Appendix 3-8

OAHU ARMY NATURAL RESOURCES PROGRAM
MONITORING PROGRAM

RESULTS OF KAHANAHAIKI CHIPPER SITE VEGETATION MONITORING FIVE YEARS AFTER INITIAL CLEARING

INTRODUCTION

Kahanahaiki Management Unit (MU), located in the northern Waianae Mountains, is home to a variety of endangered plants, one endangered tree snail, and some high-value stands of mesic forest. The Oahu Army Natural Resource Program (OANRP) manages Kahanahaiki MU with the goal of protecting rare taxa and improving habitat. Kahanahaiki is heavily invaded with non-native plants. *Psidium cattleianum* is the dominant invasive tree in the MU, occurring in dense monocultures. Few native species thrive in *P. cattleianum* stands, and it is not appropriate or preferred habitat for rare taxa. Seeds remain viable in the soil for less than three months (Uowolo and Denslow, 2008). This suggests that if control is timed before fruiting periods in summer and winter, recruitment from seed can be minimized. While most management efforts historically and currently focus on weeding around native forest patches, vegetation monitoring conducted in 2009 indicated that non-native taxa comprised more than 50% cover across the MU. More aggressive efforts were needed to push non-native cover below the 50% threshold and meet restoration goals. To that end, staff built on informal trials conducted in 2002 which indicated that clear-cutting and chipping slash from *P. cattleianum* monocultures (100 m^2) efficiently controlled the invasive tree while allowing re-colonization by native plants, particularly the native tree *Acacia koa*. In 2010, staff identified a large stand of *P. cattleianum* in the southern, mostly flat end of the MU. Patches of native forest bordered the site and some mature *A. koa* persisted within the *P. cattleianum* stand. In 2010 and 2012, 0.9 ha of *P. cattleianum* in this area was clear-cut with chainsaws, and a chipper (Bandit model 65 XP) was used to grind up large slash piles (Figure 1). Clearing was timed to coincide with the senescence of the *P. cattleianum* seed bank, three to six months post-fruiting, to minimize seedling germination. Substantial natural recruitment of *A. koa* was anecdotally observed on the site. Native plant restoration efforts were limited to one opportunistic outplanting of *Canavalia galeata*, and extensive hand-broadcasting of *Bidens torta*. Extensive follow-up weed control was conducted, consisting of “clip and drip” herbicide treatment. The objective of the “chipper site” project was to reduce alien vegetation cover, increase native vegetation cover and diversity, and connect surrounding native forest patches, ultimately working towards management goals of < 50% non-native and > 50% native vegetation cover in the MU. Monitoring was conducted to document change in vegetation cover, frequency, and richness in association with this project.

METHODS

Monitoring of understory and canopy vegetation following clear-cutting was conducted in 2012 and 2015. To obtain frequency and richness data, all native and non-native species present in the understory and canopy were recorded in 1 x 3 m plots. Native and non-native understory percent cover was categorically recorded in 1 m^2 plots (using portions of the same 1 x 3 m plots used for documenting frequency and richness) as 0-25, 25-50, 50-75, or 75-100%. Canopy cover estimates (native and non-native taxa combined) were obtained using Gap Light Analyzer (GLA), Version 2.0 software (Frazer et al. 1999) from hemispheric photographs of the canopy taken from the center of each 1 x 3 m plot. Non-permanent plots were randomly located within chipped areas as well as adjacent untreated areas with similar vegetation cover and composition (used as a control, representative of conditions prior to treatment). Areas cleared in 2010 and 2012 were each monitored in 2012 and 2015, allowing for a range in time elapsed following clear-cut treatment from less than one month to five years post-chipping (Table 1). Canopy cover, understory cover, and species richness were analyzed using Kruskal-Wallis tests. Species frequencies were analyzed using chi-square and Fisher's exact tests. Analyses were performed in IBM SPSS Statistics Version 20.

