations of ATF, Clidemia hirta, Psidium cattleianum and Tibouchina herbacea within project areas.
- Geo-database of GPS points of species created within Data Hui weed standards.
- Distribution/Abundance maps for target species

- 1 Running work station (computer and software) for GIS analyses
- 4 trained staff in weed data analysis for future efforts

Accomplishments:

We have completed the purchase of new Dell Optiplex 960 computer workstation and two widescreen monitors for side-by-side viewing of imagery. We have also purchased ESRI ArcGIS 10.0 licenses for GIS analysis of these areas.

We were able to work with the RMH imagery up to about 3,400 feet although its resolution was approaching 2 cm accuracy in some areas. Areas higher than this got too blurry to use due to being flown at a different date and under more trying conditions. After some preliminary tests with the lower elevation imagery, it was evident that understory species (*Tibouchina herbacea* and *Clidemia hirta*) would be next to impossible to pick out with any certainty, so we decided to focus on *Psidium cattleianum*. We picked target areas, mostly on ridge tops which had the clearest imagery and would be accessible to ground truthing, and started searching from higher elevations to lower elevations.

Trial analysis lent us 296 potential points for Strawberry guava which were arbitrarily selected in the landscape from likely trees detected in the imagery. We were able to reach 61 points on the ground to check their validity, of which 43 points were in fact *Psi cat* and 18 were a different species, giving us a success rate at identifying *Psi cat* using the imagery of 70%, which for preliminary results are good (See Map A, p12.). There are still 235 points that we have not visited on the ground for verification and many of these are in areas where we know there are large stands of *Psi cat*. Inaccuracy of ortho-rectified images and even small inaccuracies of ground GPS units makes it difficult in densely populated target areas to confidently determine if individual plants were specifically indentified in the imagery.

Three personnel were able to work with the images to attempt analysis and did receive hand own training from Resource Mapping Hawaii to work with imagery and navigate the mosaic system. One staff member ended up giving their best effort to yield results from the imagery and performed the above analysis. Further crew training was postponed due to the lack of promise in our batch of imagery.

It is recommended that future analysis of imagery be more rigorous and should locate target species within strictly defined areas. Each identified target should then be confirmed on the ground for presence and absence. The area should also be swept by ground personnel to find any individuals that may not have been detected through imagery analysis. In this manner, a truer understanding of the merits of the analyzing imagery would be realized. Again the low resolution quality of the imagery made this exercise impractical.

The image analysis would have been more valuable in higher elevation areas, but the lack of quality in this zone would not have been possible due to the low resolution of the imagery. Therefore, as of September 20, 2012, remaining portions of this category had been re-budgeted to "helicopter operations."

PHASE 4: Technical Report
Deliverables:

- Published report on findings from Data Hui and Resource Mapping Efforts

Accomplishments:
Our originally proposed goal of using high resolution aerial imagery technology had faced significant challenges in completing the proposed deliverables. First, poor weather and rugged terrain let us only obtain a small portion of the imagery we had proposed. Secondly, due to the weather and terrain challenges, the imagery that we did collect was of poor resolution, making it impossible to discern the proposed species using imager analysis techniques at the given resolutions. Because of these limitations, it was not practical to spend time or money on training to analyze the insufficient data or to write up a technical report describing these pitfalls.

Again, As of September 20, 2102, this category has now been re-budgeted to "weed management plan" activities.

PHASE 5: Planning
Deliverables:

- 5 Year Weed Management Plan for Kapunakea Preserve and PKW lands for species of Strawberry guava, T. herbacea, C. hirta, and ATF.
- Goal timeline for invasive species removal in project areas
- Plan for 5 year renewal of imagery for same project areas to address changes.

Accomplishments:
We have completed a 5-year weed management plan for all of WMMWP including the Kapunakea and PKW lands. After meetings with Partners and top botanists on Maui, priority species have been set within each management unit and action plans have been established for these species over the next five years. This is a "living" document: priority species may be added and actions set forth if new information and/or new locations are discovered. See attached Weed Management Plan.

The timeline deliverable was not specifically addressed given the complexity of the weed control and the number of species. Instead we defined a spatial goal to work from the top of the mountain to the 2,800 foot contour (which creates a 15,000 acres management area) and to remove all priority species from within this zone in five years at a total cost of over 3 million dollars.

