PROBLEMS WITH THE LONG-TERM MAINTENANCE OF MĀMANE (*SOPHORA CHRYSOPHYLLA*) IN THE CENTRAL CRATER AREA OF HALEAKALA NATIONAL PARK

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Sophora chrysophylla (Salisb.) Seem., better known as māmane, is a native species in the legume family and the dominant tree species in the central crater region of Haleakala National Park (HALE). Its distribution here coincides for the most part with older substrates, growing in soils predominantly composed of or covered with ash and cinders such as around the bases of pu'us or cinder cones, and on the steep inner walls of the Crater.

Unfortunately, during the last 200 years the number of individuals and, in some cases, the distributional area of māmane have been reduced. This reduction has been blamed primarily on extensive browsing pressure on the trees and seedlings by cattle (*Bos taurus* L.) and feral goats (*Capra hircus* L.). In the drier sections of the Crater, such as between Maunahina and 'Ō'ilipu'u, areas which were once fairly densely covered by māmane trees up to 4 m tall are now reduced to scattered stands of trees with many standing and fallen dead trunks. A similar situation can be seen on the cliffs above Crystal Cave Trail at Kalua Awa where only a few living māmane trees remain.

Māmane by itself is an important component of this dry subalpine ecosystem in the summit depression of Haleakalā. Its bright yellow flowers provide a rich source of nectar for the native bird species found here which include the 'Apapane (*Himatione sanguinea*), the 'Amakihi (*Loxops virens*), and in the wetter areas around Palikū, the 'I'iwi (*Vestiaria coccinea*). Other common plant species found in this habitat include pūkiawe (*Styphelia tameiameiae* (Cham.) F. Muell.), pilo (*Coprosma montana* Hbd.), the native grass *Deschampsia australis* Nees ex Steud., and 'ūlei (*Osteomeles anthyllidifolia* Lindl.). The 'āhinahina or Maui silversword (*Argyroxiphium macrocephalum* Gray) is found here also; however, its populations have likewise been reduced drastically by damage from herbivores. Many other species of both plants and animals are components of this ecosystem. However, some of them are extremely rare now, found only in areas which are somewhat protected from the cattle and goats.

It has been long recognized that the māmane ecosystem in Haleakala National Park is both valuable and in danger of being destroyed as the pressure from introduced animals continues. Management questions which need to be addressed include: (1) how

much damage has already been done to this ecosystem; (2) what is the recovery potential of the native species here; and (3) how can the exotic pressures on the ecosystem be controlled and, hopefully, eliminated?

In partial answer to the last question, at least some of the exotic animal pressure has been removed with the elimination of cattle grazing within Haleakala National Park. However, the goats still remain and, more recently, a new threat has arrived: axis deer (*Axis axis* (Erxleben)), which is rapidly becoming established on East Maui.

In this paper I will discuss some of the results of a project which I have been conducting in Haleakalā since 1976. Emphasis in this case will be on problems dealing with the long-term maintenance of māmane in the central crater area of Haleakalā under continued disturbance pressures from introduced herbivores.

Sampling methods

In 1965, a fenced experimental māmane enclosure was constructed in an area of high goat impact below Honokahua on the trail between Bottomless Pit and Palikū. In 1975, I was requested to evaluate the changes in and around the enclosure in the 10 years since its contruction. The only baseline information which was available at the start of this project was a crude map of the fenced area and a set of 20 photographs showing different views of the māmane trees there. Through support from the Cooperative Park Studies Unit (CPSU) at the University of Hawaii, I have revisited this site on numerous occasions during the last five years. On these trips I have been able to relocate most of the original 1965 photographic points and rephotograph the enclosure from them. Additionally, the vegetation inside the fence has been mapped in great detail and seeds have been collected from both the trees and the ground to test their viability. Finally, a māmane tree position mapping program has been initiated for the area around the enclosure, which has allowed for a structural analysis of the tree population. This information should show how many trees have died in recent years and what their replacement rate is by either vegetative or seedling regeneration.

Changes Within the Māmane Tree Enclosure from 1965 to 1976

When the photographs of the enclosure taken in 1965 are compared with those taken in 1976, only a few differences in the vegetation inside the enclosure are apparent. The most noticeable change is the browse-line, evident in 1965, which is no longer present on the trees within the fenced area in 1976. My expectation was that as the goat browsing pressure was eliminated, new seedlings would become established and more trees than the original six within the enclosure would be filling in the open spaces. However, no new seedlings became established

inside the enclosure in the 10 years since the animals were removed despite an abundance of māmane seeds both inside and outside the enclosure.

