Assessing the most effective weed control re-treatment interval for *Clidemia hirta*-dominated areas at Opaeula Lower Management Unit, Oahu

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INTRODUCTION

The goal of this study was to guide Oahu Army Natural Resources Program (OANRP) weed control planning for *Clidemia hirta* at Opaeula Lower Management Unit (MU), where dense understory cover of this weed occurs (Fig. 1). This species is targeted due to its ecosystem altering characteristics and tendency to create thick monotypic stands. Several questions are addressed pertaining to the effect of weeding *C. hirta*-dominated areas. To what extent does *C. hirta* and other weed taxa rebound if an area is not re-weeded for 6, 12 or 18 months? In the course of weeding a small degree of understory native vegetation trampling occurs. Does re-weeding at 6 months cause further damage to native vegetation? How does species diversity change in response to weeding at different intervals? How long does it take for <10 cm tall *C. hirta* plants (typically not treated during weeding) to become reproductive? Does canopy cover change in response to understory weeding within 18 months?

Figure 1. a) Locations of study plots at Lower Opaeula Management Unit, Oahu, and b) photo of *Clidemia hirta*

METHODOLOGY

Field Methods: Plots (5 x 21 m) were monitored in May 2013 (month 0) and November 2014 (month 18) among 4 weeding treatments:

Plot 1: control plot – not weeded
Plot 2: weeded at 0 & 6 months
Plot 3: weeded at 0 & 12 months
Plot 4: weeded at 0 months

Understory percent cover (using point intercept, n = 80 points), species richness (in 1 m^2 quadrats, n = 20), and canopy openness (using hemispheric photographs, n = 20) were monitored. To assess *C. hirta* maturation time, 50 individuals < 10cm tall were tagged within a 5 x 5 m plot, and monitored every 6 months from May 2013 to November 2014. Weeding included all non-grass mature and immature plants and most seedlings.

Data Analysis: Analysis included chi-square and Fisher's exact tests for change in understory cover within plots over time, and differences between plots at the end of the trial; t-tests for species richness change over time; and ANOVA with Tukey's post-hoc comparisons for differences in species richness between plots at the end of the trial, and for canopy openness in hemispheric photographs derived using Gap Light Analyzer (GLA), Version 2.0 software (Frazer et al. 1999). Analysis of change in non-grass weeds and non-vegetated area was based on initial weed cover in Plot 1, as Plots 2, 3, and 4 were weeded prior to baseline monitoring. Anecdotal observations determined that weed cover was similar among all 4 plots at the start of the trial.

RESULTS

Non-native understory percent cover: There was a significant decrease in *C. hirta* ($p < 0.001$) and total weed cover ($p < 0.001$), but a significant increase in total weed cover excluding *C. hirta* ($p < 0.001$), among all weeded plots (Fig. 2 and 3). The most commonly occurring grass, *Paspalum conjugatum*, also increased significantly from very low (Plots 2 and 4) and low (Plot 3) to moderately low cover in all weeded plots. At the end of the trial, *C. hirta* cover differed significantly among all plots, ranging from very low to high in relation to the time elapsed since the last weeding effort (6, 12, and 18 months prior for Plots 3, 2, and 4, respectively, and Plot 1 never weeded). Total weed cover differed among plots ($p < 0.001$) except for Plots 2 and 3, ranging from moderate to very high, also in relation to time since weeding last occurred. Total weed cover excluding *C. hirta* differed among plots ($p < 0.001$) with the exception of Plots 3 and 4, ranging from moderately low (Plot 1) to moderate (Plot 2) to moderately high/moderate (Plots 3 and 4).

Native understory percent cover: There was a significant increase in native cover (from low to moderate) for Plots 2 and 3 ($p < 0.001$). Though initially absent, by the end of the trial, *Acacia koa* was present in all plots at very low cover, representing a small significant increase in Plots 2 and 4 ($p = 0.024$). *Cibotium chamissoi* had a small significant increase in the control plot ($p = 0.044$), and a larger increase in Plots 2 and 3 ($p < 0.001$). *Nephrolepis exaltata* subsp. *hawaiiensis* had a significant increase (from very low to low cover) in Plot 2.

Non-vegetated percent cover: There was a very small significant increase in non-vegetated area in Plot 2 ($p = 0.022$) from very low to low percent cover.

Species richness: Non-native species richness increased significantly in Plots 3 ($p < 0.001$) and 4 ($p = 0.001$) (Fig. 4). At the end of the trial, there were significant differences in non-native species richness between plots ($p = 0.001$), with pairwise differences between Plot 1 and Plots 3 and 4 (Plot 1 vs. 3: $p = 0.001$; Plot 1 vs. 4: $p = 0.049$). There was a marginally significant increase in native richness in Plot 3 ($p = 0.057$).

