Native Hawaiian teas in peril: Habitat loss and preservation of *Māmaki* (*Pipturus albidus*) and *Koʻokoʻolau* (*Bidens hawaiensis*) in wet lowland rainforests on Hawaiʻi Island

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Introduction

The Hawaiian Islands are home to ~1,200 vascular plant species, many of which are listed as endangered, candidates to be listed, or are species of concern[1]. Approximately, 50% of Hawaiian plant species are naturally restricted to a single island[2] correlating with decreased resilience against habitat loss[3]. Furthermore, ~43% (~400) of all federally threatened and endangered plant species occur in Hawaiʻi[3,4]. Land use conversion from lowland rainforest to agriculture and urban developments have led to highly fragmented lowland rainforests. The few remaining fragmented forests exist predominantly on the islands of Kauaʻi and Hawaiʻi[5]. Researchers are seeking to determine optimal management strategies to mitigate habitat loss, preserve habitat quality, and restore Hawaiian ecosystems. Of particular concern are plants of cultural and ethnobotanical value such as *Māmaki* (*Pipturus albidus*) and *Koʻokoʻolau* (*Bidens hawaiiensis*). Natural resource land managers are designing management plans to include biocultural and ethnobotanical factors.

Research Objective

How does urbanization, invasive species introductions, and Rapid *ʻŌhiʻa* Death (ROD) impact the habitat range and species distribution of *Māmaki* (*Pipturus albidus*) and *Koʻokoʻolau* (*Bidens hawaiensis*) in lowland wet and mesic rainforests in the district of Puna on Hawaiʻi Island?

Figure 1: *Māmaki* (*Pipturus albidus*)[6]

Figure 2: *Koʻokoʻolau* (*Bidens hawaiensis*)[6]

Ethnobotanical Uses

Historically, *Kahuna Lāʻau Lapaʻau* (Hawaiian traditional herbal practitioners) utilized >180 plant species to heal the community[7,8]. Two commonly used plants, brewed as herbal green teas are *Māmaki* and *Koʻokoʻolau.*

Traditional uses:

Māmaki

- Leaves: primarily used as a tonic/tea; treated thrush; regulated blood sugar, blood pressure, and cholesterol; purified the blood[9,10]
- Fruit: used as a mild laxative[11,12]
- Bark: used to make fine mats, *kapa* (a coarse cloth), rope and cordage[11]

Koʻokoʻolau

- Predominantly used as a tonic/tea; treated thrush, constipation, asthma, and tuberculosis[10]
- Often used in combination with other plant species (e.g., *ʻōhiʻa lehua – Metrosideros polymorpha*, *ʻōhiʻa ʻai – Eugenia malaccensis*, *kukui – Aleurites moluccana*, and *kō – Saccharum officinarum*)[10]

Contemporary uses:

Māmaki

- Leaves: frequently sold in local markets; global interest is increasing. Concentrations of (+) catechins and rutin (believed to have antioxidant and other potential health benefits) are significantly higher than in other commercial tea leaves[13]
- Extracts: selective anti-viral activity, anti-bacterial, and anti-fungal properties[14]

