OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

MONITORING OF UNDERSTORY VEGETATION CHANGE IN ASSOCIATION WITH IPA CONTROL OF *MORELLA FAYA* ONE YEAR POST-TREATMENT AT PALIKEA

INTRODUCTION

Incision Point Application (IPA) herbicide treatment of problematic non-native trees allows staff to effectively treat numerous individuals over a large area in a relatively short amount of time, with very small doses of pesticides. *Morella faya* is common throughout Palikea, and due to its ecosystem altering characteristics, is on the Hawaii Noxious Weed List, and considered a high risk weed species (Division of Plant Industry 2003; Hawaii-Pacific Weed Risk Assessment 2009). Vegetation monitoring of Palikea MU in 2014 determined *M. faya* to be the second most frequently encountered non-native tree within the MU (45% frequency), after *Schinus terebinthifolius* (63% frequency) (OANRP 2014). Recommendations were made for partial canopy thinning/removal of this species, as it is one of the more easily managed canopy weeds, and has infrequent recruitment. Large *M. faya* trees were selectively treated using IPA on November 3-4, 2015 at Palikea, including approximately 116 trees within the MU fence, and 81 outside the fence (Figure 1). This was the first round of multiple selective treatments that may be conducted, pending further discussion of management strategies for this taxon at Palikea. Understory vegetation change in association with IPA treatment of *M. faya* was documented using point intercept monitoring of a subset of treated trees within Palikea MU. Initial baseline monitoring was conducted within the first few months (December 9 and 14, 2015, and January 6, 2016) following treatment, before substantial canopy reduction and any resulting understory response occurred. Subsequent monitoring of the same trees occurred after one year, on November 9, 2016, and January 25-26, 2017.

METHODS

Point intercept monitoring was used to assess percent cover of native and non-native taxa in the understory directly below treated *M. faya* trees within Palikea MU. All species “hit” below 2 m above ground level (AGL) at points along transects were recorded. A 5 millimeter diameter pole was used to determine “hits” (live vegetation that touches the pole) along an outstretched measuring tape. Point intercepts were recorded at 25 randomly sampled treated trees every meter (m) along 5 m long transects in each cardinal direction from the tree, or alternatively, every 0.5 m along two 5 m long transects oriented North and South, or East and/or West or if slopes were too steep to the North or South (n = 500 points). Using two transects with more closely spaced point intercepts per tree was an effective attempt to expedite the data collection process, as monitoring took longer than expected using four transects with fewer point intercepts per tree. The same methods were used for baseline and 1-year post-treatment monitoring. Substrate in locations where no vegetation was intercepted in the understory was recorded as soil/leaf litter, rock, moss, etc. Trees were marked (with a combination of yellow and orange-black striped flagging) and tagged with unique identification numbers. Approximations of percent cover were obtained from the proportion of “hits” among all intercepts. The overall health (noted as healthy, moderate, poor, or dead) of trees and defoliation ranking of 1 to 4 (1: 100%, 2: > 50%, 3: < 50%, and 4: 0% defoliation) as per Leary et al. (2013) were also documented to assess treatment efficacy. Hemispheric photographs were taken of the canopy on the south-facing side of each sampled tree to document canopy openness. Photographs were taken at 2 m AGL, aimed 180° from the forest floor. Gap Light Analyzer (GLA), Version 2.0 software (Frazer et al. 1999) was used to determine percent canopy openness, using the

