Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Final Report for the Hawaii Invasive Species Council Project for FY14

Title: Targeting High-Priority Miconia Patch Populations with an Accelerated Intervention Schedule utilizing Herbicide Ballistic Technology (HBT)

Content Area: Control

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Partners: MISC, KISC, OISC

Executive Summary:

Miconia (*Miconia calvescens* DC) is a HISC priority species with over a 20-year legacy of dedicated management across the state. The ISCs have good intelligence on nascent patch populations colonizing extreme, remote locations on Kauai, Oahu and Maui where accessibility is difficult to impossible. Herbicide Ballistic Technology (HBT) is a new weed intervention platform with the capability of administering effective herbicide doses with long-range precision and accuracy, which enhances aerial surveillance operations with the combined actions of detection and elimination (i.e., intervention). The mission of this project was to deploy accelerated intervention schedules to ten high-priority patch populations with the goal to establish a steady-state condition of each patch for sustaining long-term management with an optimized marginal cost of operation.

Original Project Deliverables:

This project will acquire an HBT inventory that can deplete an estimated 5000 high-value miconia targets. We will be able to report measureable target reductions in all patches where interventions are administered. Finally, we will update methods for measuring progress based on simple GIS protocols for generating spatially and temporally explicit interpretations with statistical value.

Measures of Effectiveness:

The basic unit of measure in this project is target density, which serves as an absolute value of progress (i.e. target reduction), but also serves as a direct influence on operational efficiency values. For example, target density establishes the slope coefficients for search efficiency and herbicide use rate. Thus, we have measured concomitant improvements in these functions with each sequential operation reducing target density.

The vision of this strategy is to optimize the cost of future operations with an initial accelerated schedule leading to a steady-state condition of extreme low target densities and to build intelligence by characterizing the demographic profiles of each patch population with enhanced surveillance/intervention protocols.

Results

For FY14, we conducted 34 aerial missions with 145 hours of operational flight time and 80% projectile inventory consumption (~120,000) targeting nascent miconia populations on Kauai, Oahu and Maui. We exceeded our deliverable milestone with effective treatment to 5,356 targets. The total net area surveyed in this project was 6,552 ha (16,184 acres), with >93% of this area contained within the East Maui Watershed. Our average dose rate was 22.6 projectiles per target (4.5 g ae), which is 20% less than the average dose of targets treated from 2012-2013. The total treatment footprint was 10% of the total searched area at 653 ha, with a total herbicide use rate in this footprint at 26 g ae ha^{-1}, equivalent to 0.38% of the maximum allowable use rate. This is a highlight to the surgical nature of the application technique and the strategic initiative to focus on high-value, incipient target populations.