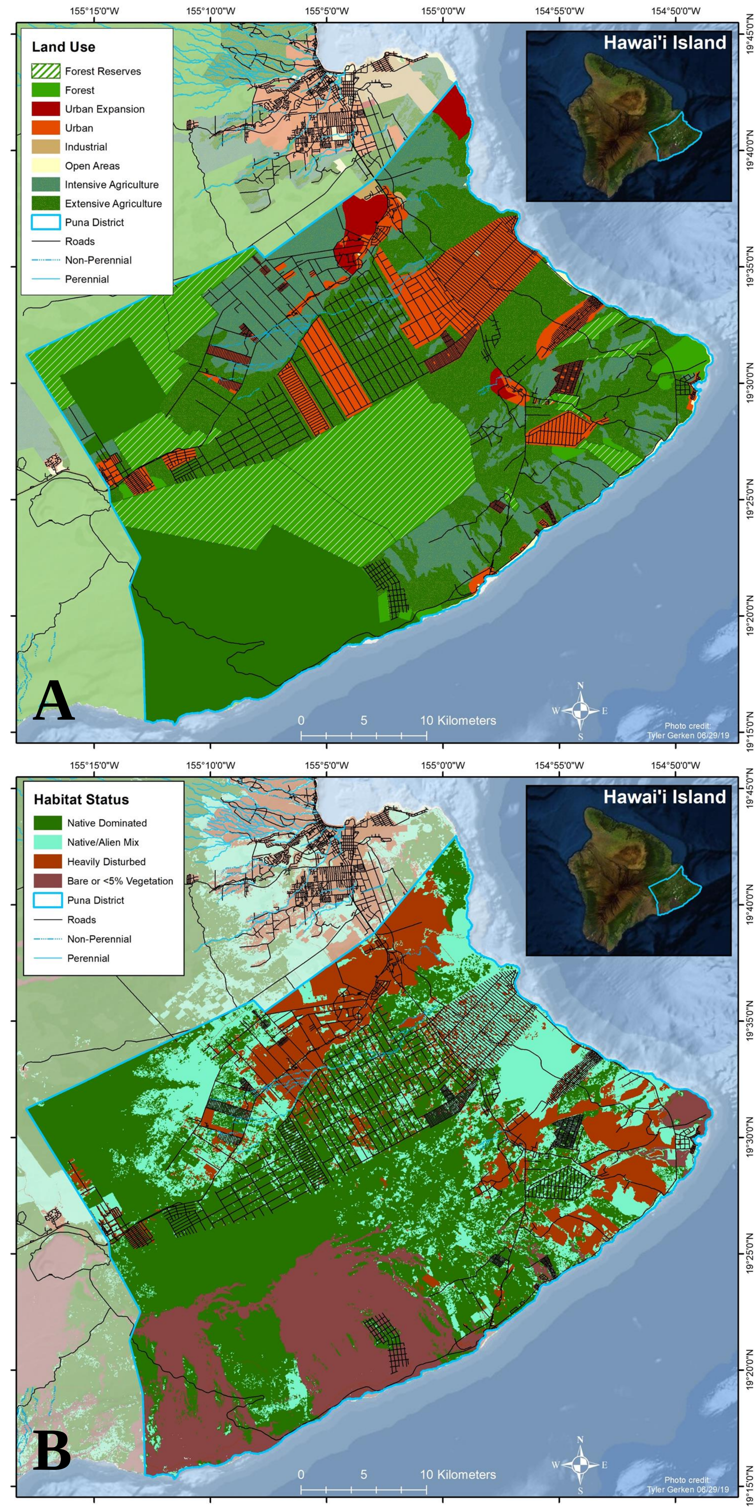
Koʻokoʻolau

- Overall use appears to be declining, possibly due to declining range

Study Site: Puna, Hawaiʻi Island, Hawaiʻi

Ka ua moaniani lehua o Puna **– The rain that brings the fragrance of the lehua of Puna**

Puna ("*well-spring*") is the eastern most district on Hawaiʻi Island. Puna was known for its abundant natural resources, particularly *ʻōhiʻa*, *lauhala* (*Pandanus tectorius*), *maile* (*Alyxia stellata*), *ʻieʻie* (*Freycinetia arborea*, and *noni* (*Morinda citrifolia*).



Puna Development:

- Approximately ½ of all development in Hawaii is occuring in Puna[15]
- Between 2000-2016, population increased 45%[16]

Land Use in Puna:
(1300 Km^2)

- Conservation Forest: 558 Km^2 (43%)
- Urban: 179 Km^2 (14%)
- Open: 9 Km^2 (1%)
- Agriculture: 556 Km^2 (43%)

Habitat Status in Puna:

- Native Dominated: 579 Km^2 (45%)
- Native/Alien Mix: 284 Km^2 (22%)
- Heavily Disturbed: 225 Km^2 (17%)
- Bare or <5% Vegetation: 213 Km^2 (16%)

Figure 3: A: Major Land Use Types in the district of Puna on Hawaiʻi Island, Hawaiʻi; **B**: Habitat Status in Puna[17]

Ecosystem-Modifying Invasive Species

- Of the 8,000-10,000 plant taxa introduced to the Hawaiian Islands, only ~90 are classified as extremely harmful due to competition, ecosystem modification, and biogeochemical habitat degradation[18]
- Strawberry guava is capable of invading over half (~120,000 ha) of conservation lands on Hawaiʻi Island[19] while Miconia occupies ~100 ha on Hawaiʻi Island and quickly shades out native trees[20]