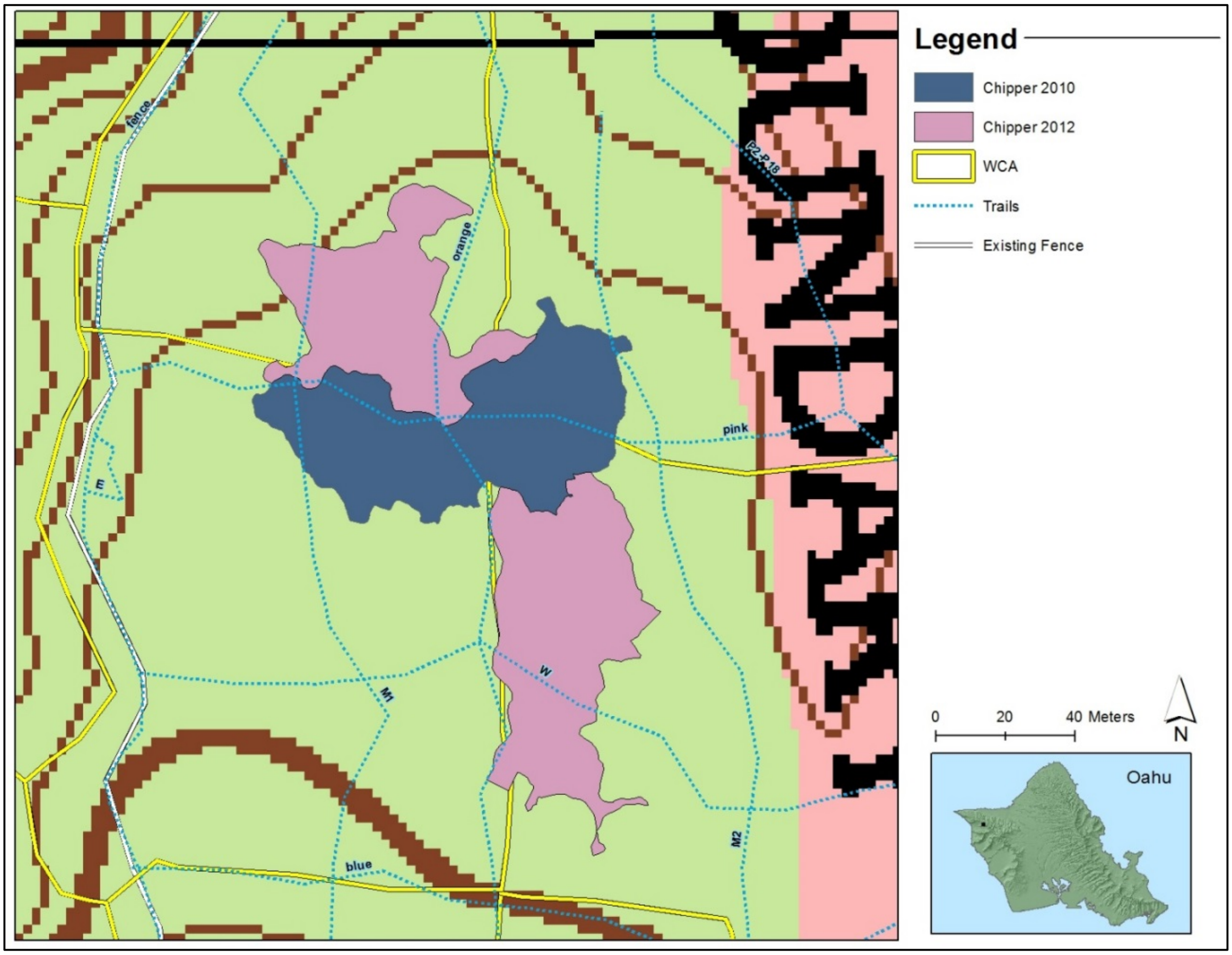

Figure 1. Locations of areas clear-cut of non-native vegetation using chainsaws and a chipper in 2010 and 2012 in Kahanahaiki MU, Oahu.

Table 1. Monitoring time intervals of plots in clear-cut areas in Kahanahaiki MU.

Time elapsed following chipper treatment	Year chipped	Year monitored	n
Control	N/A	2012	21
< 1 month	2012	2012	20
2 years	2010	2012	23
3 years	2012	2015	20
5 years	2010	2015	20

RESULTS

Canopy

Prior to chipping, the area was densely canopied (> 75% median cover) and dominated by non-native taxa (primarily *P. cattleianum* and *Schinus terebinthifolius*), with the native vine *Alyxia stellata* also occurring frequently, and the native tree *Metrosideros polymorpha* present to a lesser extent (Figures 2-4). Immediately following treatment, the canopy was largely open (< 25% median cover) and dominated by native species (mainly *Metrosideros polymorpha* and *A. koa*). After two years, canopy cover remained low and predominantly native, with *A. koa* becoming more prevalent. After three to five years, the canopy continued to refill (35-41% cover) with predominantly native taxa (mostly *A. koa*, *A. stellata*, *M. polymorpha* and *Psydrax odorata*), and to a lesser extent with non-native taxa (largely *Passiflora edulis* and *S. terebinthifolius*). Striking reductions in non-native taxon frequencies over the span of five years post-treatment occurred for *P. cattleianum* and *S. terebinthifolius* (Table 2). Native species frequency changes after five years included a marked increase in *A. koa*, and an overall decline in *A. stellata*. However, *A. stellata* rebounded significantly between less than one month and five years post-chipping (from 0 to 45%, chi-square: $p = 0.001$).