PHASE 6: Implementation (mostly funded through other grants)
Deliverables:

- Data collected on number of species controlled or treated, acres surveyed and acres controlled.
- Aerial/ground surveys to assess recovery after removal

Accomplishments:
Ground truthing of imagery as well as the removal and treatment of priority species was started in project areas and was covered by matched funds, but was limited due to the lack of high resolute imagery. Control of weeds that we found during this project was covered by other grant monies; however we did survey a total of 220.6 acres using the RMH imagery. This imagery partly helped us to focus our control areas on the mountain, leading to the following treatment numbers: (*Acacia mearnsii and Cinchona species were not originally specified in the grant proposal, however due to increasing concern by land managers we have begun to control these species).* (See Maps C-D, pp.13-14) for each species' control efforts).

- Num Plants Controlled or Treated **(funded by other grants)**:
  - Psi cat: 3,899
  - Cli hir: 695
  - Aca mea: 7
  - Cinchona sp (Quinine): 7
  - Tib her: 50
- Acres Surveyed:
  - RMH Imagery: (**This grant)** 220.6 acres
  - Aerial Surveys: **(funded by other grants)**(Psi cat only) 1,340.74 acres
- Ground Acres Swept and Controlled: **(funded by other grants)**
  - Psi cat: 85.2
  - Cli hir: 52.9
  - Aca mea: 5.6
  - Cinchona sp (Quinine): 6.2
  - Tib Her 3.6

Other activities:

NEW PHASE: *Macaranga tanarius* Priority Weed Range Assessment:
To help achieve HISC objectives and obligations within this grant and to utilize remaining monies which were not utilized for other planned phases, WMMWP gained approval to assess the range of the invasive Macarange tanarius. This species was known to be extensive in Waikapu Valley, but it had not been well documented in adjacent areas such as Iao Valley where it was known in relatively low numbers. Prior to the assessment it was thought to be theoretically possible to contain the species to Waikapu and remove all other outliers.


Figure 1: Dense Stand of *Macarange tanarius* in Waikapu Valley, 2012

Aerial weed surveys for *Macaranga tanarius* were conducted on four

different dates: 8/21, 8/23, 8/28, and 8/29/12. In the process WMMWP staff also gained knowledge of Toona ciliata, which shared a similar range and was also easy to detect given a unique color and form. Therefore WMMWP is also presenting findings for this species.
This grant provided helicopter funds while staff time was supported by funds from the Department of Water Supply. An initial ground survey was conducted in Waikapu Valley to familiarize our team with the core infestation of the invasive plants *Macaranga tanarius* and *Toona ciliata* and become attune to their visual characteristics. During each of the four helicopter operations, the crew first conducted reconnaissance in Waikapu Valley in order to gain a "site image" to ensure accurate identification of the target species.

Figure 2: The dark Green Canopy of *Toona ciliata* begins to spread in Waikapu Valley, 2012

Searches for the species subsequently took place in and around Waikapu, Iao, Ukumehame, Launiopoko, and
Olowalu Valleys. Map E (p.15) shows the flight lines and waypoints collected during the aerial surveys and outlines specific areas observed to have significantly high densities of *M. tanarius* and/or *T. ciliata*. Ground survey information conducted in certain areas was also documented and continues to be supplemented as we expand ground surveys for this species.

These follow up aerials gave us a better idea of the extent of these populations as well as outlier locations. Outliers were typically on steep slopes and in inaccessible areas. The flight missions generally followed the contour of the terrain at 500ft intervals between 1500ft and 3500ft elevation depending on the number of target species found. Each valley was broken down into sub watersheds and flown at the various levels, this method proved valuable in an otherwise potentially disorienting exercise. Track lines were also taken and used to navigate with confidence and maintain adequate coverage.

Results proved that these species had a range far greater than was previously known and added these species to our priority species lists for a range that now includes not only Waikapu and Iao Valleys but also Ukumehame, Olowalu, Launiupoko, and North and South Waiehu. These findings were disappointing and the range of the plants were also impressive along the elevation gradient which put Toona thriving at heights of 3,700 feet elevation and Macaranga at 2,800 feet in elevation in mesic to wet forest.

Despite these ranges, our mapping effort did describe a range which lends itself to a control strategy which may limit its spread should a suitable tactic be identified. Control methods for this species will require aerial applications of herbicide via spray ball or Herbicide Ballistic Technology, under the guidance of Dr. James Leary of UH, CTAHR. Ground work may be possible in limited areas once more inaccessible outliers are removed and ranges retract to on the ground access areas.