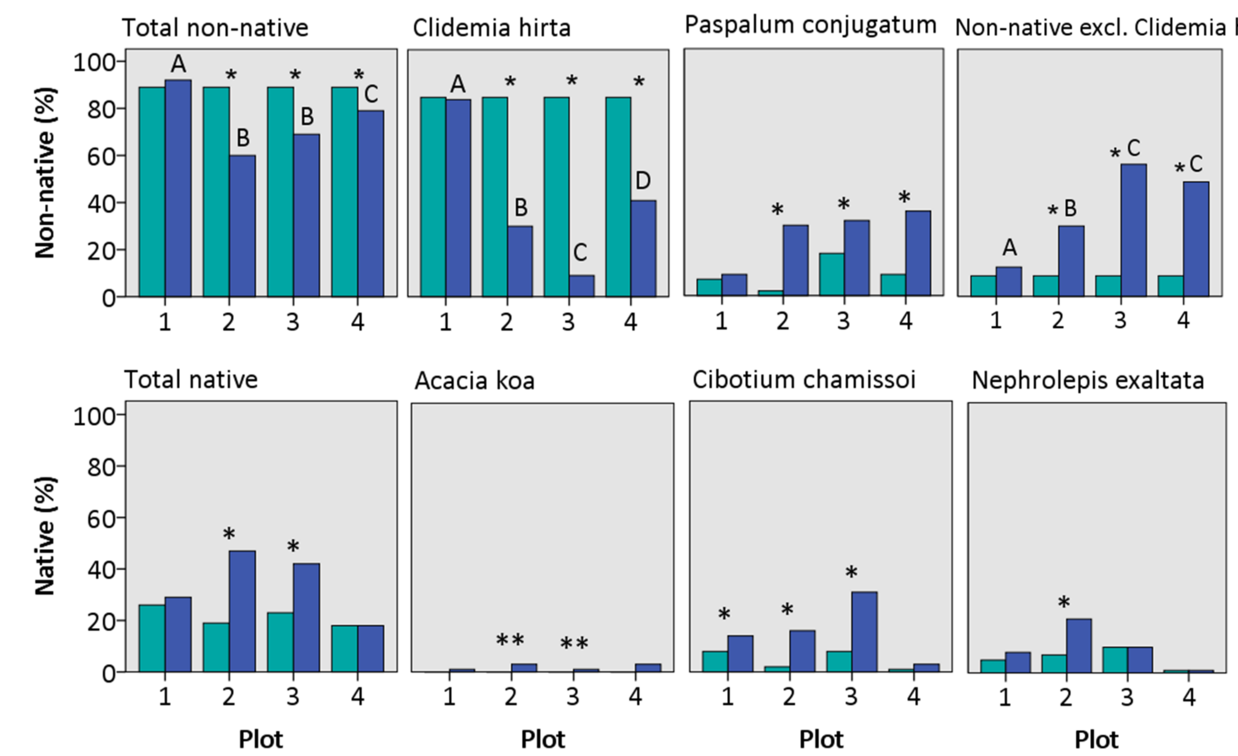

Figure 2. Percent cover of non-native and native understory vegetation at the beginning (before) and end (after) of the trial. *Significant, **marginally significant, change within plots. Letters denote significant difference between plots at the end of the trial.

