Management, Recovery, and Implications of Climate Change on Critically Endangered Species such as *Hesperomannia oahuensis*

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**Abstract**

Recent climate change in the Hawaiian Islands has resulted in decreased average rainfall and increased average temperature which is negatively impacting many native plant species. Therefore, changing climate must be a consideration when creating recovery plans for these endangered species. Without this preparation, there is the possibility of catastrophic results such as extinction because decrease in precipitation amounts and an increase in average temperature have a direct negative impact on plants and their reproductive success. This is especially a concern in the Hawaiian Islands because they serve as a biodiversity hotspot and contain a significant number of endangered species as well as many endemic species that are found nowhere else in the world. One such endangered plant species is *Hesperomannia oahuensis*. This species is on the brink of extinction with only 6-10 individuals remaining in the wild in two populations on O‘ahu, Hawai‘i. Currently, this species faces many threats from ungulates, rats, and increasingly, climate change. While performing field work, lab work, and interviews, I assisted and learned about the current management plan for this species, which includes protecting individual plants from ungulates and rats through fences and rat traps, as well as techniques such as hand-pollination and micropropagation, or plant cloning, in order to increase the population size of this species. This management is showing signs of success because hand-pollination is resulting in viable seeds, and for the first time this year, some of the seedlings produced by hand-pollination have reached maturity. Although this management plan is producing some successful results, alterations to this plan are necessary in order to prepare for the effects of climate change.

**Introduction**

“Biodiversity hotspots” are areas around the world that serve as pockets with more species richness and diversity than other areas around the globe (Dobson). Human development and, more broadly, climate change, can significantly affect these precious areas. These hotspots are often exploited at a high rate by humans because of the rarity of the species living there and the abundance of the plant species. This human influence is not only being felt in the Hawaiian Islands, however, but rather globally in the form of anthropogenic climate change. The Hawaiian Islands are an extremely important example of a biodiversity hotspot (Noss). This chain of unique islands is inhabited by 90% endemic species, and many of the remaining species are native to the islands. As a result of human interaction with the Hawaiian environment, many of these species are on the verge of extinction. The effects of climate change, such as increased temperatures and decreased precipitation, are beginning to show ill effects on certain species. One such plant species is *Hesperomannia oahuensis*. This paper aims to explore the current recovery plan of this particular species and explain how a factor of growing concern, climate change, deserves consideration in the future reintroduction and recovery plans for this and other endangered plant species.
How Climate Change Could Impact Hawai`i

It is fairly well known that the global climate is changing. Average temperatures are increasing, weather patterns are changing, and glaciers are melting resulting in increased sea levels. Recently, this issue gained significant media coverage when the Intergovernmental Panel on Climate Change (IPCC) reported that 95% of scientists now agree that climate change is anthropogenic, or human caused (*Working Group I Contribution*). The detailed effects of this issue are outside the scope of this paper, so it will not be discussed in-depth here. Nevertheless, the impact of climate change is not one that will be felt equitably around the globe, with the greatest producers of emissions likely to feel a smaller burden than developing nations and islands.

The Hawaiian Islands face a significant risk of negative impacts from climate change because of the already delicate balance of its ecosystem. As a result of climate change, increased cyclone activity around the Hawaiian Islands is predicted (Murakami). Many reports show that Hawai`i is overdue for a cyclone, so it is predicted that one will hit the islands in the near future. Future projection models for climate change predict that air temperature, ocean temperature, and sea level will rise, while rainfall will decrease. In addition, ocean acidity is predicted to increase as the oceans are forced to become more substantial carbon sinks. All five of these factors have recently been observed in the Hawaiian Islands. Although some of the changes are small, the overall trends are alarming, and if these trends continue, the impact on the islands could be detrimental (*Climate Change in Hawaiian Islands*).

In relation to *Hesperomannia oahuensis* specifically, climate change could also prove to be harmful. With the already low seed and pollen viabilities of this species, an increase in air temperature and a decrease in precipitation could only exacerbate the problem. Many seedlings could die from increased evaporation if there are higher temperatures (Ooi). This might then lead to reductions in the success of hand-pollination efforts if the seedlings fail to reach reproductive maturity. Also, this might then lead to the greater possibility of a single storm event causing significant damage to this species if the storm directly hits the area where the two populations of this species exist. It is possible that the decrease in the population size of this species is related to the effects of climate change (“5-Year Review: Short Form Summary” 2013). This was particularly notable during 2000-2003 when a drought hit this species’ habitat, and 12-18 plants were lost (Ching-Harbin). The threat of the effects of climate change is one that needs to be addressed in the future recovery of this species.