A B

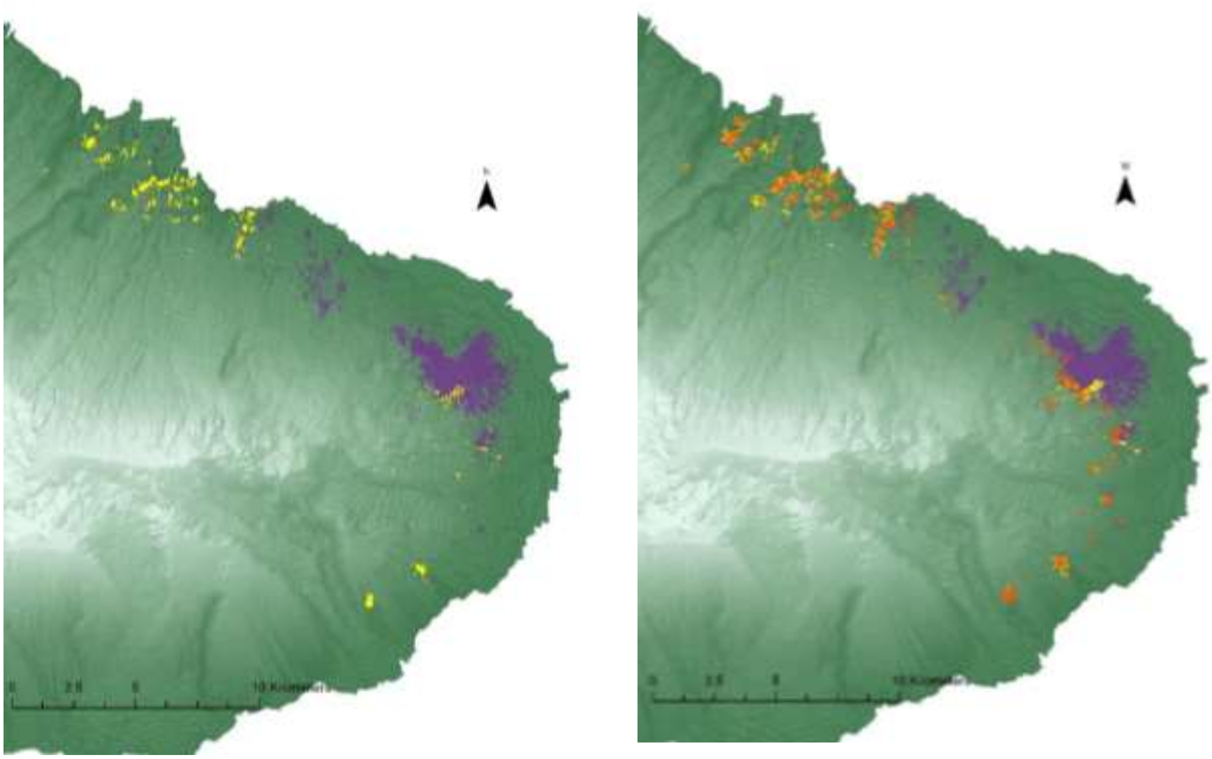

Figure 1. East Maui Watershed with historical miconia points (purple; 1991-2011) with HBT target points recorded prior to this project (A; yellow; 2012-2013) and HBT target points recorded during this project time period (B; orange; 2014)

With well over 95% of the historical use of HBT focused on East Maui Watershed, measures of effectiveness are better measured from these more robust data sets. From 1991 to 2011 there is a record of 270,591 treated miconia targets (most recorded from 2000-2011), with 11,750 listed as mature and a majority of these targets treated with the aerial long-line sprayer. Starting in 2012, HBT became the primary utility in aerial management operations. In three years of operations, we have conducted 72 missions, treating 12,746 miconia targets, including 193 mature targets, covering a total net area >6900 ha (e.g., >17,000 acres) (Fig 1). From these total values, this 2014 project contributed 29 missions, effectively treating 5,191 targets (Fig. 1B), which are both ~40% of total accomplishments to date.

This strategy is highlighted by an accelerated frequency of target interventions with an intent to mitigate spread, but it is also highlighted by a regiment of persistence and consistence. Quarterly (3-month interval) accumulations of operational flight time (OFT) reached 300 hours in approximately three years with a strong positive linear fit ($R^2 = 0.99$) at a rate of 9.5 hours OFT (i.e., six fuel cycles) per month (Fig. 2). Similarly, strong linear trends fit target accumulation and net area expansion over time. The target acquisition rate over three years was 36.4 targets hr^{-1} (Fig. 3). Area effectively surveyed (protected) has expanded at a rate of 22.6 ha hr^{-1} (e.g., 55.8 acres hr^{-1}), while the target footprint (i.e., area occupied) has expanded at a rate of 2.6 ha hr^{-1} (Fig. 4). It is worth noting that based on current procedures in calculating area, a single, isolated target is equivalent to one hectare. Based on the rate of target accumulation and expansion of the target footprint, this roughly translates to ***one new incipient target detected, for every thirteen targets treated***. Although the delimited target footprint continues to expand, the (protected) containment area surrounding this footprint is expanding at a faster rate and is currently >7-fold greater size.