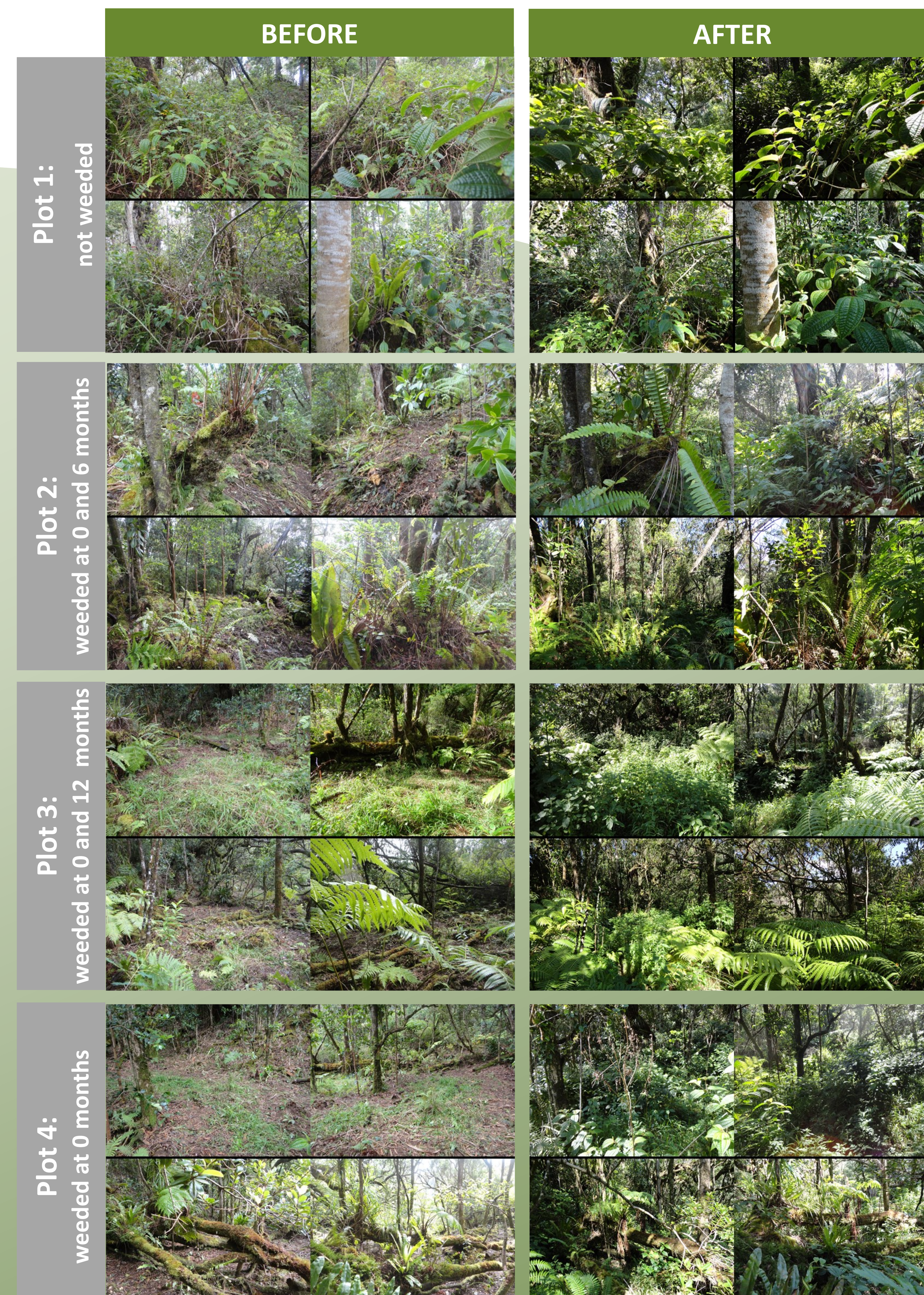

Figure 3. Photopoints of plots at the beginning and end of the trial, with images taken from the north, east, south and west corners (shown counterclockwise from top right image) of each plot.

Maturation time: Among the tagged *C. hirta*, one individual was mature by 12 months, and 43% of the remaining live plants were mature by 18 months. Many of the immature plants remained small, and were beneath dense *C. chamossoi* cover. A treefall occurred between months 12 and 18, and created a light gap that may have prompted *C. hirta* growth and maturation. At the end of the trial, all plots had mature *C. hirta*, including Plot 3, which was weeded only 6 months earlier.