This is a question that is already being addressed by several scientists including Adam Vorsino, a member of the Vulnerability Assessment Project Team for the United States Fish and Wildlife Service. This assessment project analyzed most threatened and endangered species in Hawai`i in order to determine the present and future vulnerability of each of these species as a result of climate change. In order to complete this data analysis, a method called Bayesian networks was used which allows for multiple factors to be compared at one time. The graphical models produced from this analysis take the form of factors in a system represented as nodes connected to other factors by causal or correlative relationships using arrows. Through this method, it was possible to quantify “the vulnerability of over 1000 species of Hawaiian plants by determining the amount, quality, and distribution of projected areas lost, gained, and maintained in climate-compatible areas between now and 2100” (Fortini, et al.). As a result of this analysis, it was learned that the current tolerable habitat, or inhabitable environment for a specific species, of less than half of the species analyzed overlaps with tolerable habitat in 2100. This change in
habitat location will come as a result of climate change. However, in 2100, most Hawaiian species will still have at least five habitat areas where they could survive. Overall, the Asteraceae family of which *Hesperomannia oahuensis* is a member is considered at one of the levels of highest vulnerability to climate change of any family analyzed (Fortini, et al.). This suggests that *Hesperomannia oahuensis* is at an even greater risk for extinction if climate change continues to take place.

**Political Framework**
In order to provide some protection for species that are on the verge of extinction, the Endangered Species Act (ESA) was instituted in 1973 by President Richard Nixon (Overview). This act is managed by the United States Fish and Wildlife Service and the National Oceanic and Atmospheric Administration, and it has two main goals:

- “Protect endangered and threatened species, and then pursue their recovery”
- “Conserve candidate species and species-at-risk so that listing under the ESA is not necessary” (Overview)

These goals are crucial to future ecosystem protection because it is much more cost effective and less time consuming to protect a common species than one that has moved to the brink of extinction.

In Hawai`i specifically, there are several institutions working to protect endangered plant species such as *Hesperomannia oahuensis*. One such institution is the O`ahu Plant Extinction Prevention Program. This program works to protect species that have fewer than fifty individuals remaining in the wild. Botanists from this institution often work in the field to protect endangered species. In addition, the Harold L. Lyon Arboretum also works to save endangered plants but through such processes as *ex situ* micropropagation, or plant cloning. This process is completed to increase the number of individuals of a particular species and to allow for a stock of plant material of endangered species to exist if the species were to become extinct in the wild. Many other institutions across the state, including the Fish and Wildlife Service, the Department of Land and Natural Resources, and many others all work to save endangered species in Hawai`i.

**Background on Hesperomannia oahuensis**

**Populations**

*Hesperomannia oahuensis* is one species that is listed under the ESA. It is listed as endangered, the highest protection status that can be afforded under the ESA. The few remaining individuals, between 6-10, all live within two populations in the Wai`anae Mountains on O`ahu (“5-Year Review: Short Form Summary” 2013). This species has recently undergone a taxonomic change. Previously, it was thought that this species and another on the island of Maui, *Hesperomannia arbuscula*, were the same species. Within the past year, though, it was determined that these two species are actually genetically distinctive, so the species on Maui is now called *Hesperomannia aborescens* while the species on O`ahu is now named *Hesperomannia oahuensis*. This name change is significant for two reasons. The first reason is that the population size of both species decreased as a result of this taxonomic change (see Figure 1). Now, we do not have one endangered species, but two critically endangered species. Secondly, because the species on Maui and the one on O`ahu are not identical species, genetic diversity within the species was lost. Geographic separation allowed for diversity to exist between the individuals on the two islands, but now, that diversity no longer exists (Morden).
Figure 1: The population size of *Hesperomannia oahuensis* has decreased in recent years (“5-Year Review: Short Form Summary” 2013). This may be due to a variety of factors, possibly including climate change or reflecting the recent name change of this species.