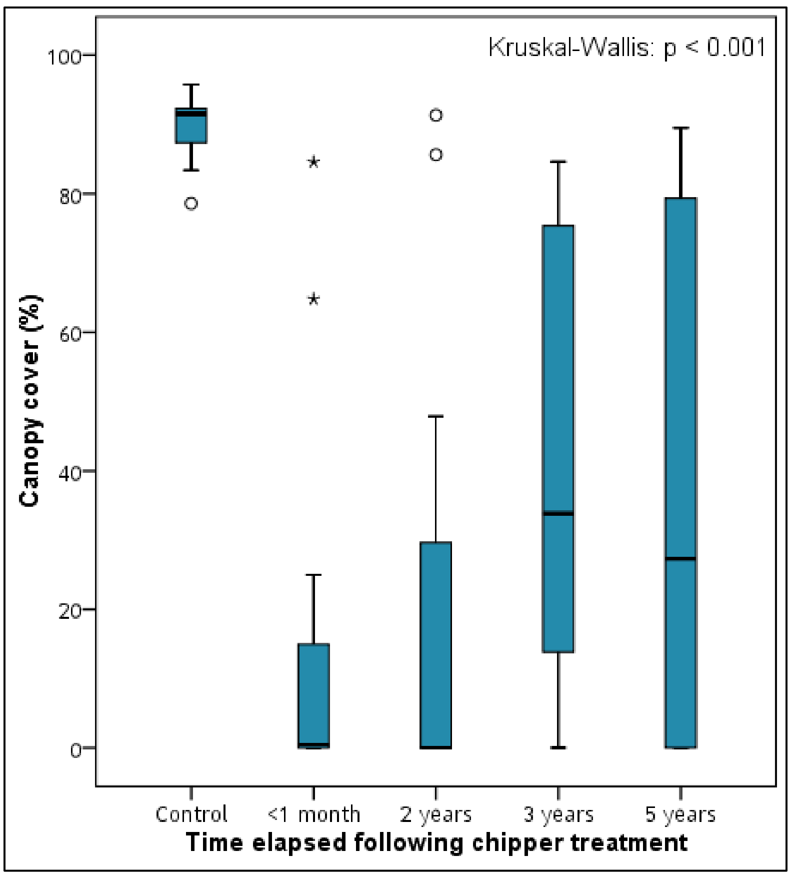

Figure 2. Boxplots of canopy cover over time following chipper treatment at Kahanahaiki. Cover includes both native and non-native taxa.