Future actions include the need for conducting treatment trials which explore the use of different application methods, herbicides and doses. Possible management and treatment strategies will have to consider cost.

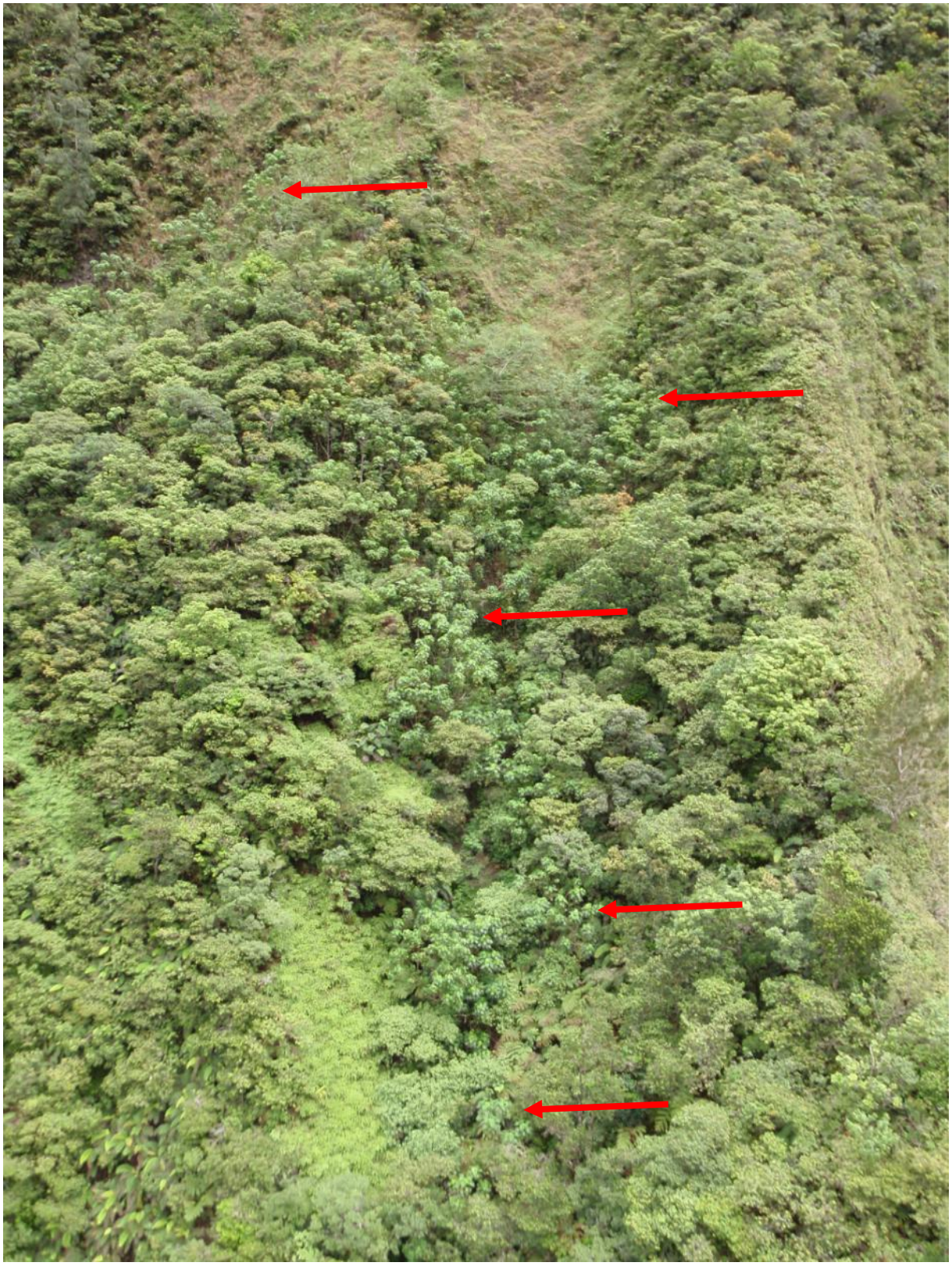