**Geographic Range and Threats**

*Hesperomannia oahuensis* also has a small geographic range and a very specific habitat. It currently exists in two populations, both of which are in the Wai`anae Mountain Range on O`ahu. One population is present in Makaha Valley, and the other is located on the Pahole Natural Area Reserve. Both of these areas are protected from such threats as ungulates and rats because fences have been constructed, and rat traps are placed near each individual plant in order to prevent rats from eating the plants. This species is also a habitat specialist, occurring in mixed-mesic forests with 50-80% shade and undisturbed, moist soil in the Wai`anae Range (Ching-Harbin). This specific habitat is extremely small in size, mainly due to the destruction of this habitat by humans. A common threat to many Hawaiian species is humans, especially through the impact of the devastation of native habitat, the introduction of invasive species, and other non-sustainable behaviors such as significant pollution. This species faces an even greater threat from humans because of its sensitive root system. This plant cannot sustain human or animal traffic because of its sensitive root system, so if an individual puts pressure on the roots, then it is likely that the individual plant will die (Ching-Harbin).

**Pollinators**

Another challenge to the recovery and ultimate delisting under the ESA for this species is poor pollination. At this point, this species has no natural pollinators. It is suspected that the old pollinator of this species was a native Hawaiian bird, such as the `Amakihi or `Apapane, both of which are still present on O`ahu. It is also possible that bees historically pollinated this species. None of these pollinators are extinct, but since the population size of this species became so small, a natural pollinator was no longer attracted to these rare plants (Ching-Harbin). In order for a pollinator introduction to take place, a large number of individual plants need to grow in a small area, and the flowers of many of these individuals need to bloom simultaneously. If this occurs, a pollinator might be attracted to the area, especially because this species has a
large quantity of nectar. Potential future pollinators include moths, honey bees, and the native bird Amakihi (Ching-Harbin).

More specific information about *Hesperomannia oahuensis* and characteristics that are proving problematic for its recovery are included in an appendix at the end of this paper.

**Previous Work Completed**

Work is being completed to prevent this species from becoming extinct by multiple institutions, including the Harold L. Lyon Arboretum, the O`ahu Plant Extinction Prevention Program, the Nature Conservancy of Hawai`i, and the O`ahu Army Natural Resource Program (Ching-Harbin). Funding is also provided by the United States Fish and Wildlife Service and the State of Hawai`i. In order for this species to be considered recovered, it must have three populations of twenty-five or more individuals, have representation *ex situ*, such as in a seed storage facility or greenhouse, and be protected from controlled threats. Currently, there are only two populations of *Hesperomannia oahuensis*, and this species is not represented *ex situ*. However, this species is considered controlled from threats, as fences and rat traps have been constructed that are successfully keeping ungulates and rats away from the plants (“5-Year Review: Short Form Summary” 2013).

**Current Management Strategy and Assessment of *Hesperomannia oahuensis***

As explained above, the current management of *Hesperomannia oahuensis* consists of four separate strategies. To manage this species, the following strategies have been employed:

- Place fences around the populations of this species and maintain those fences in order to prevent the plants from being eaten or trampled by ungulates.
- Place rat traps next to each individual plant. By trapping the rats, the individual plants have a greater chance of survival because their plant material is not being consumed.
- Hand-pollination of the individuals remaining in the wild.
- Micropropagation of plant material from this species.

Both the fences and rat traps have succeeded in protecting these species from what the ESA describes as “controlled threats” (*Overview*). All of these strategies are meant to protect this species from extinction either through increasing population size and preventing the current population size from further decline.

I was involved with the current management of this species through my immersion with the Lyon Arboretum and the O`ahu Plant Extinction Prevention Program.

**Methodology**

In completing my research on *Hesperomannia oahuensis*, I employed three main strategies:

1) Clean out rat traps surrounding the individual plants
2) Hand-pollinate the individual plants
3) Interview individuals who are experts in conservation or know a significant amount about this particular species

**Results and Discussion**

While visiting Hawai`i, I assisted with cleaning out rat traps around these plants. I also helped with the hand-pollination of this species. When we hand-pollinated, we used pollen from an individual plant in Makaha Valley to pollinate two flowering individuals on the Pahole
Natural Area Reserve in order to provide genetic diversity in the plant population. We also installed a camera to take a photograph once a day of a bud on an individual plant. This photograph was then sent to an individual working for the O’ahu Plant Extinction Prevention Program. When the bud was in bloom, a botanist would once again be sent into the field to hand-pollinate this newly-bloomed flower. I was also able to extensively interview several conservation experts in Hawai’i including Peter Wiggin and Susan Ching-Harbin.