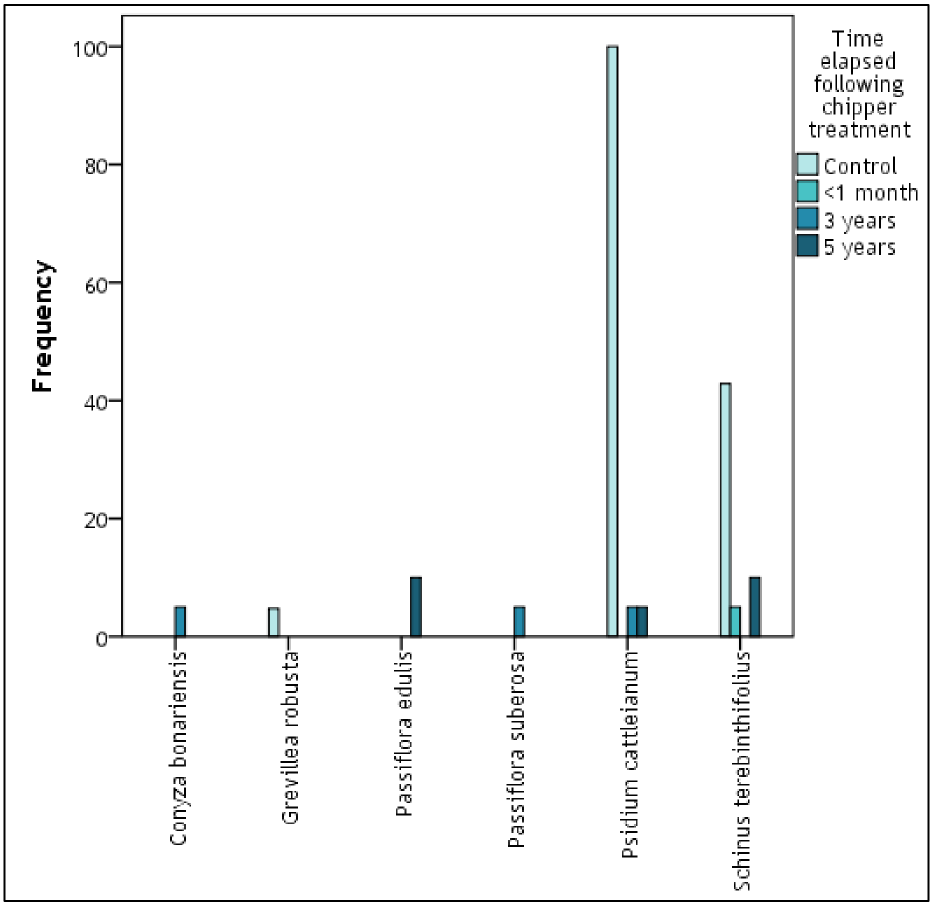

Figure 3. Non-native taxon frequencies in the canopy among plots over time following chipper treatment at Kahanahaiki MU. No non-native canopy occurred in plots at two years post-treatment.

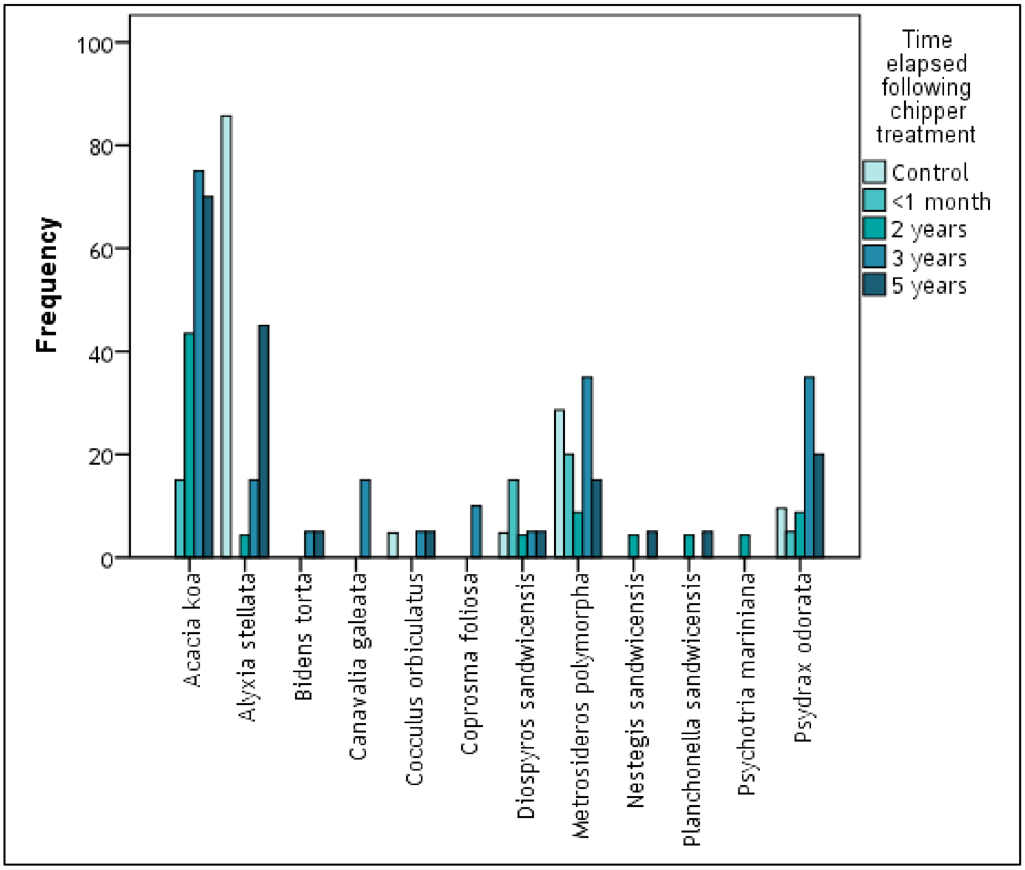

Figure 4. Native taxon frequencies in the canopy among plots over time following chipper treatment at Kahanahaiki MU.