Māmane Seed Germination Tests

As it seemed possible that the māmane seeds being produced were either damaged or infertile, viability tests were conducted on seeds collected from dried pods on the trees and from the ground in 1975 and 1976. The results of this experiment showed that (1) germination was greatly enhanced if the seed coat was scarified; and (2) seeds collected from the trees (i.e., the previous year's crop) showed nearly 90% viability (both germination and growth to 10 cm), while seeds collected from the ground had a germination rate of only 30%. There was no way of telling how old the seeds from the ground were as the seed coats are very tough and these collections may have represented seeds produced over several years. However, the seeds being produced by the māmane trees here are viable.

Despite the fact that viable seeds are being produced each year, only a very few instances of recent seedling establishment could be found anywhere in this area. Occasionally on visits to the enclosure after long periods of wet weather, I found a few germinating seeds on the ground. However, none of those noted ever became established. There are two possible explanations for this lack of seedlings. First, something is destroying the seedlings as they grow up--not goats in this case as they are excluded by the fence but possibly game birds such as chukar (*Alectoris chukar*) or pheasants (*Phasianus* spp.), both of which are common here. The second explanation may be that environmental conditions must be just right for seed germination and subsequent seedling growth to the size that it can withstand long periods of dry weather which are very common in the Crater. The substrate is very sandy; therefore, it is very poor at holding much available moisture in the upper 10 cm of soil. Unless a seedling can get its roots deep enough quickly, it will desiccate.

If seedling regeneration is naturally rare in this area, then to survive under such conditions māmane must have an alternate regeneration strategy, such as vegetative regeneration, to remain in this habitat.

Vegetative regeneration is a reasonable adaptation for plants growing in drier areas, and indeed this growth pattern is found in māmane. However, complications are introduced into the system if goats consume all of the vegetative shoots that are produced. When the main trunk finally dies, nothing will replace it and the tree position will be lost.

Analysis of Māmane Tree Populations Around the Enclosure

To get a better idea of how common vegetative regeneration is for the maintenance of māmane in this area, I started mapping the individual trees around the area of the enclosure noting trunk size, crown cover, and vigor for each tree, plus the number and condition (live or dead) of vegetative basal shoots. What I found was very disturbing. Of the 38 māmane tree positions mapped so far, 39.5% had a live main trunk with live vegetative basal shoots; 15.8% had a live large trunk but no live basal shoots; 21% had a dead main trunk but some live basal shoots; and 23.7% of the mapped positions had only a dead trunk remaining. Stated another way, 23.7% of the trees which were previously alive here were now dead and have not been replaced.

Although the results presented here are based on only a sample of 38 trees for an area of approximately 2 ha surrounding the enclosure, it appears to be fairly typical of the situation in this portion of the Crater. A more extensive mapping program is being planned to expand this sample.

It is most important also to note that nearly every tree outside the fenced area showed a browse-line at about 1.5 m. The only vegetative shoots which could survive were those in the center of the clump. In some cases all of the vegetative shoots were killed by browsing.

Conclusions and Recommendations

What is the future outlook for māmane in this portion of Haleakalā Crater? The answer depends on what is done and when. Unquestionably, the feral animals in Haleakala National Park need to be controlled--more specifically, they need to be eliminated--as soon as possible. The lack of seedling regeneration underscores the urgency for preserving those trees which are established already. Although a very large number of seeds are produced each year, the vast majority will fail to either germinate or get established unless the proper climatic conditions prevail, primarily an extended wet period. In the meantime, as the existing large trunks of the trees die, they will not be replaced unless their vegetative basal shoots can survive the animal damage. If they cannot survive the animal browsing, there will be, and indeed there is, a net loss in the number of trees in the area. Already many areas which once supported māmane trees in this portion of the Crater now only show skeletons where live trees once stood.

The longer the elimination of feral animals is put off, the harder it will be for the vegetation to recover. Control efforts to date have been, in my opinion, virtually ineffectual although well-intended. The control program in this Park has consisted primarily of occasional goat drives and hunts by National Park Service employees, with local hunter participation through the Deputy Ranger goat control program.

The lessons learned in Hawaii Volcanoes National Park (HAVO), mainly through the efforts of Don Reeser, need to be applied to Haleakalā also. The conclusions made at HAVO were that all efforts at large-scale goat control were meaningless unless the problem could first be contained. This containment was accomplished at HAVO by contructing a perimeter fence around the goats' habitat within the Park, further subdividing the area with internal fences, and finally eliminating the goats from each management unit. The success of the HAVO goat control program has been phenomenal.

Unless Haleakala National Park gets the fencing support that Hawaii Volcanoes National Park got, the outlook for long-term maintenance of the dryland ecosystems within the Park boundaries looks very bleak. Already some of the areas have been irreparably damaged. It is important that the National Park Service act immediately on the fencing program for Haleakala National Park. The problem cannot be allowed to continue any longer.