Smothered in *Sphagnum*: Managing Moss at Ka´ala

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Introduction

The high level of expertise required for bryophyte identification has meant that invasive mosses have been given little attention in Hawai´i. *Sphagnum palustre*, a bog moss, was purposely introduced to the Ka´ala Natural Area Reserve (NAR) on O´ahu in the 1960's (Hoe 1973) from the Big Island, where it is thought to be indigenous (Hotchkiss *et al.* 2002). Though *Sphagnum*, on O´ahu, cannot produce spores, an eightfold increase in the size of the core infestation has been observed over the last 12 years. Through vegetative reproduction, *Sphagnum* now occupies an area estimated at 1.25 ha).

Sphagnum impacts in Hawaii are not well documented, nonetheless, bryologists consider it a threat to endemic bryophytes and speculate it may prevent regeneration of *Metrosideros polymorpha*, an endemic tree species (Waite 2007). Results of a formal Weed Risk Assessment following the model developed by Daehler and Denslow (2007) demonstrate *Sphagnum* is "(l)ikely to be invasive in Hawaii and on other Pacific Islands" (Clifford and Chimera 2009). Elsewhere, *Sphagnum* species are known to strongly modify their habitat. *Sphagnum* has morphological attributes which favor the formation of highly-saturated, heat-retaining, nutrient-poor, acidic soils. These conditions enhance their growth at the expense of vascular plant growth (van Breeman 1995).

In the fall of 2008, the Oahu Army Natural Resource Program (OANRP) conducted two field studies. STUDY 1 compared vascular plant species richness and abundance between pristine (*Sphagnum* free) and invaded (*Sphagnum*) areas. STUDY 2 investigated the efficacy of manual removal of *Sphagnum* against that achieved with the application of a low or a high dose of St. Gabriel's Moss Killer (SGMK). SGMK is an organic mossicide composed of clove oil and vinegar (Fig. 1). It shows promise as a safe, less labor-intensive means of controlling *Sphagnum* than manual removal. In addition, we wanted to document any non-target impacts to native vascular plant species attributable to these control methods.

Materials and methods

STUDY 1

Sixty plots measuring 1 m^2 were established at Ka´ala NAR. Half were situated 5-15 m from the furthest edge of a *Sphagnum* invaded area, while the remainder fell within the invasion but at least 1 m from the boardwalk which bisects the infestation. All plots were at least 2 m from the next nearest plot. All *Sphagnum* plots were 100% invaded. The species identity and number of stems above and below 1 m were recorded for all vascular plants. Following data collection, comparison of species richness between *Sphagnum* and *Sphagnum* free plots were analyzed using a two-sample T-test. The effect of *Sphagnum* on the abundance (as indicated by stem counts) of common vascular plant species < 1 m was analyzed using a general linear model (GLM). *Only* species that occurred in 4 or more plots of each type (referred to here as common species) were used in the analysis.

Figures

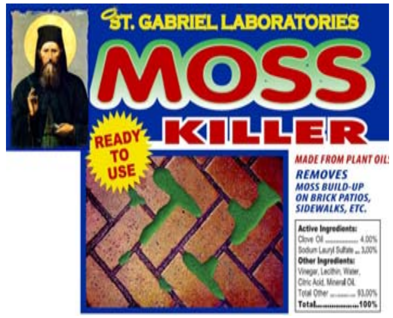

FIGURE 1. Label and active ingredients in St. Gabriel;s Moss Killer (SGMK)

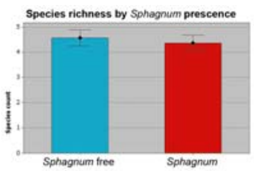

FIGURE 2. Vascular plant species richness (N = 30). Bars are ± 1 SEM

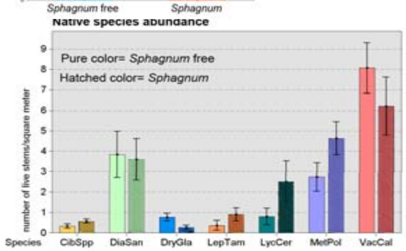

FIGURE 3. Vascular plant species abundance in *Sphagnum* vs. *Sphagnum* free plots. Bars are ± 1 SEM

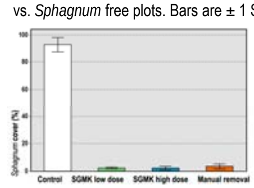

FIGURE 4.Comparison of *Sphagnum* removal methods 6 months after treatmebnt. Bars are ± 1 SEM