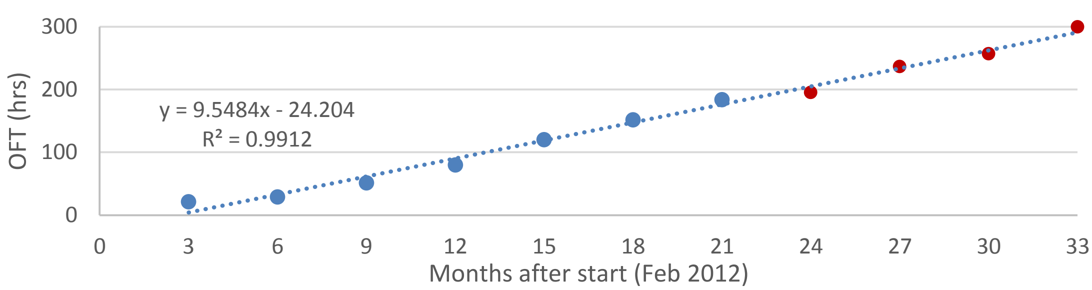

Figure 2. Quarterly accumulation of operational flight time (OFT; hrs) over a 3-year period starting Feb 2012. Note the linear fit with slope function (hrs $month^{-1}$) denoting the consistent rate of operational flight time (OFT) utilized in (planned) frequent missions. The red points are the most recent values generated during the project time period (2014).

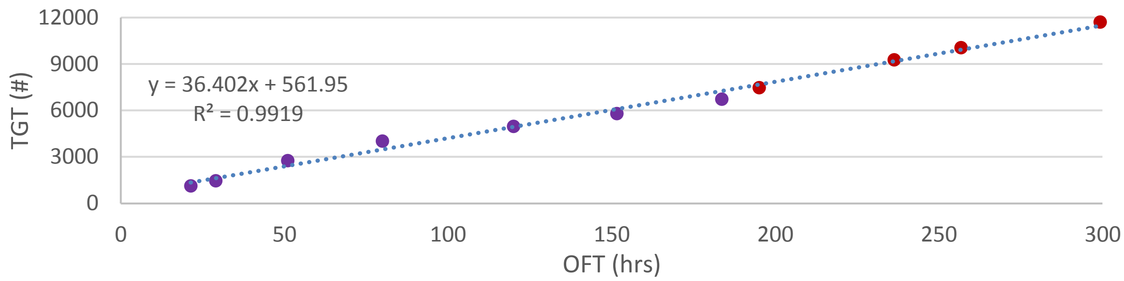

Figure 3. Net targets accumulated in 300 hrs OFT. Note the linear fit with slope function designating target acquisition rate (TGT hr^{-1}). The red points are the most recent values generated during the project time period (2014).

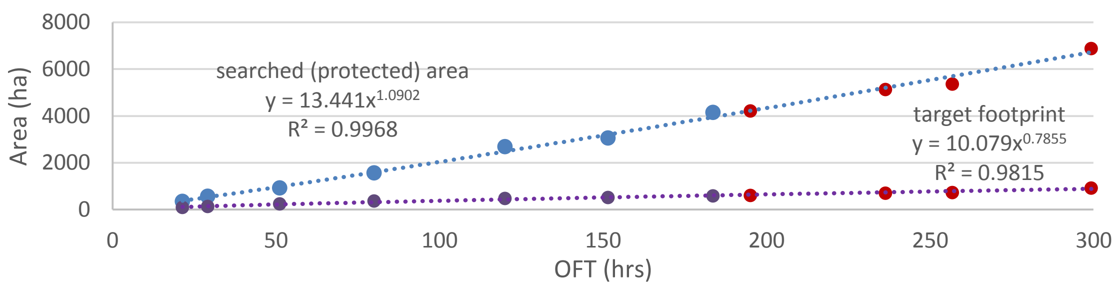

Figure 4. East Maui Watershed area (ha) surveyed (light blue) and the target foot print (purple) designated in 300 hrs OFT from 2012-2014. Note the linear fits with slope functions denoting rates of area expansion (ha hr^{-1}). The red points are the most recent values generated during the project time period (2014).