Table 2. Frequency (%) among plots in the control group and five years post-chipping for taxa with significant changes over time. Native taxa are in boldface. Significance values derived from Kruskal-Wallis tests for all time intervals.

	control	5 years post-treatment	p
Canopy			
Acacia koa	0	70	< 0.001[a]
Alyxia stellata	86	45	0.006[a]
Psidium cattleianum	100	5	< 0.001[a]
Schinus terebinthifolius	43	10	0.018[a]
Understory			
Acacia koa	0	75	< 0.001[a]
Bidens torta	0	60	< 0.001[a]
Clidemia hirta	5	40	0.009[b]
Cocculus orbiculatus	0	30	0.009[b]
Conyza bonariensis	0	35	0.004[b]
Coprosma foliosa	5	45	0.004[b]
Crassocephalum crepidoides	0	45	< 0.001[b]
Dianella sandwicensis	0	45	< 0.001[b]
Mesosphaerum pectinatum	0	40	0.001[b]
Psidium cattleianum	90	25	< 0.001[a]
Rubus rosifolius	0	65	< 0.001[a]

[a]chi-square, [b]Fisher's exact

Understory

Similar to the canopy, the understory was also densely covered with non-native vegetation (predominantly *P. cattleianum*) prior to chipping, and had a decrease in non-native vegetation cover immediately and continuing up to five years following chipping, and an increase in native vegetation cover by two years after chipping (Table 3). Thirty-three non-native taxa and thirty-one native taxa were present in the understory (Figures 5 and 6). Increases in frequencies occurred for several non-native taxa by five years post-chipping, including *Clidemia hirta*, *Conyza bonariensis*, *Crassocephalum crepidoides*, *Mesosphaerum pectinatum*, and *Rubus rosifolius*. In parallel with its change in the canopy, there was a significant reduction in *P. cattleianum* after five years. Numerous native taxa also had marked increases in frequency by five years, including *A. koa*, *B. torta*, *Cocculus orbiculatus*, *Coprosma foliosa*, and *Dianella sandwicensis*. Though *A. stellata* had a major decline (from 86 to 0%) in the first month following chipping (chi-square: $p = 0.002$), this taxon rebounded by five years to prior levels (80%, chi-square: $p = 0.679$).

Table 3. Median percent cover of native and non-native understory vegetation over time following chipper treatment. Significance values derived from Kruskal-Wallis tests for all time intervals.

Time elapsed following chipper treatment	Non-native	Native
Control	75-100	0-25
< 1 month	0-25	0-25
2 years	0-25	25-50
3 years	25-50	25-50
5 years	0-25	25-50
p	< 0.001	< 0.001