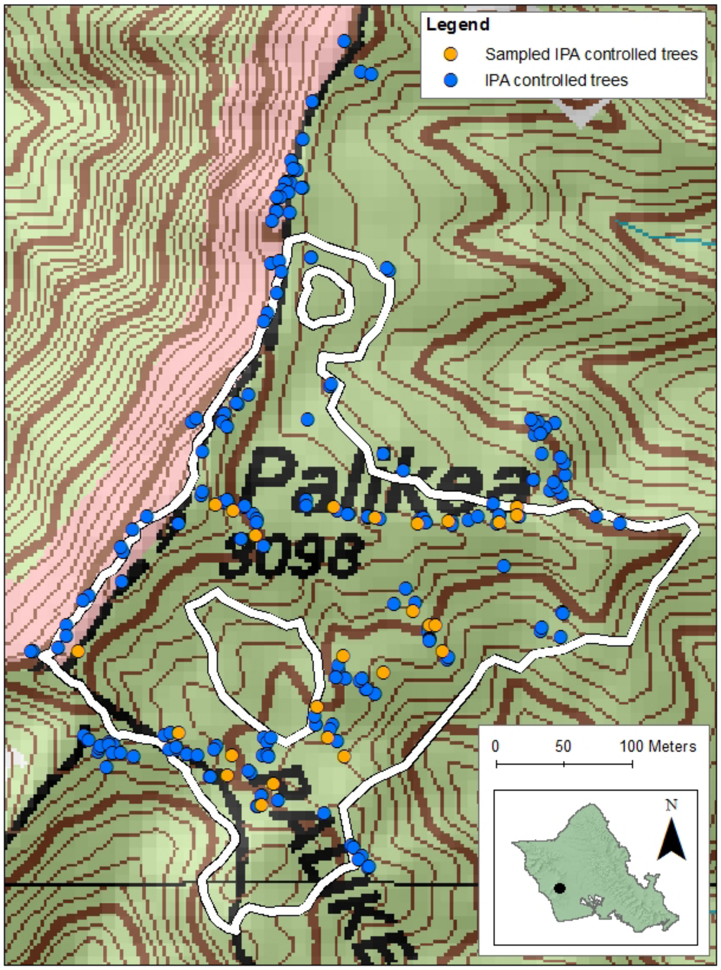

Figure 1. Location of IPA controlled *Morella faya* at Palikea, including locations of trees sampled for monitoring associated understory vegetation response.

hemispheric canopy photographs. Statistical analyses included chi-square tests for understory percent cover, and a paired t-test for canopy openness. Only significant results with statistical power > 0.90 were recognized (G*Power 3.1.9.2).

RESULTS

Understory vegetation cover beneath the sampled *M. faya* trees one year post-treatment at Palikea included 53.4% non-native taxa (primarily shrubs and grasses), 51.0% native taxa (primarily ferns and shrubs), and 11.8% non-vegetated area (Table 1). The most prevalent non-native taxa one year post-treatment were *Rubus rosifolius* (22.6%), *Clidemia hirta* (17.4%), and *Blechnum appendiculatum* (5.8%) (Table 2). Predominant native taxa included *Nephrolepis exaltata* subsp. *hawaiiensis* (11.8%), *Dicranopteris linearis* (10.2%), and *Cibotium chamissoi* (6.2%). Significant changes from baseline observations in the understory included increased cover for non-native herbs, non-native shrubs, and *R. rosifolius*, as well as decreased cover for non-native tree taxa, *M. faya*, and non-vegetated area (Table 3). While the increase in understory vegetation filled in much of the non-vegetated areas, the understory also became more multilayered, with a significant increase in the proportion of point intercepts with 2 non-native taxa per locus (from 7 % to 14%; chi-square test: $p = 0.0001$, $X = 14.99$). Overall species diversity increased for native, and particularly non-native, taxa, from 38 to 41 native and 13 to 20 non-native taxa from baseline monitoring to one year post-treatment. Subsequently, the ratio of native to non-native taxa decreased from 3:1 to 2:1.

During monitoring 1 year post-treatment, expansion of *R. rosifolius* cover was anecdotally observed primarily in weedy lower elevation sub-ridge, slope, and gulch regions, but to a lesser extent in exposed upper elevation ridge areas with more native habitat. *Rubus rosifolius* cover increased significantly in both region types in the understory below IPA treated *M. faya* trees (chi-square tests: exposed upper ridge native areas $p < 0.001$, $X = 11.46$, $n = 260$; lower sub-ridge, slope and gulch weedy areas $p < 0.001$, $X = 43.39$, $n = 240$). However the increase in cover below sampled trees in the lower weedier regions (from 10.8% to 37.1%) was much greater than for those in the upper native regions, which remained below 10% (Figure 2).

During baseline monitoring, most sampled *M. faya* trees were beginning to show signs of declining health (5 healthy, 15 moderate, 5 poor), wherein leaves were browning and/or beginning to defoliate. All trees had some degree of defoliation, with a median ranking of 3 (< 50% defoliation). One year post-treatment, all trees had substantial signs of declining health or mortality (11 poor, 14 dead), with all tree canopies completely defoliated (Figure 3). Most live trees had basal sprouts or budding leaves, while two only had live cambium. Baseline mean canopy openness increased significantly from 17.7% to 32.1% one year post-treatment (paired t-test: $t = -7.159$, $df = 24$, $p < 0.001$).