Target densities encountered in operations are reducing over time (Fig. 5). According to the best fit exponential decay function this reduction rate is 0.7% hr^{-1}. Search efficiency and herbicide use rate have shown correlations to target densities encountered (Leary et al. 2014). In this study, we continue to see these trends (Fig 6A and B). Search rate (ha hr^{-1}) has increased one hectare for every 6 hours OFT and helps explain the proportional expansion in searched area relative to the target footprint (see Fig. 4). The dramatic improvements in search rate efficiency is also partially explained by strategic decisions for dedicating resources to reconnaissance missions into new locations (with no targets detected) accommodated by opportunities created by substantial target density reductions in the known target locations. In the history of HBT operations, herbicide use rate (HUR) has never exceeded 1% of the maximum allowable use rate (67.2 g ae ha^{-1}) (Fig 6B). Moreover, HUR has a decay rate of 0.2% hr^{-1} explained by the compounding effects of lower target densities encountered (i.e., expanding search area) along with a measurable decline in herbicide dose rate (g ae $target^{-1}$) (Fig. 6C). This dose reduction corresponds to our observations of treating smaller targets perceived as recruits of latent seed banks in these known locations. This is one of the primary values of the higher revisit frequency of an accelerated intervention schedule. Contrary to previous beliefs, we are detecting targets that are <0.5 m tall and have been lethally treated with as little as one projectile (~0.2 g ae).

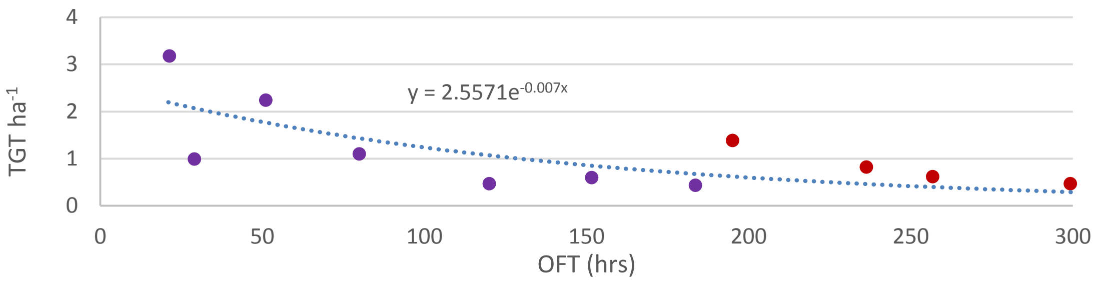

Figure 5. Reduction of target (TGT) densities encountered over time. Note negative exponential fit with a decay rate of 0.7% hr^{-1}. The red points are the most recent values generated during the project time period (2014).

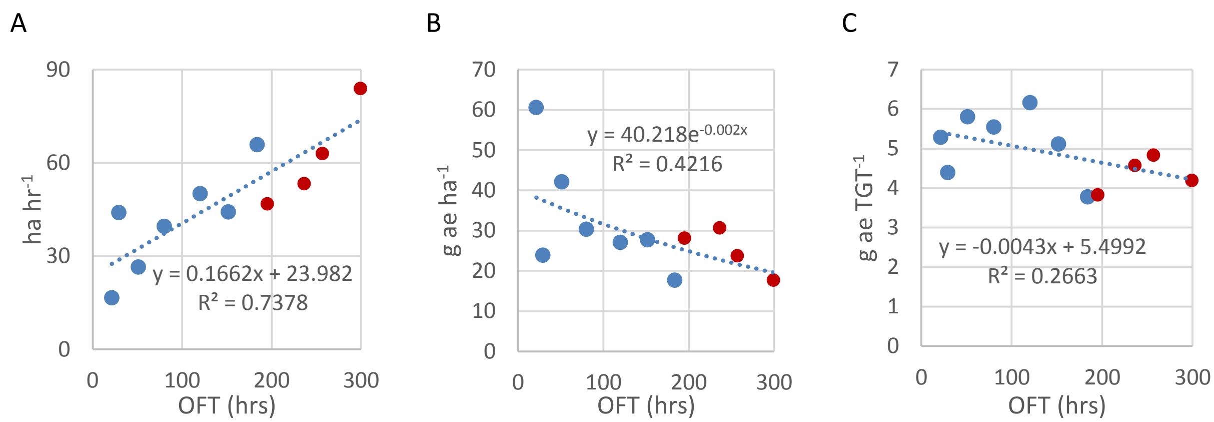

Figure 6. Mean search rate (A) herbicide use rate (B) and herbicide dose rate (C) over time. The red points are the most recent values generated during the project time period (2014). Note: g ae = grams acid equivalent of active ingredient.