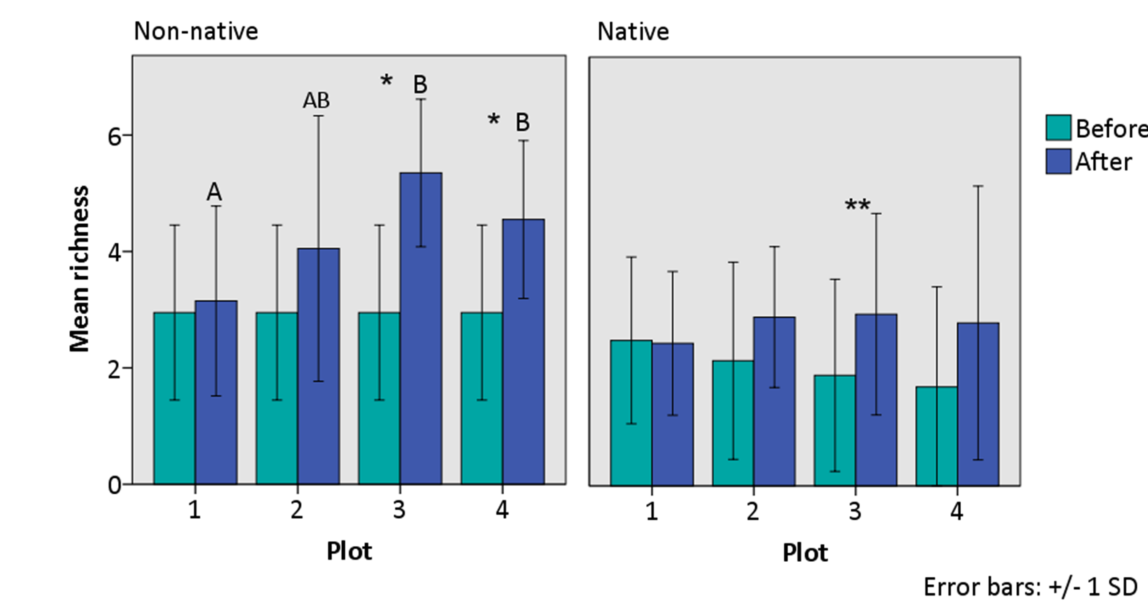

Figure 4. Mean non-native and native species richness at the beginning and end of the trial. *Significant, **marginally significant, change within plots. Letters denote significant difference between plots at the end of the trial.

Canopy openness: There was no significant change in canopy openness among the weeded plots, yet, there were significant differences among plots at the end of the trial ($p < 0.001$) (Fig. 5). Plot 2 was more open than all other plots, while Plot 4 was the least open.

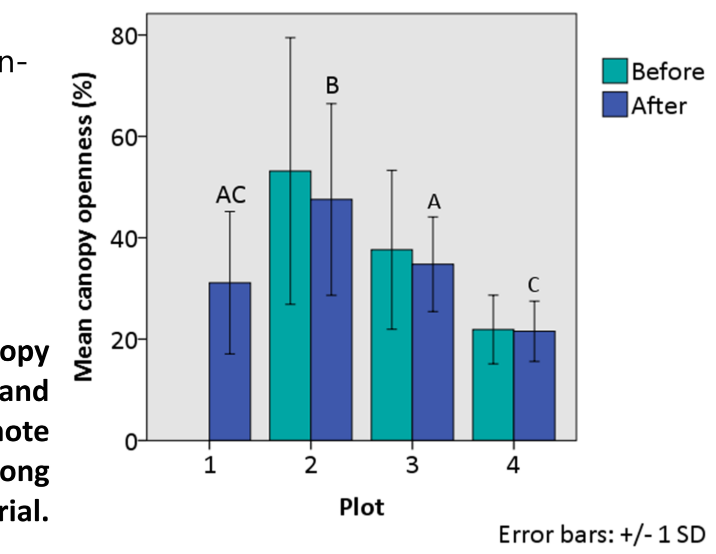

Figure 5. Mean percent canopy openness at the beginning and end of the trial. Letters denote significant differences among plots at the end of the trial.

SUMMARY AND RECOMMENDATIONS

Understory cover: Weeding *C. hirta*-dominated understory at Lower Opaeula produces reduced *C. hirta* cover paired with an increase in native cover after 18 months if initial weeding is followed by additional weeding 6 or 12 months later. However, substantial increased cover of non-native weeds other than *C. hirta* occurred, particularly the alien grass *P. conjugatum*. The plot weeded only once had very poor results after 18 months, with no change in native cover, and a resurgence of non-native cover to nearly as high as it was prior to weeding. ***Re-weeding (including grass control) should occur within 6 to 12 months, in order to allow native cover to expand, and prevent weed cover from returning to near prior levels.***

Species richness: Increased weed species richness resulted from a 12 to 18 month delay in re-weeding. As native species richness did not change substantially, the increase in native cover that occurred in the plots weeded twice was largely an expansion of species already present. ***Because C. hirta-dominated areas are partially replaced by other weed taxa, care should be taken to ensure that more problematic weeds do not become established.***

Maturation time: Though the minimum time for *C. hirta* maturation from the small immature stage was 12 to 18 months in the seedling plot, the presence of mature plants in a plot weeded only 6 month prior to the end of the trial suggests that the minimum time to maturation is < 6 months, and may be influenced by light availability. ***If there is an impetus to deplete the* C. hirta *seed bank, weeding should occur more frequently than 6 months, particularly in areas with greater light availability. Additionally, weeding must be ongoing, as* C. hirta *forms a long lived seed bank (Brooks and Setter, 2012). However, such a high frequency of weeding will limit the total area that is feasible to weed. Additionally, there will likely be a continual influx of* C. hirta *seeds from the surrounding areas. Depletion of the* C. hirta *seed bank is likely an impractical endeavor.***

Canopy openness: Differences in understory change among plots may have been influenced by differences in light availability, as canopy openness differed among plots. ***Clearcutting non-native canopy in this area is not advised, unless there are resources to follow up and prevent* C. hirta *from becoming established.***

REFERENCES

Brooks, S. J., and S. D. Setter. 2012. Soil seed bank longevity information for weed eradication target species. *Pak. J. Weed Sci. Res.*, 18: 73-83.

Frazer, G. W., C. D. Canham, and K. P. Lertzman. 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.