**Hand-pollination**

Hand-pollination is a labor-intensive technique that involves the pollination of one individual plant with pollen from another individual. By using pollen from different individuals, the genetic diversity of the remaining and future species will increase. In order to complete this technique, pollen is collected from a single plant and then stored. This pollen must be kept cool and used within six weeks of collection in order to ensure that it remains viable (Ching-Harbin). In order to place pollen on a plant, an applicator such as a fine paintbrush or eye makeup brush is used to gently brush the pollen onto the stigmas of the plant. Using this technique, it is hoped that new individuals will grow (2010 Makua and Oahu Implementation Plan Status Report).

Recently, this hand-pollination has seen some success. Hand-pollination of this species began in 2007, but for the first time this year, the seedlings produced have reached maturity. Also, some viable seeds were produced as a result of this technique (Ching-Harbin). If hand-pollination can continue to succeed and produce more individuals that mature and are reproductively viable, then there will be greater genetic variance available within the population and an increased number of healthy plants will result. This would then allow individual plants to be out-planted into the already existent populations. In addition, some plants could be kept in a greenhouse and seeds germinated there, or the seeds themselves could be placed into a seed storage facility such as the one at the Lyon Arboretum in Honolulu. Finally, it is possible that some plant material might become available for usage in micropropagation, the plant cloning process.

**Micropropagation**

The process of micropropagation is one that can quickly and efficiently clone individual plants in order to increase the numbers of individual plants. This process involves placing individual plants or plant parts inside a nutrient-filled test tube and allowing them to grow. This aspect of conservation is so critical because it rapidly increases population size to the point that some individuals might be out-planted from the cloned group. When plants are kept in test tubes, if the species becomes extinct in the wild, there is still plant material remaining ex situ (Sugii). Unfortunately, in the case of *Hesperomannia oahuensis*, micropropagation techniques have failed. As a result of the small population size of this species, there is little plant material available for experimentation. This plant material has not positively responded to the nutrient gel in the test tubes, and it consequently died. If more plant material becomes available as a result of hand-pollination efforts, however, then it is possible that micropropagation efforts might continue. If different concentration nutrient gel is tested, then we might succeed in cloning this species and prevent it from going entirely extinct (Wiggin).

**Evaluating Effectiveness**

In many regards, the current management plan of *Hesperomannia oahuensis* is both succeeding and failing. Generally, this plan is succeeding because this species is not yet extinct,
and the population size is actually increasing as of this year with viable seeds produced and individuals reaching reproductive maturity. This development is extremely promising because it suggests that human intervention might be able to eventually recover this species to the point that it is de-listed from the ESA. Additionally, rats and ungulates are affecting this species to a lesser extent than in the past. Both of these factors taken together suggest that the future outlook for this species is promising. Even with the failure of micropropagation techniques and the labor-intensive nature of hand-pollination and micropropagation, it seems that this species is slowly recovering. Although this may be true, this plan may fail because of a looming problem that might influence the success of all aspects of the management and recovery plans of this species: climate change (“5-Year Review: Short Form Summary” 2013).

**How Climate Change Affects Plants**

The effects of climate change can negatively impact plant species. Temperature and precipitation changes may cause significant challenges, especially for species that are unable to quickly adapt or who are especially sensitive to changes in these environmental factors. As a result of decreased precipitation, the rate of fires might increase in some areas (Ooi). In the case of *Hesperomannia oahuensis*, the increased possibility of a strong storm is concerning because all of the individuals of this species are located in a relatively small portion of O`ahu. Increased temperature and decreased precipitation are often associated with one another, and this is reflected in rising drought rates. With higher air temperatures, the possibility of drought increases. Higher air temperatures can also reduce seedling survival, decrease the number of dormant seeds of a plant, or even kill seeds in extreme situations (Ooi). Often, the effects of increased air temperature are felt even more strongly in the soil, especially if the area is exposed to direct sunlight. When this occurs, the higher soil temperatures can cause higher germination rates than usual. This is problematic because higher rates of germination mean the breaking of seed dormancy and the possibility of germinating seeds that are too immature. Consequently, the viability of the seeds is at risk. The infrequency of rainfall and more frequent droughts are troubling because they can cause greater frequencies of failed germination and seedling mortality. Similarly to increased temperatures, this negatively impacts the species’ reproductive success. Unfortunately, all of these effects of climate change are beginning to influence Hawai`i, and consequently, the plant life there.