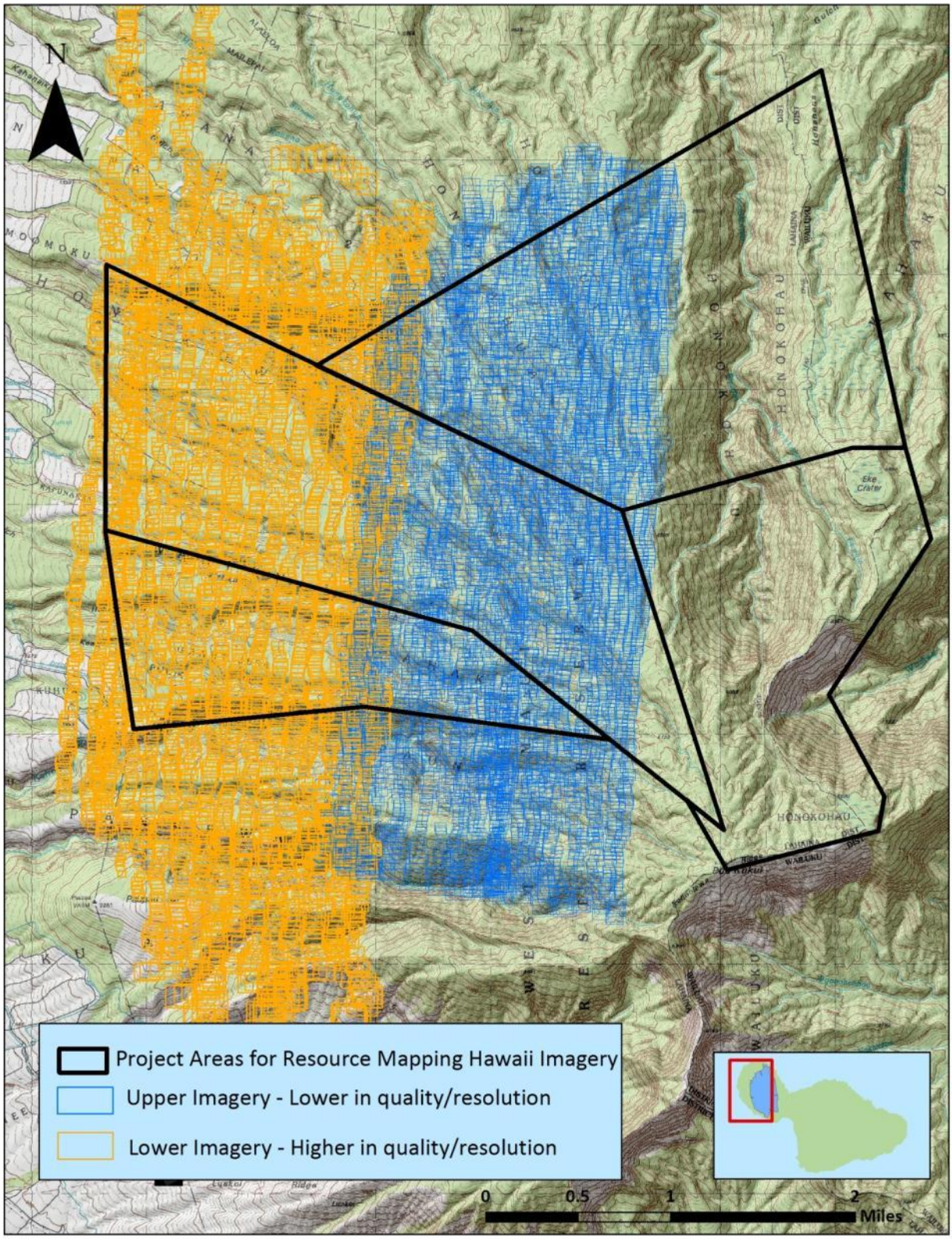
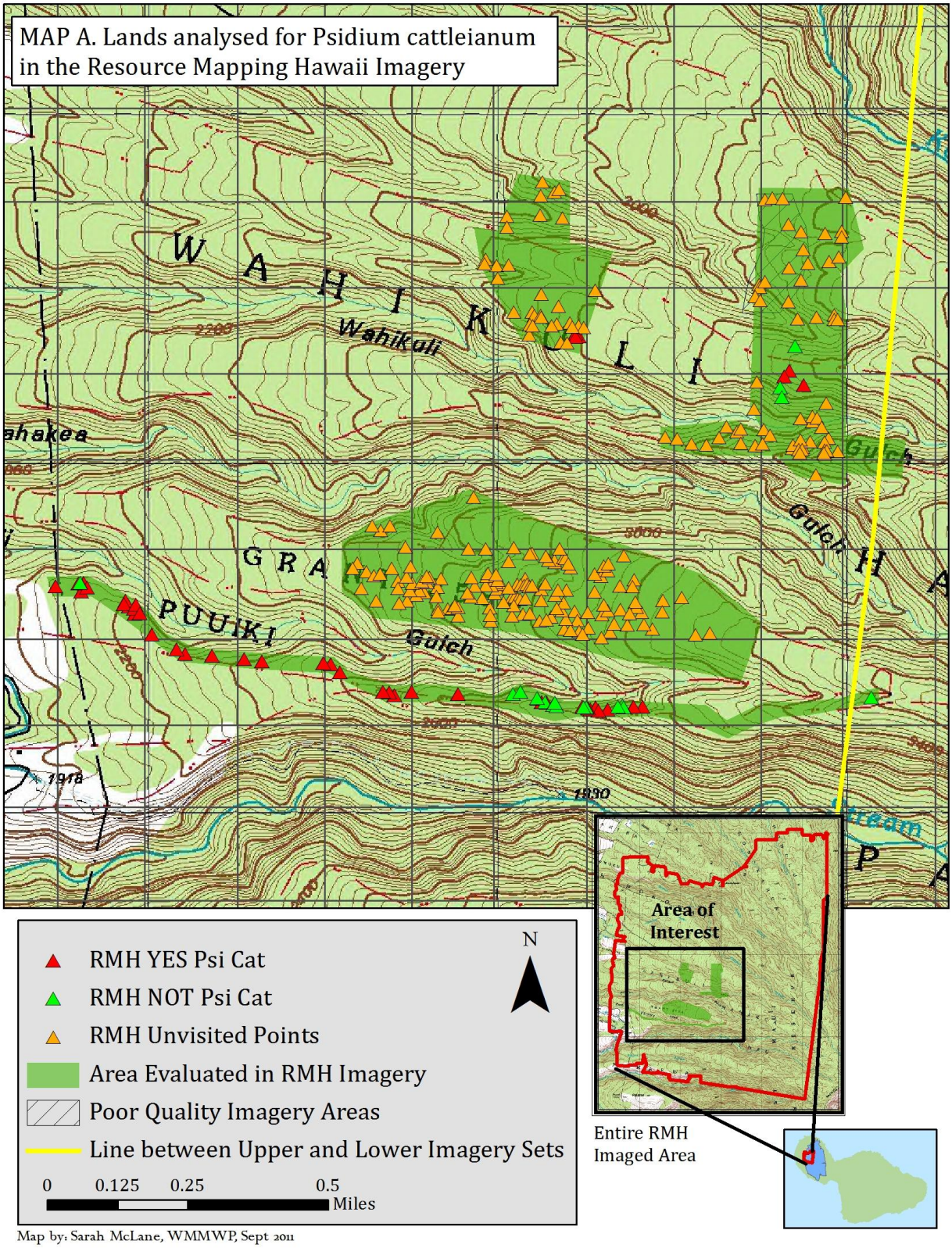
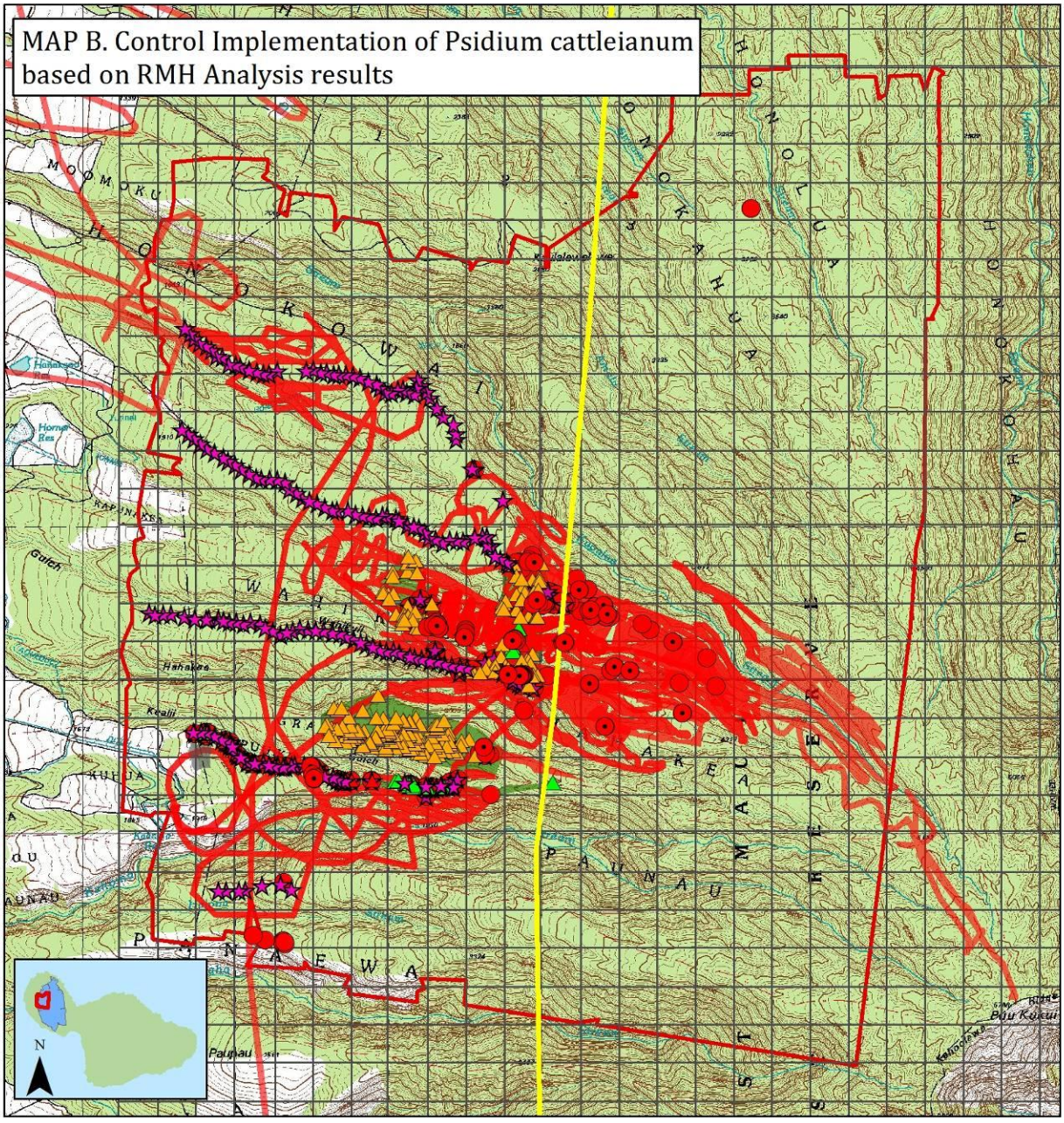


