Herbicide Treatment Methodology for Red Mangrove (*Rhizophora mangle*) in Hamakua Marsh, O'ahu

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Introduction

The Wildlife Branch of the Division of Forestry and Wildlife, State Department of Land and Natural Resources conducted a study to develop a methodology to address the encroachment on waterbird and wetland habitat by the introduced Red mangrove (*Rhizophora mangle)*. In a study conducted on mangroves as alien species, Allen (1998) noted that the most direct impact mangroves have had on the endangered waterbirds is the invasion of their foraging and nesting habitat, and that the native black-crowned night herons (*Nycticorax nycticorax hoactli*) and introduced cattle egrets (*Bubulcus ibis*) (Hawaii Audubon Society, 1993), which both prey on other waterbird chicks, nest in mangroves. Guilbeaux and Mejia-Chang (1999) directly sited mangroves as one of the factors involved in the population decline of four endangered endemic Hawaiian waterbirds, through habitat modification. This methodology development was necessitated through limitations in existing resources with which to achieve management goals. Hamakua Marsh is designated as a State Wildlife Sanctuary for several Federally endangered endemic waterbird species. This marsh is being managed by the State's Oahu District Wildlife branch, with several ongoing restoration and enhancement projects in place.

Study Area

The study was conducted in Hamakua Marsh, located in Kailua, Oahu, Hawaii. The area is a Wildlife Sanctuary, recognized by state and federal agencies as significant wetland habitat. Hamakua Marsh Wildlife Sanctuary is located along Hamakua Canal (Kawainui Stream), Kailua, Oahu. The 22.7 acre parcel was donated to the non-profit conservation organization Ducks Unlimited, Inc., by Kaneohe Ranch Ltd., and subsequently donated to the Department of Land and Natural Resources in 1995 for management as a wetland wildlife sanctuary. The area is currently undergoing restoration measures intended to open approximately 20 acres of wetlands for waterbird habitat. A total of 16 waterbird species are known to utilize the area, including four federally listed endangered bird species: the Hawaiian Stilt (*Himantopus mexicanus knudseni)*, the Hawaiian Coot (*Fulica americana alai)*, the Hawaiian Duck (*Anas wyvilliana)* and the Hawaiian Moorhen (*Gallinula chloropus sandvicensis)*. Common plant species include koa haole (*Leucaena leucocephala)*, Christmasberry (*Schinus terebinthifolius)*, Marsh fleabane (*Pluchea sp.)*, 'Ae'ae (*Bacopa monnieri*), (*Paspalum sp.)*, and Pickleweed (*Batis *maritima)*. Native plant species that are present include Akulikuli (*Sesuvium portulacastrum*), makai sedge (*Scirpus maritimus*), Makaloa (*Cyperus laevigatus*), and Pu'uka'a (*Cyperus odoratus*) (Wagner, Herbst, Sohmer, 1990).

Goals

- Develop a specific method for effective chemical control of red mangrove.
- Identify the optimal treatment concentration of Garlon 4 needed to achieve at least a 90-95% kill success rate or better, without excessive herbicide use.
- Identify any strengths and weaknesses of the application technique.

Materials and Methods

This project investigated the effectiveness of the herbicide Garlon 4, applied in different concentrations, on various growth stages of red mangrove. Garlon 4 is a target specific herbicide designated for use on woody plant species, acceptable for application in seasonally dry wetlands, like Hamakua Marsh (see Appendix A). The herbicide was applied to seven treatment plots, with four other plots to serve as control sites to receive no treatments. None of the treatment plots or their subject mangrove were situated over standing water. Garlon 4 was diluted with JLB basal bark oil to achieve the different treatment concentrations. These treatments were administered by means of hand sprayers, encircling the bases of subject individual trees. For the purposes of this study, a full treatment meant that herbicide was applied by encircling the whole base of a given mangrove. A partial treatment means that herbicide was applied on only one side of a mangrove trunk, as a treatment on a dense stand of mangrove may necessitate.

Garlon 4 was applied to seven (5 X 2) square meter treatment plots (see Table 1). Four additional plots (C1, C2, C3, and C4) received no treatment, and served as controls in representing the various sizes of red mangrove treated. Treatment plot T4, containing only Red mangrove seedlings, was treated using a foliar spray (applied to leaves only).

Table 1. Application mixtures by plot on Red mangrove in Hamakua Marsh.