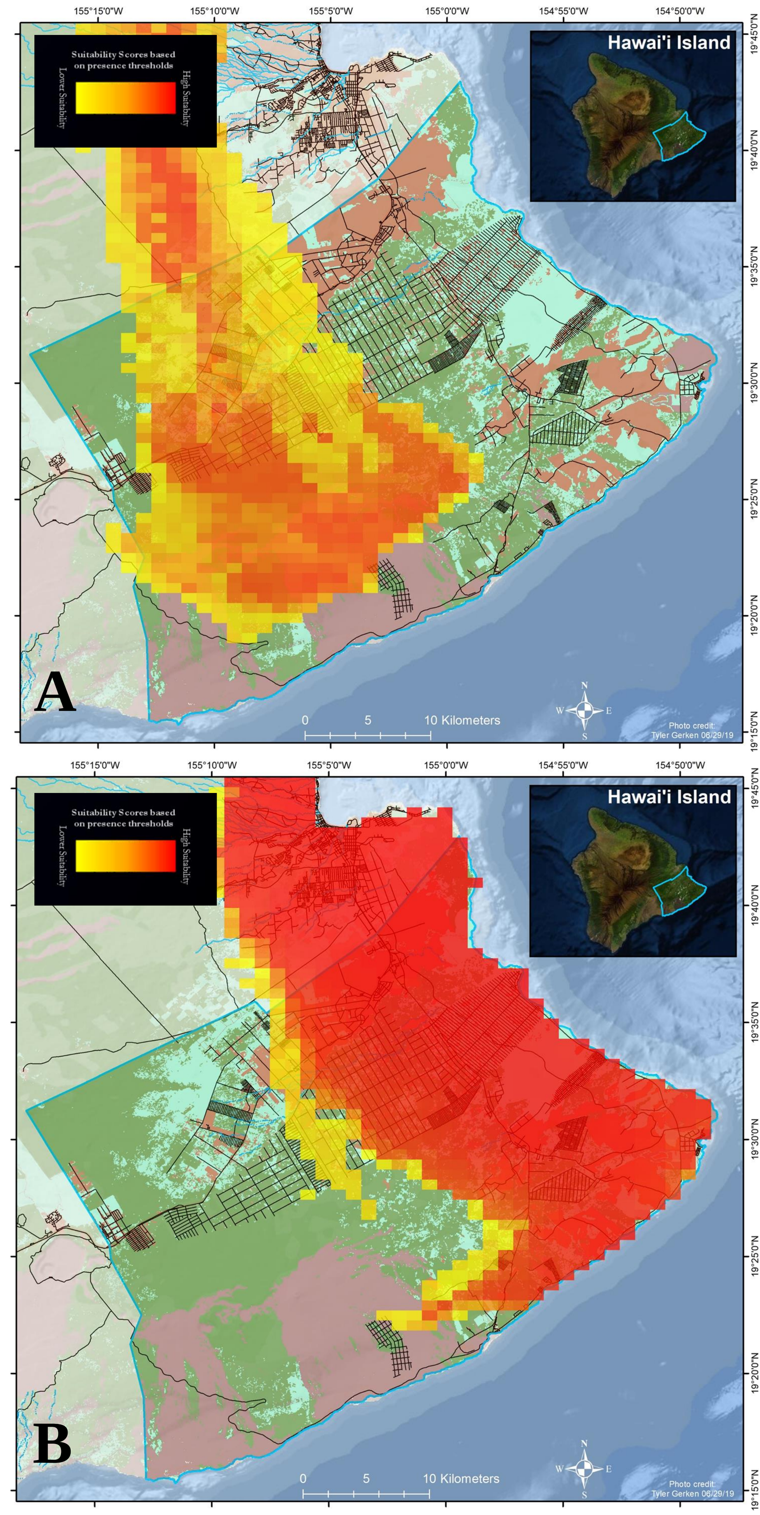


Figure 4: Current (2013) Species Distribution model/Invasibility Suitability Index of **A:** Strawberry Guava (*Psidium cattleianum*) and **B**: Miconia (*Miconia Calvenscens)*[21]