Table 1. Percent cover of native and non-native taxon groupings and non-vegetated area in the understory below IPA treated *Morella faya* during baseline monitoring and one year post-treatment at Palikea

	Baseline	1 year post-treatment
Non-native	44.0	53.4
Conifer	0.0	0.4
Fern	7.0	7.4
Grass	8.0	11.0
Herb	0.4	3.4
Shrub	20.8	36.2
Tree	9.4	3.6
Vine	3.8	5.2
Native	47.6	51.0
Fern	39.4	39.8
Herb	3.6	5.8
Sedge	0.2	0.0
Shrub	5.6	9.8
Tree	2.4	2.8
Bryophyte spp.	3.2	7.4
Non-vegetated	23.4	11.8
Dead wood	1.0	1.0
Rock	0.6	0.0
Root	0.6	0.2
Soil/leaf litter	21.2	10.6

Table 2. Percent cover of native and non-native taxa in the understory below IPA treated trees during baseline monitoring and one year post-treatment at Palikea MU. Native taxa in boldface.

Taxon	Baseline	1 year post-treatment
Rubus rosifolius	6.4	22.6
Clidemia hirta	15.6	17.4
Nephrolepis exaltata* subsp. *hawaiiensis	10.8	11.8
Dicranopteris linearis	8.6	10.2
Cibotium chamissoi	5.2	6.2
Blechnum appendiculatum	6.2	5.8
Passiflora suberosa	3.8	5.2
Ehrharta stipoides	4.8	5.0
Paspalum conjugatum	3.2	4.8
Dianella sandwicensis	3.0	4.6
Microlepia strigosa	4.2	3.6
Asplenium contiguum	2.0	3.0
Kadua affinis	0.6	2.6
Psidium cattleianum	2.8	2.4
Diplazium sandwichianum	1.8	2.4
Metrosideros polymorpha	1.8	2.4
Asplenium macraei	2.2	1.8
Melinis minutiflora	0.6	1.8
Alyxia stellata	1.6	1.6
Youngia japonica	0.4	1.6
Coprosma foliosa	0.2	1.4
Dryopteris glabra	2.2	1.2
Cyclosorus parasiticus	0.4	1.2
Doodia kunthiana	0.4	1.2
Freycinetia arborea	1.0	1.0
Pittosporum confertiflorum	0.8	1.0
Wikstroemia oahuensis* var. *oahuensis	0.2	0.8
Erechtites valerianifolia	0.0	0.8
Morella faya	6.8	0.6
Deparia petersenii	0.6	0.6
Ageratina riparia	0.0	0.6
Carex meyenii	0.0	0.6
Clermontia persicifolia	0.0	0.6
Schinus terebinthifolius	0.0	0.6
Elaphoglossum paleaceum	1.0	0.4
Elaphoglossum crassifolium	0.8	0.4
Peperomia membranacea	0.6	0.4
Asplenium caudatum	0.4	0.4
Antidesma platyphyllum	0.2	0.4
Ageratina adenophora	0.0	0.4
Ageratum conyzoides	0.0	0.4
Coprosma longifolia	0.0	0.4
Crocosmia x crocosmiifolia	0.0	0.4
Cryptomeria japonica	0.0	0.4
Leptecophylla tameiameiae	0.0	0.4
Sadleria pallida	0.0	0.4
Nephrolepis cordifolia	0.4	0.2
Sphenomeris chinensis	0.4	0.2

Table 2, continued.

Taxon	Baseline	1 year post-treatment
Athyrium microphyllum	0.2	0.2
Broussaisia arguta	0.2	0.2
Cyrtandra waiolani	0.2	0.2
Asplenium acuminatum	0.0	0.2
Asplenium lobulatum	0.0	0.2
Asplenium nidus	0.0	0.2
Bidens torta	0.0	0.2
Crassocephalum crepidoides	0.0	0.2
Dodonaea viscosa	0.0	0.2
Euphorbia multiformis	0.0	0.2
Melicope clusiifolia	0.0	0.2
Sadleria cyatheoides	0.0	0.2
Scaevola gaudichaudiana	0.0	0.2
Kadua acuminata	1.2	0.0
Cheirodendron trigynum	0.4	0.0
Diplopterygium pinnatum	0.4	0.0
Dryopteris sandwicensis	0.4	0.0
Elaphoglossum aemulum	0.4	0.0
Carex wahuensis	0.2	0.0
Cyclosorus dentatus	0.2	0.0
Elaphoglossum alatum	0.2	0.0
Melicope oahuensis	0.2	0.0
Pipturis albidus	0.2	0.0
Vaccinium reticulatum	0.2	0.0
Viola chamissoniana* subsp. *tracheliifolia	0.2	0.0

Table 3. Taxa/taxon groupings with recognized significant vegetation cover changes (statistical power > 0.90). P-values derived from chi-square tests.