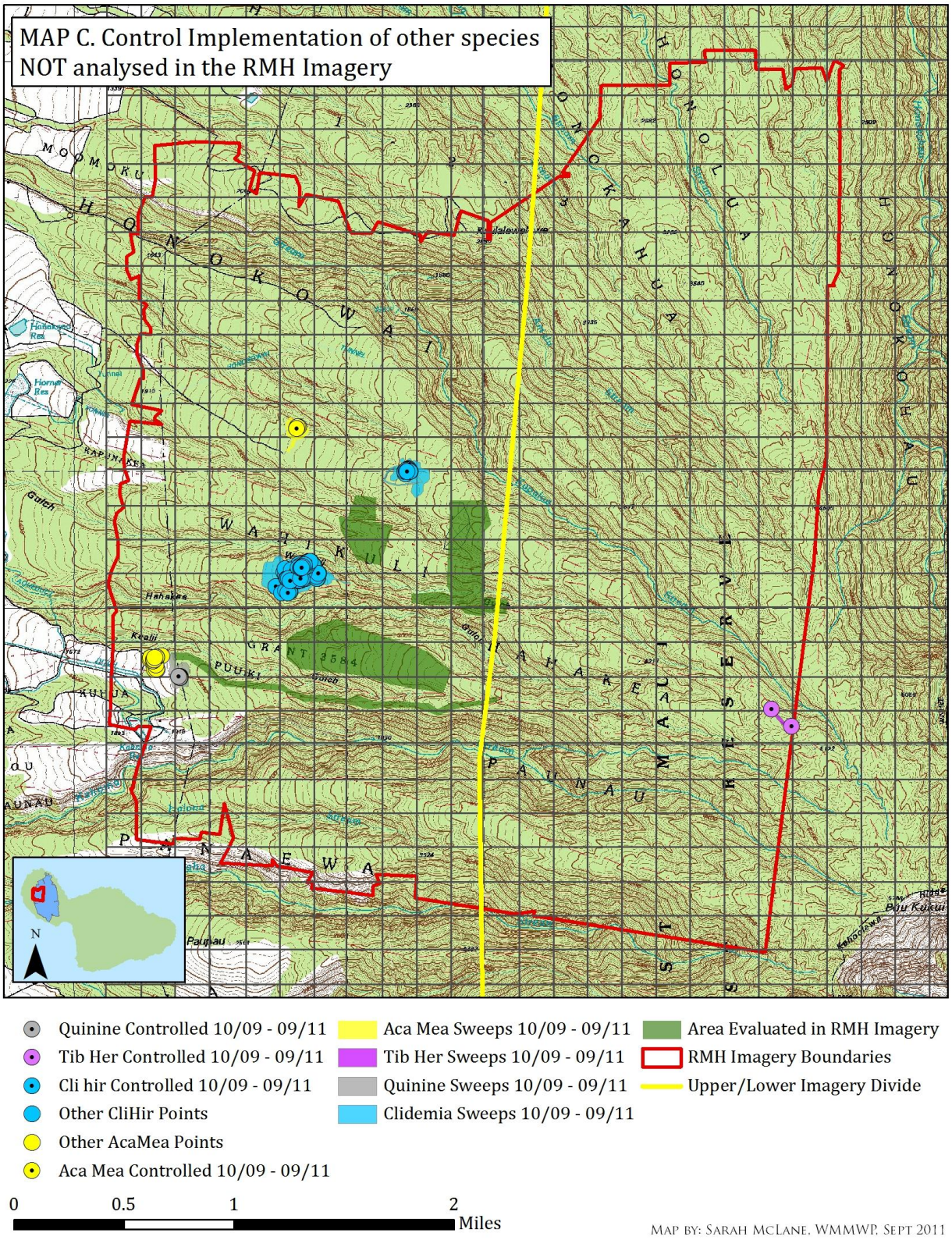
Figure 3: *Macaranga tanarius* creping into steep wet drainages in Waikapu, 2012