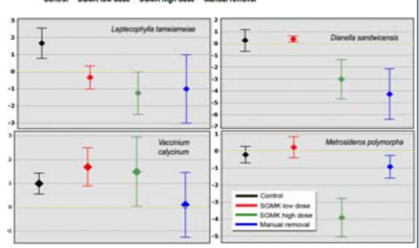

FIGURE 6. Change in stem count by species 6 months after treatment. Y axis units are in number of stems/m^2

Methods continued……

These species follow: *Cibotium spp*., *Dianella sandwicensis*, *Dryopteris glabra*, *Leptecophylla tameiameiae*, *Lycopodium cernua*, *Metrosideros polymorpha* and *Vaccinium calycinum*. Incidental species and those above 1 m could not be used due to small sample size.

STUDY 2

We established 40, 1 m^2 plots at Ka´ala NAR (10 replicates per treatment plus a control) according to methodology described in STUDY 1 for the *Sphagnum* group only (no *Sphagnum* free plots were used). All plots had 100% living *Sphagnum* cover prior to treatment. Each was randomly assigned to one of the following groups:

1. No treatment (control)
2. Manual removal of all living (green) *Sphagnum*
3. High dose of SGMK applied at a rate of 300 ml/1.5 H_2O
4. Low dose of SGMK applied at a rate of 150 ml/1.5 H_2O

Efficacy was evaluated using percent cover estimates of living (green) *Sphagnum* remaining 6 months after treatment compared against control plots. Differences due to treatment were analyzed using a one-way analysis of variance (ANOVA) followed by a Tukey's honestly significant differences test (Tukey's HSD).

Impacts to non-target species were measured using stem counts of vascular plant species 1 week before and 6 months after treatment. Changes in stem count due to treatment were analyzed using a GLM. As in STUDY 1, species above 1 m and those which occurred in fewer than 4 plots (of each treatment) were excluded from the analysis due to small sample size. Species included follow: *Cibotium spp*., *Dianella sandwicensis*, *Leptecophylla tameiameiae, Metrosideros polymorpha* and *Vaccinium calycinum.*

P values less than 0.05 were considered significant. All statistical analyses were performed with Minitab release 14 software, Minitab Inc. (Ryan *et al*. 2005).

Results and discussion

STUDY 1

Vascular plant species richness was similar in both *Sphagnum* and *Sphagnum* free areas (Fig. 2). Both contained, on average, 5 species. Abundance of common natives is shown in Figure 3. No significant difference in the abundance of these species due to *Sphagnum* presence or absence was found. Results suggest that *Sphagnum* does not uniformly depress the growth of all species, rather, it interacts with some positively (*e.g. Lycopodium*) others negatively (*e.g. Dryopteris*) and not at all with others (*e.g. Cibotium*). Such an outcome would not be surprising as *Sphagnum* is known to alter soil characteristics. Serious limitations in our study design, however, make further speculation difficult. While the placement of *Sphagnum* plots within the infestation was fairly uniform, those outside this area were likely not representative of *Sphagnum* free areas. In addition, we do not know whether areas remain free of *Sphagnum* because there has not been sufficient time for colonization to occur or whether this is due to micro site characteristics that prevent expansion. More study is merited.

Results and discussion continued….

STUDY 2

The 3 *Sphagnum* removal methods significantly reduced cover relative to the control (Fig. 4). No differences in efficacy were detected between the three *Sphagnum* control methods, although remaining *Sphagnum* cover was 4% in the manual removal group and only 2% in both SGMK groups. These results are promising as they provide an alternative to labor intensive manual removal of moss. Further, they suggest that smaller doses of SGMK can and should be tested for efficacy. In fact, trials recently concluded with doses as small as 75 ml have apparently killed moss 2 weeks following treatment (Fig. 5). More time is needed, however, to see whether the moss is truly dead.

Though differences were not significant, reductions in common native species were, on average, higher in the manual removal and high dose SGMK treatments compared to either the control or low dose SGMK groups (Fig. 6). The lack of significance may be due to small sample size and future work should investigate impacts to potentially sensitive species (*e.g. Leptecophylla* and *Dianella*). Interestingly, manual removal of moss was not without risk to non-target species. These data suggest that a low dose of SGMK is the safer (fewer risks to non-target species) and more efficacious than manual removal. Indeed, future tests of progressively lower doses SGMK may reduce risk without sacrificing efficacy.

FIGURE 5. *Sphagnum* treated with 75 ml of SGMK 2 weeks after application. The green area was not sprayed.

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