Taxa/taxon grouping	Baseline cover	1 year post-treatment cover	p	*X*	Direction of change
Non-native herb	0.4	3.4	0.001	12.071	↑
Non-native shrub	20.8	36.2	0.000	29.096	↑
Non-native tree	9.4	3.6	0.000	13.838	↓
Rubus rosifolius	6.4	22.6	0.000	52.922	↑
Morella faya	6.8	0.6	0.000	26.971	↓
Non-vegetated	23.4	11.8	0.000	49.1235	↓

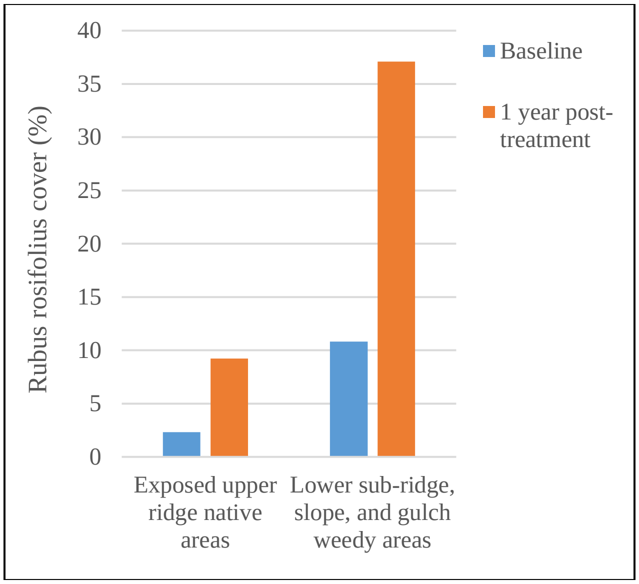

Figure 2. *Rubus rosifolius* cover in the understory below IPA treated *Morella faya* trees during baseline monitoring and one year post-treatment in lower elevation ridge, slope, and gulch weedy areas (n = 240) vs. more native exposed upper elevation ridge areas (n = 260).

Figure 3. Photographs showing defoliation in association with IPA treated *Morella faya* amongst the surrounding vegetation (left), and within the canopy of a treated tree.

DISCUSSION

The decrease in non-native tree cover that occurred in the understory was expected, as each sampled area contained a large *M. faya* tree that received IPA treatment, and live low hanging branches of that species were expected to become absent. Similarly, the significant increase in canopy openness was expected resulting from defoliation in association with IPA treatment of large *M. faya* trees within all sampled areas.

There was concern that understory weedy ingress would occur in response to increased light levels following *M. faya* defoliation. Increased *R. rosifolius* cover was apparent while monitoring some treated trees, and indeed had a significant increase in cover overall among the sampled areas, but was also anecdotally observed to be more prevalent in surrounding areas, and therefore not necessarily due to IPA treatment. Preliminary investigations of MU-scale vegetation monitoring of Palikea MU in June 2017 similarly indicate a significant increase in *R. rosifolius* understory cover (Wilcoxon signed-rank test: $p < 0.001$) as well as a significant decrease in *M. faya* canopy cover (Wilcoxon signed-rank test: $p < 0.001$) within the MU since 2014 (Figure 4). Decreased *M. faya* canopy cover in the MU-scale vegetation monitoring is presumed to be due to IPA control. However, *M. faya* canopy cover change from 2014 to 2017 did not influence *R. rosifolius* understory cover change within plots (Generalized linear model: $p = 0.860$), and *R. rosifolius* cover increased both in plots with decreased *M. faya* canopy cover (Wilcoxon signed-rank test: $p = 0.0024$. $n = 23$) as well as in plots with no change in *M. faya* canopy cover (Wilcoxon signed-rank test: $p = 0.007$, $n = 28$) (Figure 5). This suggests that increased *R. rosifolius* cover among sampled IPA treated trees is a reflection of MU-wide change in *R. rosifolius* cover unrelated to IPA control. *Rubus rosifolius* presence/absence and the extent that it got worse at each sampled tree was variable, but in general the sampled tree understories with the biggest increases in *R. rosifolius* cover were at or below the 2800 ft contour, and/or off of ridge crests. The summer months of 2016 were unusually rainy, and may have contributed to the expansion of *R. rosifolius* in those areas. Further analysis of MU-scale monitoring results may give more clarification any geographic associations with increased *R. rosifolius* cover or frequency.