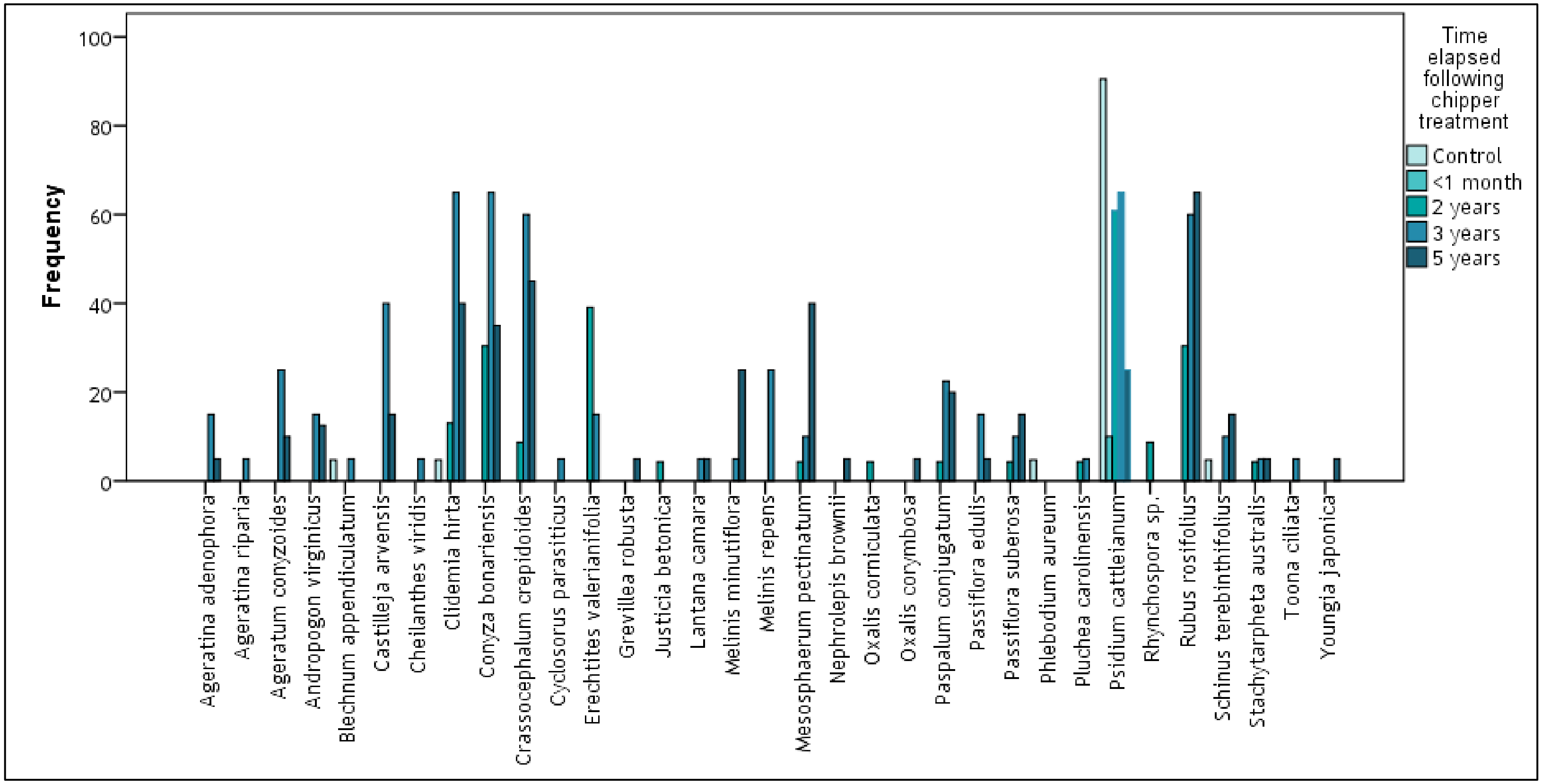

Figure 5. Non-native taxon frequencies in the understory among plots over time following chipper treatment at Kahanahaiki MU.