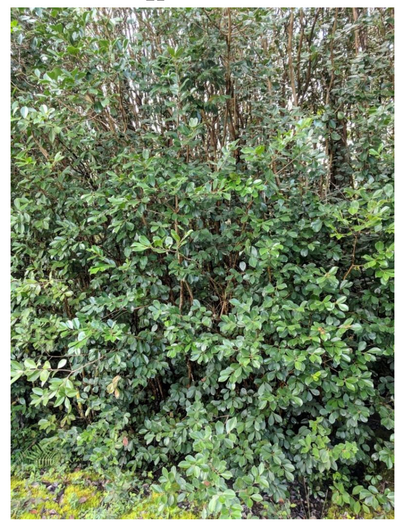


Figure 5: Strawberry guava (*Psidium cattleianum*)

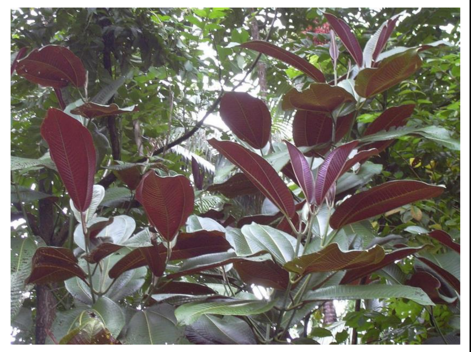


Figure 6: Miconia (*Miconia Calvescens*)

Rapid *ʻŌhiʻa* Death (ROD)

- ROD is associated with 2 invasive pathogens, a vascular wilt fungus (*Ceratocystis lukuohia*) and a canker pathogen (*Ceratocystis huliohia*) which is killing the *ʻŌhiʻa lehua*, the most dominant tree in Hawaiʻi[25]
- ROD was first detected in 2010 in the Puna District. As of Sept. 2017, >40,000 ha have been affected on Hawaiʻi Island, with the greatest mortality densities and canopy loss occuring in Puna[26]

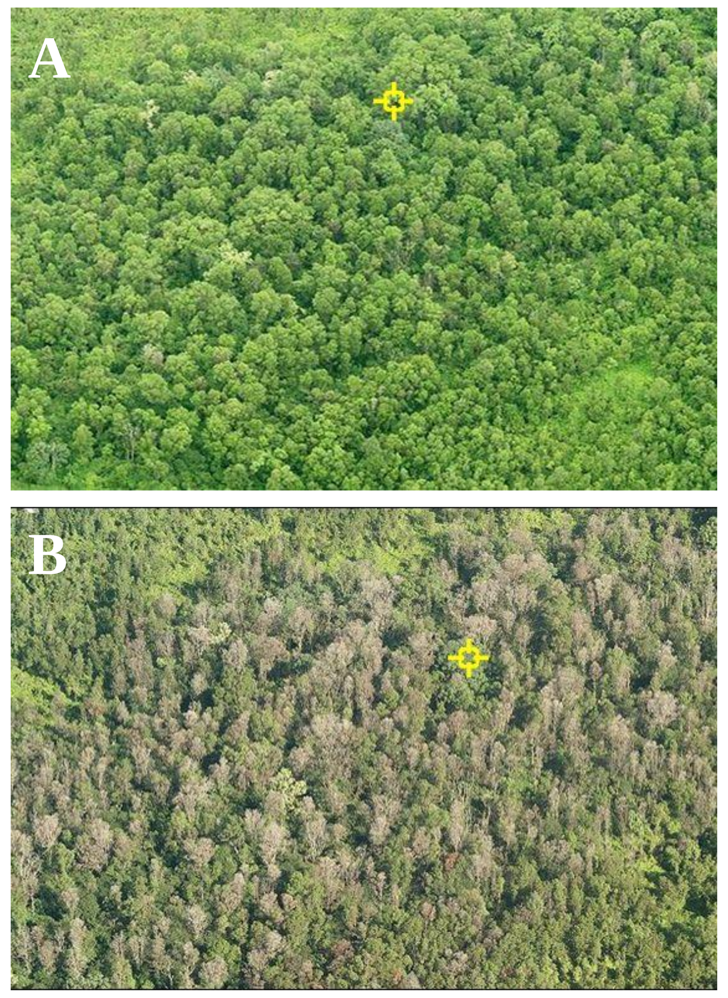


Figure 10: A: Forest canopy before ROD (2008); **B:** Forest canopy after ROD (2012) (Image by J B Friday)