Variable costs of operation, by definition, correlate to production amounts. In this study, the variable cost per unit area is directly proportional to target densities encountered. These costs include contracted helicopter services with three-person crew and projectile consumption to treat targets (e.g., estimated total at \$0.298 USD sec^{-1}). Variable costs of HBT operations show a negative exponential cost reduction over time that is highly congruent to target density reduction with a decay rate 0.6% hr^{-1} (Fig. 7; see Fig. 5). In 2014, the average variable cost of operations was \$21.20 USD ha^{-1} (i.e., \$8.54 USD $acre^{-1}$).

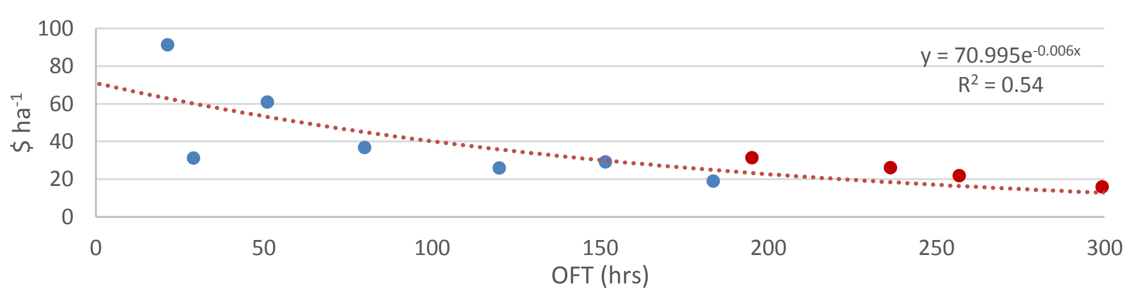

Figure 7. Variable cost of operations over time (blue points) calculated from known values of search effort and projectile consumption dependent on the target densities encountered. Note the variable cost decay rate of 0.6% hr^{-1}. The red points are the most recent values generated during the project time period (2014). Costs are derived from the inverse of search rate (e.g., min ha^{-1}) at an estimated \$1000 USD hr^{-1}, three-person crew at \$40,000 USD annual salary (including 28% fringe) and herbicide use rate at \$0.31 $projectile^{-1}$.

These Interventions are characterized as random search operations, resulting in imperfect (type II error; false negative) detection rates (Cacho et al. 2004 and 2007, Cooper et al. 2003, Frost 1999, Koopman 1946) where randomness imposed might include: (1) cryptic nature of miconia (e.g., stochasity of dispersal and recruitment), (2) extreme visual impediments of the landscape, or (3) inconsistency in search capability. Koopman (1946) developed the mathematical framework for a random search operation with the following equation for the probability of detection:

$$p_d = 1 - e^{-c}$$

Where perfect detection is impeded by the exponent of coverage (c). In this study, coverage is calculated as gross over net area accumulation. Gross and net area expansions strongly fit power functions with gross area accumulation inherently increasing at a greater rate (Fig. 8A). Gross area accumulations are partitioned into two categories: (i) net area expansion or (ii) net area coverage. Thus, in this calculation coverage saturation is increasing over time at the same power as gross area accumulation (Fig. 8B). These strong fits of empirical values allows for projection beyond the 300 hours OFT. In this report, 600 hours OFT is accomplished in just under 32 months (~3 years) at maintained levels of productivity (see Fig. 2). Moreover, target accumulation is also projected to exceed just over 20,000. If that holds true, the containment strategy has currently accumulated 58% of the projected value and fits the curve for the probability of detection of a random search operation (Fig. 8c).