Map A-1. Revised Study area and collected imagery. (From Oct 2010 report)




MAP A. Lands analysed for Psidium cattleianum in the Resource Mapping Hawaii Imagery
W A H I K U L I
Wahikuli
G R A
PUUIKI
Gulch
Gulch
Gulch
RMH YES Psi Cat
RMH NOT Psi Cat
RMH Unvisited Points
Area Evaluated in RMH Imagery
Poor Quality Imagery Areas
Line between Upper and Lower Imagery Sets
0 0.125 0.25 0.5
Miles
N
Area of Interest
Entire RMH Imaged Area
Map by: Sarah McLane, WMMWP, Sept 2011


MAP B. Control Implementation of Psidium cattleianum based on RMH Analysis results
RMH Imagery Boundaries
Line between Upper and Lower Imagery Sets
Area Evaluated in RMH Imagery
RMH YES Psi Cat
RMH NOT Psi Cat
RMH Unvisited Points
Other PsiCat Points
Psi Cat in Transect Stations
Controlled Psi Cat 10/09 - 09/11
Psi Cat Ground & Aerial Sweeps 10/09 - 09/11
0
0.5
1
2
Miles
N
Map by: Sarah McLane, WMMWP, Sept 2011


MAP C. Control Implementation of other species NOT analysed in the RMH Imagery
Quinine Controlled 10/09 - 09/11
Tib Her Controlled 10/09 - 09/11
Cli hir Controlled 10/09 - 09/11
Other CliHir Points
Other AcaMea Points
Aca Mea Controlled 10/09 - 09/11
Aca Mea Sweeps 10/09 - 09/11
Tib Her Sweeps 10/09 - 09/11
Quinine Sweeps 10/09 - 09/11
Clidemia Sweeps 10/09 - 09/11
Area Evaluated in RMH Imagery
RMH Imagery Boundaries
Upper/Lower Imagery Divide
0
0.5
1
2
Miles
Map by: Sarah McLane, WMMWP, Sept 2011

Map E. Locations of *Macaranga tanarius* and *Toona ciliata* in West Maui. Aerial flight lines are shown by the red lines, *Macaranga* points in orange, *Toona* in blue and yellow represents *Macaranga* locations taken by other organizations. High density areas of each species are depicted by the different colored hatched polygons.