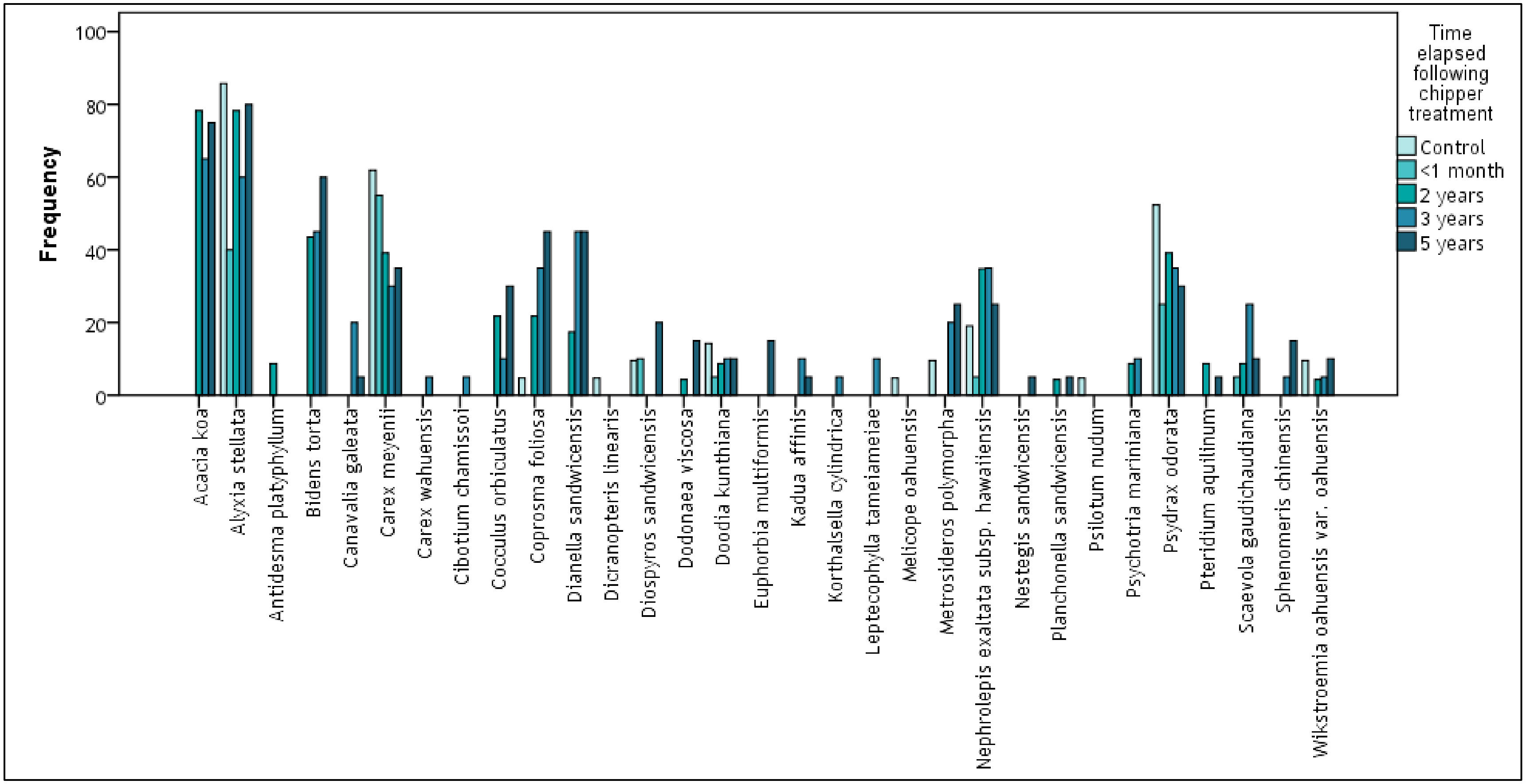

Figure 6. Native taxon frequencies in the understory among plots over time following chipper treatment at Kahanahaiki MU.

Species richness
Non-native and native canopy and understory median species richness among plots changed significantly over time following chipper treatment (Kruskal Wallis: $p < 0.001$ each) (Figure 7). Non-native canopy richness declined following treatment, while native canopy richness declined within the first two years (largely due to the decline in *A. stellata*) followed by an increase by three years. Non-native understory richness increased after two years, while native understory richness initially declined, but then increased by two to five years post-chipping. Total species diversity among all plots declined initially for the non-native and native canopy and understory, but became more diverse for all but the non-native canopy, which rebounded only to its original level (Figure 8).

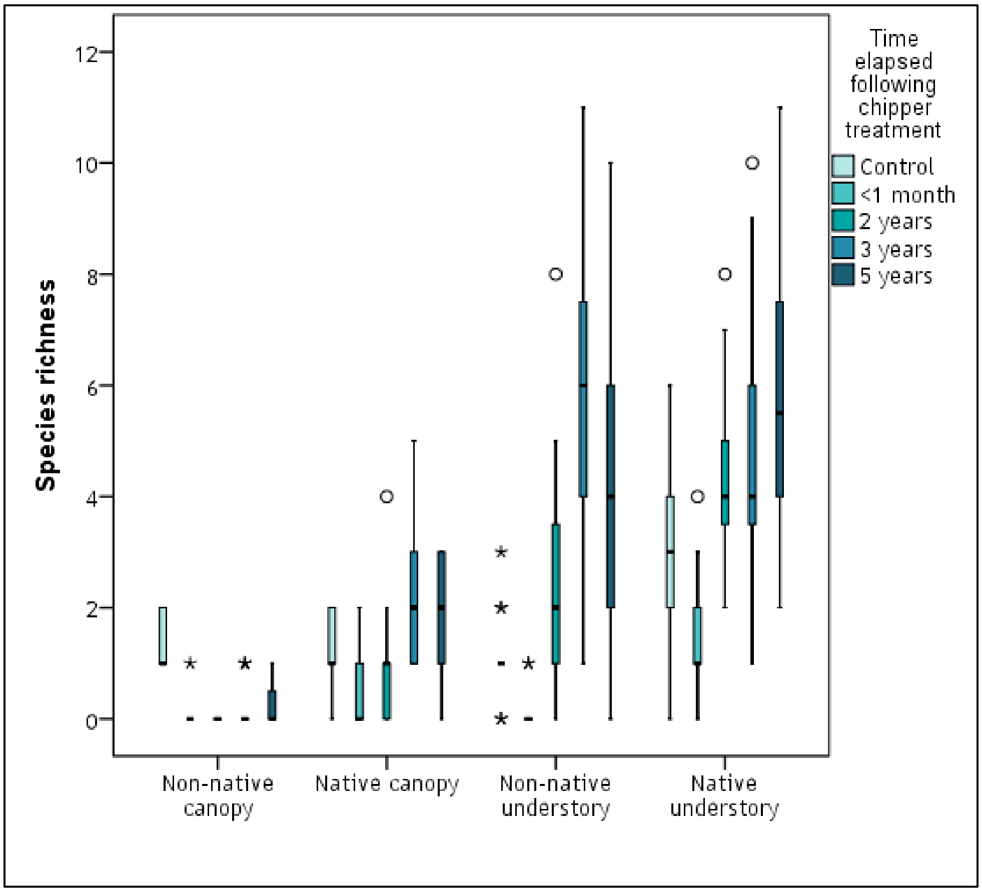

Figure 7. Boxplots of species richness among plots in the non-native and native canopy and understory in chipped areas over time at Kahanahiki MU