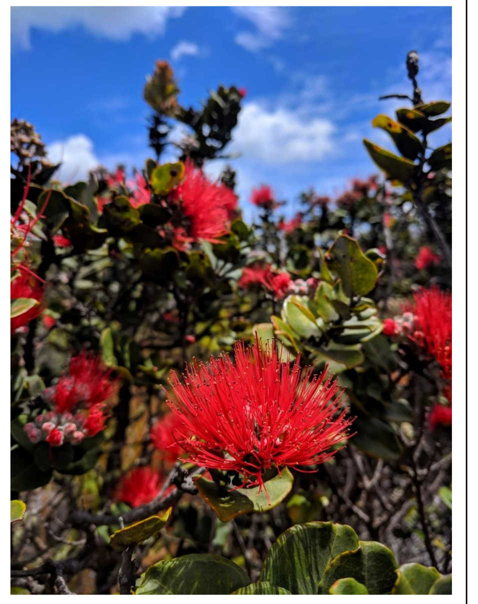


Figure 11: *ʻŌhiʻa lehua* (*Metrosideros polymorpha*)

> **"These Hawaiian rural communities are the cultural *kīpuka* (oases) from which the Hawaiian culture regenerates, as the native trees of the *kīpuka* propagate and, in time, re-establish the forest on the lava flow"**[22]
>
> – Davianna Pōmaikaʻi McGregor

Habitat Loss is Threatening the Habitat Range & Abundance of *Māmaki* and *Koʻokoʻolau*

Increasing development, expanding suitable ranges of ecosystem-modifying invasive species, and loss of native *ʻŌhiʻa lehua* canopy cover will continue to degrade the quality of lowland wet and mesic rainforests. This will increase fragmentation and reduce available suitable habitat of *Māmaki* and *Koʻokoʻolau.*

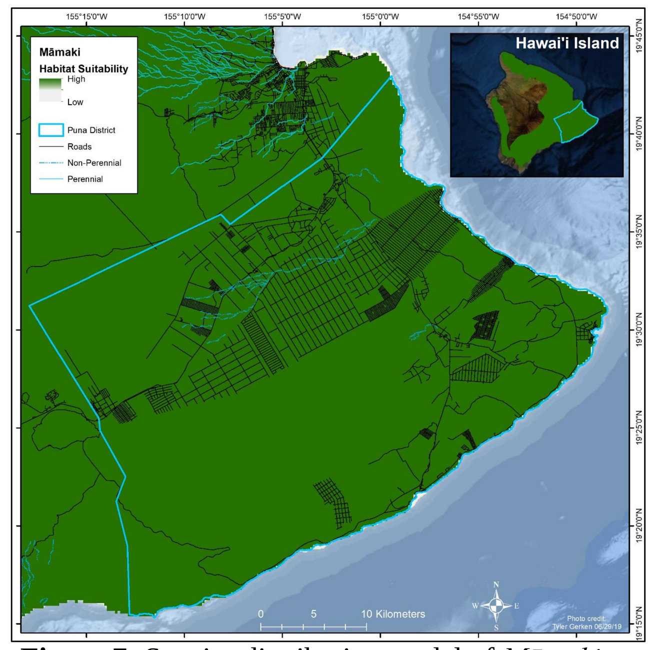


Figure 7: Species distribution model of *Māmaki* (*Pipturus albidus*) on Hawaiʻi Island, Hawaiʻi. Model created using the program Maxent overlaid with rainfall and min/max atmospheric temperature data.[23,24]