**Conclusions**

For *Hesperomannia oahuensis*, much progress has been made towards recovery, but further action is needed to save this plant species. Hand-pollination and the fencing and rat trap placement around the individuals of this species should continue because it has been successful so far. Furthermore, it is necessary that an appropriate micropropagation technique is established in order to create more individual plants and return a few individuals in case *ex situ* problems arise in the field. It is also essential that a pollinator be reintroduced for this species. Hand-pollination cannot continue indefinitely because of the cost and time commitment needed to implement this technique. It is necessary that this species becomes capable of survival and reproduction without such extensive human intervention. The current management plan of this species fails to address climate change as a barrier to recovery. *Hesperomannia oahuensis* serves as an example of a species that might already be responding to the effects of climate change as evidenced by its dwindling population size in recent years (“5-Year Review: Short Form Summary” 2013).
It is unknown exactly how climate change might affect this species and others on a large scale. The effects will likely vary from region to region, with coastal areas experiencing a more significant impact than inland areas. Some regions might even benefit from a changing global climate by receiving more rainfall or milder annual weather. Despite these isolated possibilities, the effects of climate change are negative and potentially catastrophic when considered over the global average.

Most importantly for the protection of any species, both endangered and non-endangered, is the consideration of climate change. As shown by the case of *Hesperomannia oahuensis*, climate change might cause the decrease of a plant species population to the point of the brink of extinction. Ideally, political will and scientific consensus regarding climate change would turn into international action to minimize some of the causes of climate change such as burning of fossil fuels. Unfortunately, the current driving force behind many environmental policies is economic, and it is restricting progress towards solving the anthropogenic causes of climate change. Therefore, the next necessary step is planning for climate change and considering its consequences. In the context of endangered species, this means placing an emphasis on climate change and its effects in the recovery plan for each of these species. The future of many species on Earth depends upon our readiness to deal with the consequences of anthropogenic climate change, so it is imperative that strategies are formulated to combat these environmental changes.
Appendix:
This appendix provides additional information about *Hesperomannia oahuensis* and several of its characteristics that are impeding its progress towards a recovery from the verge of extinction.

- *Hesperomannia oahuensis* has low pollen and seed viability, with the pollen viability in some individuals as low as 14% (“5-Year Review: Short Form Summary” 2009). Since the pollen viability is so low, it becomes difficult for this species to successfully reproduce.

- The pollen of this species is only viable for a short period of time (Ching-Harbin). When hand-pollination takes place, the pollen must be kept refrigerated and used within six weeks of collection. This places a strain on the hand-pollination system because it requires more frequent visits into the field by botanists.

- The seeds of this species are extremely heavy, so they have a small distribution area (2010 Makua and Oahu Implementation Plan Status Report). As a result, it is virtually impossible for this species to expand its habitat range outside of its preferred mesic habitat. This lack of location diversity is problematic because it makes the chances of the species being affected by an area-specific storm, disease, or other disaster more likely.

- The individual plants are very likely self-incompatible, a characteristic that is common for a species in the Asteraceae family (Ching-Harbin). Since this species needs pollen for a different plant to produce viable seeds, the current lack of a natural pollinator becomes an even greater issue. Even if a pollinator were to stop at a flower of this species, it is unlikely that the pollen collected on that pollinator would reach another individual of this species because the individual plants are not all located in close proximity.

- This species is very intolerant to drought (Ching-Harbin). The O`ahu Plant Extinction Prevention Program brought water to this species throughout a drought that hit O`ahu during 2000-2003, but the attempts were not successful. If an individual plant loses its leaves, then it will not recover and die.

- There is very little historical documentation of this species since 1778 when James Cook and Westerners arrived in the Hawaiian Islands (Ching-Harbin). Therefore, this suggests that this species was always rare. It is also possible that this species was never considered common because it is so habitat specific. However, even though this species was always rare, its numbers have declined significantly from historically recorded values.
Works Cited


Wiggin, Peter. “Re: *Hesperomannia oahuensis* Question.” Message to Margaret A. Beetstra. 15 Sept. 2013. E-mail.