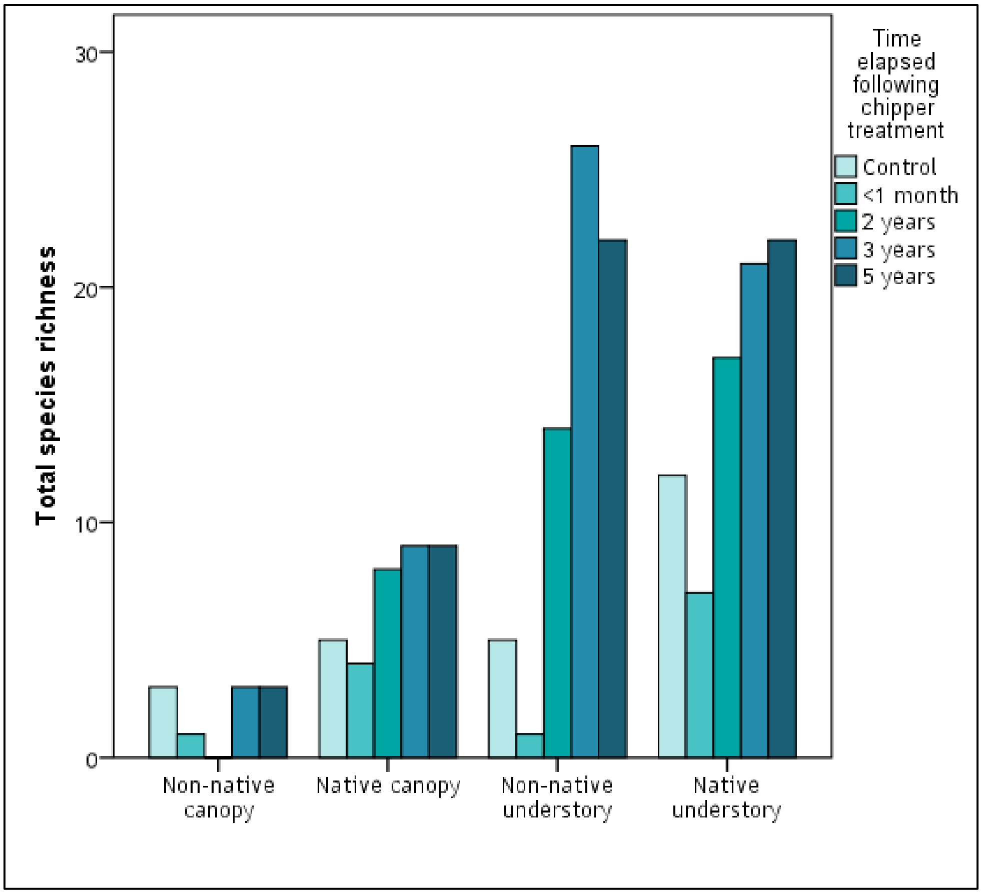

Figure 8. Total species observed among all plots in chipped areas over time at Kahanahiki MU

SUMMARY AND DISCUSSION

Dramatic changes occurred in the native and non-native canopy and understory in the five years following the initiation of clearcutting with chainsaws and a chipper in a non-native dominated region in Kahanahaiki MU. Cover, richness, and frequencies of tree species declined in the non-native canopy, but increased for the native canopy. Though richness and frequencies of several taxa increased in both the non-native and native understory, overall cover markedly declined for non-native, and increased for native, vegetation. While rebounding levels of non-native taxa occurred in the understory, the change in non-native composition is noteworthy. The non-native species (*C. hirta*, *C. bonariensis*, *C. crepidoides*, *M. pectinatum*, and *R. rosifolius*) that colonized the understory are known to colonize and thrive in disturbed areas, and are assumed to have less inhibiting effects on native taxa recovery as compared with the *P. cattleianum*-dominated community that was present prior to clearing. It was presumed that such taxa would colonize the area, and that this new mixed native and non-native community would be capable of supporting greater native diversity and cover. Yet, it was understood that on-going follow-up weeding would be necessary to avoid exchanging one non-native community for another.

Management goals of < 50% non-native canopy and understory cover were achieved and maintained, and progress towards the goal of > 50% native canopy and understory cover was made over the five year period following chipper treatment. Despite this progress, Kahanahiki MU vegetation monitoring results revealed that median native understory and canopy cover remained unchanged, and non-native understory and canopy increased, between 2009 and 2015 for the MU, as the areal extent of the chipper site project was insufficient to effect beneficial change on an MU scale (OANRP, 2015). Many additional aggressive projects such this would be necessary to influence MU scale progress towards management goals.

REFERENCES

Frazer, G.W., Canham, C.D., and Lertzman, K.P. 1999. Gap Light Analyzer (GLA), Version 2.0: Imaging software to extract canopy structure and gap light transmission indices from true-colour fisheye photographs, users manual and program documentation. Copyright © 1999: Simon Fraser University, Burnaby, British Columbia, and the Institute of Ecosystem Studies, Millbrook, New York.

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