Plot	Mixture	Mangrove Size Range (DBH in cm)	Application
*T0	100% G4	0.8-11.5	Partial basal coverage
T1	100% G4	0.5-3.7	Full basal coverage
T2	50% G4/50% JLB	0.5-4.2	Full basal coverage
T3	25% G4/75% JLB	0.7-5.0	Full basal coverage
T4	50% G4/50% JLB	seedlings	Foliar on seedlings only
T5	50% G4/50% JLB	0.5-2.6	Full basal coverage
T6	50% G4/50% JLB	3.2-16.0	Full basal coverage

* Plot T0 was treated in August of 1999, all others treated February, 2000.

Data on subject trees was taken based on the date of treatments, the treatment type, and health of individuals. Grades of health are listed as follows:

0 - Healthy, no necrosis, green foliage
1 - slight necrosis, tips live, apex live, 90% healthy
2 - moderate necrosis, 50% healthy
3 - severe necrosis, tips bare, some live foliage, sprouts
4 - appears dead, no live foliage
5 - dead, no shoots, peeling bark, wood dry

Plots treated in February 2000 were checked for overall health initially at one month, and finally, at three months. Plot T0 was monitored for long term efficacy.

Results

All of the Red mangrove trees within the four control plots were health rated at zero (healthy, no necrosis, green foliage) at the close of the study. The health of each treatment plot was as follows:.

Table 2. Health ratings for treatment plots at Hamakua Marsh.

Plot	Mixture	One Month	Three Months
T1	100% G4	3 to 4 3 - severe necrosis, tips bare, some live foliage, sprouts; 4 - appears dead, no live foliage	5 - dead, no shoots, peeling bark, wood dry
T2	100% G4	3 to 4 3 - severe necrosis, tips bare, some live foliage, sprouts; 4 - appears dead, no live foliage	5 - dead, no shoots, peeling bark, wood dry
T3	50% G4/50% JLB	2 to 3 2 - moderate necrosis, 50% healthy; 3 - severe necrosis, tips bare, some live foliage, sprouts	3 to 5 3 - severe necrosis, tips bare, some live foliage, sprouts 4 - appears dead, no live foliage 5 - dead, no shoots, peeling bark, wood dry
T4	25% G4/75% JLB	5* - dead, no shoots, peeling bark, wood dry	5* - dead, no shoots, peeling bark, wood dry
T5	50% G4/50% JLB	3 to 4 3 - severe necrosis, tips bare, some live foliage, sprouts; 4 - appears dead, no live foliage	5 - dead, no shoots, peeling bark, wood dry
T6	50% G4/50% JLB	2 to 3 2 - moderate necrosis, 50% healthy 3 - severe necrosis, tips bare, some live foliage, sprouts	4 to 5 4 - appears dead, no live foliage 5 - dead, no shoots, peeling bark, wood dry

* Seedlings attained a rating of 5 after less than one week.

All control plots maintained a health rating of zero, for 100% of the control subjects, throughout the course of the study.

Please refer to Appendix B for photo documentation of the treatment plots at the initiation of the study and again after three months.

Discussion

Garlon 4 herbicide application as a methodology in the removal of Red mangrove is apparently effective. Macnae (1968) noted the fertility of the mangrove environment, and Hamerton (1967) coupled that quality with the abundance of water found in mangrove habitats to point out the increased susceptibility of plants to herbicides. The goal in this herbicide application study was to achieve at least a 90-95% kill rate, from a given herbicide concentration.

Plot (T3), which received a 25% Garlon 4, 75% basal bark oil, achieved an 86% kill success at the close of the study. Of the 65 individual mangrove trees treated within this plot, 56 were health rated at five, and nine individuals were rated at three to four, at the end of three months. The goal of this study was to attain a certain level of success with a given treatment, rather than placing emphasis on when the desired kill success was achieved in relation to the duration of the study. At one and three months during the course of the study, a health rating was given to each of the test plots and revealed a lag in the rate of necrosis onset in plot (T3). This lag may have been attributed to the concentration of Garlon 4 in the treatment, but eventually achieved the desired 90-95% kill rate in a health assessment made after the close of the experiment, in August 2000.

Plot (T0) was treated in August of 1999 and therefore was not health rated at one and three months as the rest of the test plots were. This area was treated without the thoroughness and purpose of a study in mind, but may provide preliminary qualitative data on this application method. However, a health rating was assessed in February 2000 at the initiation of this study, to record the long-term efficacy of a partial treatment on the various sizes of red mangrove existing in the plot. The overall health rating given to this plot was a five, although several individual mangrove which were health rated at zero to one. There were individual plants which had gone untreated and some which were treated insufficiently, judging by the herbicide mixture's stain left on the mangrove trunks.