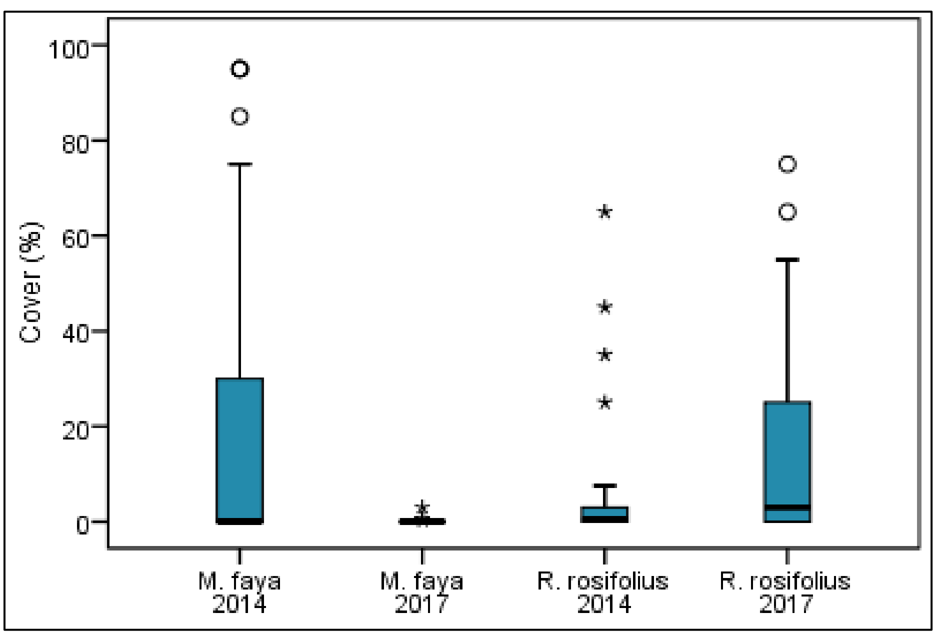

Figure 4. Percent cover of canopy *M. faya* and understory *R. rosifolius* among plots in 2014 and 2017 from Palikea MU vegetation monitoring.

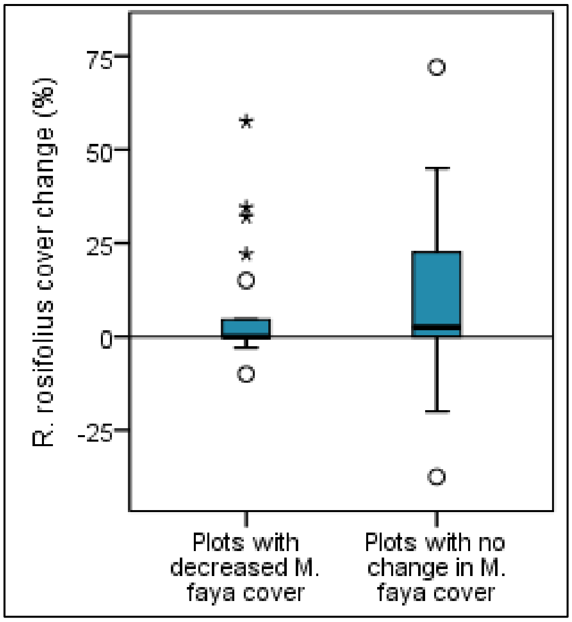

Figure 5. Cover change of understory *R. rosifolius* among plots with decreased vs. no change in *M. faya* canopy cover between 2014 and 2017 from Palikea MU vegetation monitoring. Positive numbers indicate increased cover, while negative numbers indicate decreased cover.

As with weeding efforts in association with MU-scale monitoring, WCA and ICA weeding actions occurred and will proceed irrespective of monitored trees (i.e., crews neither target nor intentionally avoiding weeding around trees used in this trial). Point intercept monitoring of understory change in association with *M. faya* IPA treatment will continue on a three year interval, to coincide with the MU-scale vegetation monitoring for comparison purposes.

While the MU-scale monitoring at Palikea was useful for distinguishing vegetation change that occurred as a direct result of IPA control vs. change occurring across the MU unrelated to treatment, future efforts to monitor understory vegetation change associated with IPA treatment at other MUs or for other taxa may more accurately reflect direct impacts of treatment by also monitoring untreated trees as a measure of control. The increased field time required to monitor untreated trees could be compensated for by monitoring fewer treated trees. While this would lessen representation of treated trees, statistical power could be maintained by increasing the number of point intercepts per tree. E.g., 10 treated and 10 untreated trees could be sampled with point intercepts every 50 cm along five transects per tree, for a total of 500 intercepts for treated trees and 500 intercepts for untreated trees. The greater capacity to assess direct impacts from treatment would likely outweigh the limitations of diminished representation of treated trees.

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