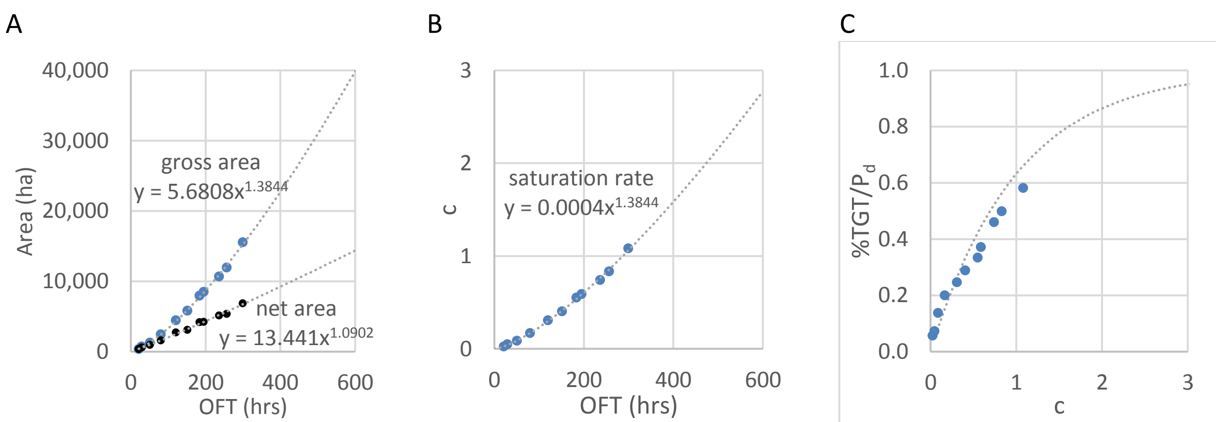

Figure 8. Gross (blue) and net (black) area expansions projected to 600 hours OFT (A) Coverage saturation over the same projected time (B) and percent target detection over projected coverage saturation (c) from the fitted function *pd =1-e*$^{-c}$ for probability of detection (*pd*) of a random search operation.

Conclusion

The approach for an accelerated intervention schedule via mobilization of the HBT platform is demonstrating progress with metrics in target density reduction, protected area expansion and cost optimization. Consistency of a high-frequency intervention strategy has accommodated strong mathematical fits of the empirical data, which allows for ***critical assessments of projected future outcomes.*** With maintained operational capacity, target densities will continue to decline, while area expansion and coverage will continue to increase (Fig. 9). As we continue to reach the extent of the miconia habitat in the East Maui Watershed, gross area accumulations will bias towards coverage saturation with reduced contributions to net area expansion. We may also observe momentary increases in target density as operations start to shift to delimiting the boundary of the core infestation (in progress; see Fig. 1). Costs will ultimately be optimized to the point when targets are no longer detected within a known location where flight time with crew becomes the only variable. This also becomes the milestone where deceleration of intervention frequency occurs, leading to further compounded cost reduction, which may be achievable within decade.

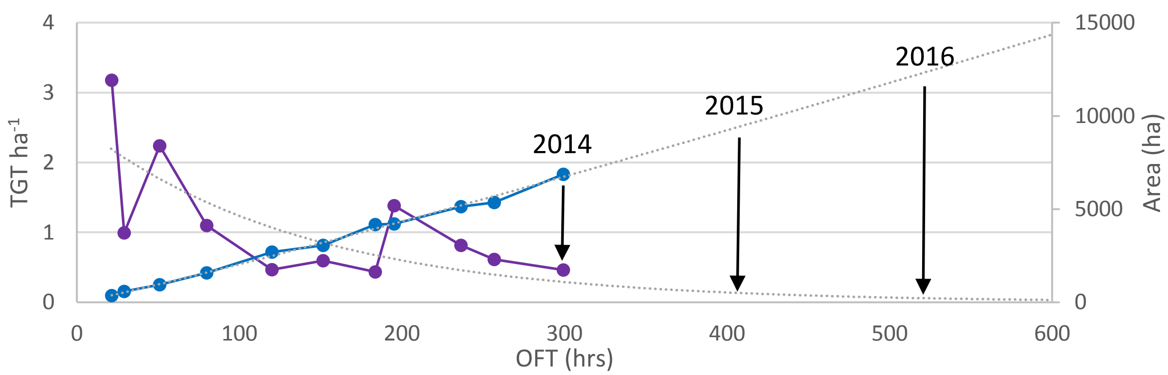

Figure 9. Projections of target density reduction and protected area expansion with maintained operational capacity.

Citations

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