Plot (T6) also showed a slight lag in the completeness of necrosis at the conclusion of the study. This may have been attributed in part to two factors. The treatment for plot (T6) was implemented four days later than the rest of the treatments, as a need arose to represent specifically, the largest size class of red mangroves, in this study. The significance of four fewer days of treatment could be defined in saying that it may simply take more time for a given treatment to equally affect large mangrove, as opposed to smaller mangrove. It is worth noting, though, that at the conclusion of the experiment, eight of the ten treated mangroves were health rated at four or five. The other two individuals were rated at one. The failure to completely kill these two plants may have been due to herbicide having been applied below the plant's highest stilt root, and a pattern of this situation had been forming during the study and will be addressed further.

The inability of a treatment to completely kill a subject mangrove suggests that the placement of herbicide on a mangrove may influence a given treatment's effectiveness. Plot (T6), and treatments conducted at Hamakua marsh prior to the study, showed that herbicide administered below the highest stilt root may not kill the tree. This result was observed in instances involving larger mangrove and could suggest that the newest or highest growth may be supported by its highest stilt roots. However, this did not occur in all cases of large mangrove treated below the highest stilt roots. A follow up herbicide application would address these mangrove and other individuals missed during an initial treatment.

Pickle weed (*Batis maritima*) adjacent to treated mangrove, had died off by what may have been Garlon 4 released from the treated mangrove, or as a result of overspray drift (Appendix C). Plants located downwind of the treatment plots were a part of an area that had died off within a few weeks of having been treated. This die-off occurance, though, appeared not to be a result of wind borne over-spray alone, based on the expanse or reach of the die off, and lack of breezes at the time of treatment. At the time of treatments, the weather was notably hot and still. Application of the herbicide mixture generated some splatter, but the mixture of Garlon 4 with the JLB oil is very viscous, and does not lend itself well to wind borne drift in liquid form. The Kerosene component in the Garlon 4 may have been volatilized into a gas and drifted off of the mangrove, having carried some of the herbicide with it. This reaction has not been noted in literature though similar instances have been known to occur. Garrnett (Personal Communication) noted that oil based herbicides can spread at high temperatures with still wind conditions, so volatilized herbicide mixtures are not "diluted" by breezes. The native plant species occurring in the area, were well out of the die-off area. Other untreated mangrove and fleabane individuals adjacent to treatment plots also experienced this phenomenon, but to a lesser extent. This was not a cause for concern in this case as efforts to control *Batis* are ongoing at Hamakua Marsh, and there were no desirable species affected. The die-off reached out in some areas to 20 meters from the treated mangrove and may be used as a general guide in preventing future unwanted die-offs of desired species.

This methodology, being developed to benefit water birds, has already encouraged Hawaiian gallinules to use the wetlands. The stand of mangrove had been acting as a partition between the marsh and adjacent waterway, preventing direct access from one area to the other. Following herbicide treatment, the mangrove has defoliated and provided better access for waterbirds to transit form the Hamakua Canal into the mudflat areas of the sanctuary.

Summary

Based on the effectiveness of the different treatments, administered to the various growth stages of red mangrove, it is apparent that this species is highly susceptible to herbicides (Hamerton, 1967). The concentration of Garlon 4 to be utilized in possible red mangrove removal projects would be up to the resource manager. Based on the success of the various treatments, the recommendation would be to use a 50% strength Garlon 4 mixture, or stronger, and to fully treat all mangrove above the highest stilt root, to reduce the need for follow-up applications.

A need arose during the application of treatments, to consider the use of a partial treatment as opposed to a full treatment. A partial treatment would be defined as herbicide applied on only one side of a mangrove, not fully encircling its trunk. This method of application would be appropriate in dense stands of young red mangrove where access and reach into these areas is difficult. In a large stand of mangrove of the density and size range in plot (T5), a partial treatment would be much easier to implement and more cost efficient, if sufficient enough to achieve the desired effect. The partial treatment attempted in plot (T0) prior to this study showed positive success for all sizes of red mangrove treated in this manner. The ability of a partial treatment's kill rate in contrast to that of a full treatment, has not yet been quantified. Again, this plot was treated without the purpose and thoroughness of a study in mind, but may provide preliminary qualitative data on this application method.

It is important to reiterate that the appropriate use of Garlon 4 is strictly governed by the definitions set forth in its label. The label makes clear that this herbicide is not to be applied to a plant situated over standing water although appropriate for seasonally dry wetlands, therefore those individuals which elude the scope of treatment by an herbicide such as Garlon 4, must be removed by other means. One method employed in addressing such mangrove would be to remove them by means of a chainsaw. Although the use of Garlon 4 dose not allow for complete removal of all individual red mangrove in a given stand, it does apply to the larger portion of a grove, as more individual plants are found situated inland of those growing directly in standing water.