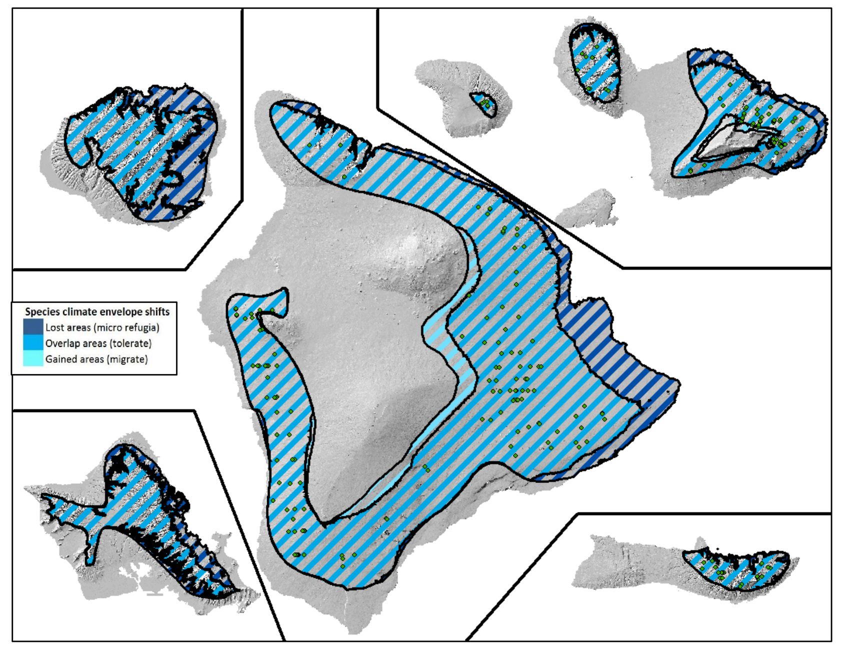


Figure 8: Projected response zones of *Māmaki* (*Pipturus albidus*) throughout Hawaiʻi Island based on current and future climate-compatible areas by the year 2100 (Fortini et al. 2013)[4]

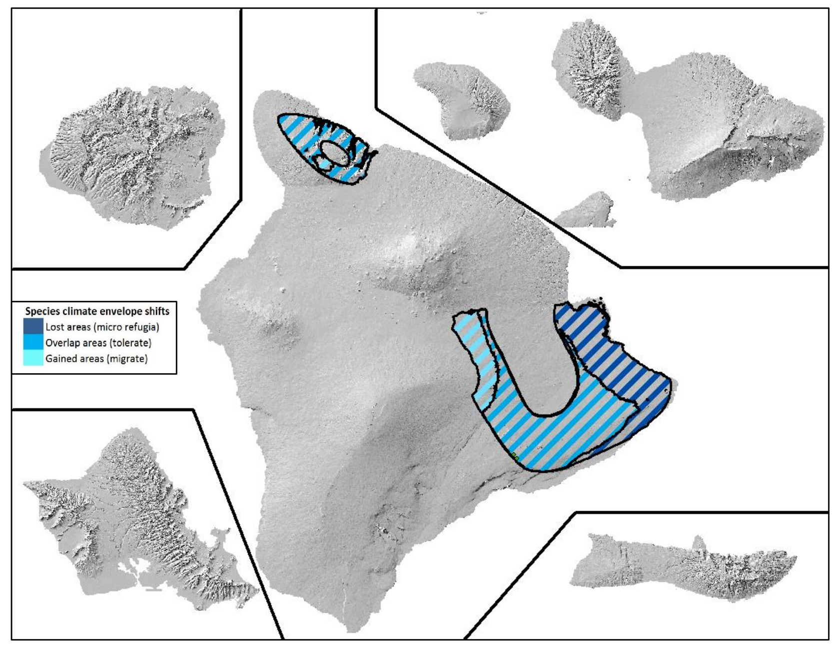


Figure 9: Projected response zones of *Koʻokoʻolau* (*Bidens hawaiensis*) throughout Hawaiʻi Island based on current and future climate-compatible areas by the year 2100 (Fortini et al. 2013)[4]

Discussion and Conclusion

- Successful restoration efforts must integrate Hawaiian conservation values—*ahupuaʻa* (traditional land division) system of natural resource management—with scientific research and monitoring
- *Māmaki* is capable of survival, growth, and trait plasticity in low-light environments and may be useful in ongoing restoration projects[27] *Māmaki* demonstrates strong pioneering abilities, successfully reestablishing in a previously cleared lowland wet rainforest, exhibiting the largest relative frequency and relative cover[28]
- Restoration efforts should apply the projected species range climate models to tailor preservation and restoration within forest reserve management plans
- Future research should analyze the forest dynamics of *ʻŌhiʻa lehua* following ROD to better understand native and exotic species regeneration. Restoration of ROD impacted landscapes are necessary to mitigate the encroachment of invasive species
- Due to limited data on *Koʻokoʻolau* (*Bidens hawaiensis*), monitoring and restoration strategies are paramount for this species of concern

References

1. U.S. Fish and Wildlife Service, 2012, Species reports—Listings and occurrences for Hawaii: U.S. Fish and Wildlife Service Environmental Conservation Online System.
2. Price, Jonathan P. 2004. "Floristic Biogeography of the Hawaiian Islands: Influences of Area, Environment and Paleogeography." *Journal of Biogeography* 31: 487–500.
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