Species Report
Pleomele fernaldii (*Dracaena fernaldii*) (halapepe)
Version 1.0

Photo credit: Hank Oppenheimer, Plant Extinction Prevention Program

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EXECUTIVE SUMMARY

Pleomele fernaldii (hala pepe) is a long-lived perennial tree in the asparagus family (*Asparagaceae*). It is an endemic species that is found only on the island of Lānaʻi in the Hawaiian islands (Wagner et al. 1999, p. 1,352). Currently, there are two wild population units known containing more than 1,000 individuals that mostly consist of old, mature trees with very little regeneration of seedlings (Oppenheimer 2019, pers. comm). The new combination for this species is *Dracaena fernaldii* in the most recent taxonomic treatment in the checklist of Hawaiian flora (Smithsonian Institution 2023, entire).

Historically, *Dracaena fernaldii* has been known throughout Lānaʻi on both the leeward and windward sides. Currently, *D. fernaldii* is found from Hulopoʻe and Kunoa Gulches southeast to Waiakeakua and Puhiʻelelu Ridge (St. John 1947, pp. 39–42; USFWS 2019, entire; PEPP 2008, p. 75) in two population units called Lōpā-Waiʻopa-Haua and Kapōhaku-Kaunoa- Hoʻokiʻo. This species is found between the elevations of 1,608 to 3,051 feet (ft) (490 to 930 meters [m]) in the gulches and cliff faces of remnant dry forest and mesic forest (Wagner et al. 1999, p. 1352; USFWS 2019, entire; National Tropical Botanical Garden 2019; Oppenheimer 2019, pers. comm.). The habitat is generally categorized as a native wet forest, mesic forest, and mesic grassland and shrubland. The soil type is classified as rough mountainous land, rock outcrop, and Kahanui silty clay (USFWS 2019, entire).

The main threats to *Dracaena fernaldii* are introduced ungulates, nonnative plants, drought, fire, hurricanes, introduced rats, lack of regeneration, loss of native pollinators and seed disperser agents, and climate change. Conservation actions that are helping to control these threats include ungulate fencing, control of nonnative plants and rats, monitoring, and surveys. There are no seeds in storage and no propagules growing in a nursery for this species.

We define resiliency for *Dracaena fernaldii* based on the metric of population size. We define redundancy for *D. fernaldii* based on the metrics of the number of populations, resilience of populations, and the distribution of the species across its range. We define representation for *D. fernaldii* based on the genetic diversity and habitat variation within and among populations.

The decreased geographic range, low population size, and relatively low number of individuals have compromised the range-wide redundancy, representation, and resilience of *Dracaena fernaldii* in the current condition. Given that there are currently two wild population units and more than 1,000 mostly old mature individuals known, we evaluated the species' resilience and representation as low, and redundancy as very low, in the current condition. Therefore, we would expect *D. fernaldii* to be particularly vulnerable to the habitat impacts of all the threats listed above. Therefore, we conclude that the species' overall current condition viability is low.

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INTRODUCTION

Pleomele fernaldii (hala pepe) is a long-lived perennial tree in the asparagus family (Asparagaceae). It is an endemic species that is found only on the island of Lānaʻi in the Hawaiian islands (Wagner et al. 1999, p. 1352; Smithsonian Institution 2023, entire). Historically known throughout Lānaʻi, this species is currently found from Hulopoʻe and Kunoa Gulches southeast to Waiakeakua and Puhiʻelelu Ridge (St. John 1947, pp. 39–42; U.S. Fish and Wildlife Service [USFWS] 2019, entire; Plant Extinction Prevention Program [PEPP] 2008, p. 75).

Species Report Overview

This biological report summarizes the biology and current status of *Pleomele fernaldii* and was conducted by Pacific Islands Fish and Wildlife Office. The biological report provides an in-depth review of the species' biology, factors influencing viability (threats and conservation actions), and an evaluation of its current status and viability.

The intent is for the Species Report to be easily updated as new information becomes available, and to support the functions of the Service's Endangered Species Program. As such, the Species Report will be a living document upon which other documents such as recovery plans and 5-year reviews will be based.

Regulatory History

Pleomele fernaldii was listed as an endangered species on May 28, 2013 (78 FR 32013, May 28, 2013). No critical habitat has been designated for this species (81 FR 17888, March 30, 2016).

Methodology

We used the best scientific and commercial data available to us, including peer-reviewed literature, grey literature (government and academic reports), and expert elicitation. Because little information is available about *Pleomele fernaldii*, we used basic plant biology to identify the needs of individuals, populations, and the species. To the best of our ability, we used the current taxonomy at the time this report was drafted.

To assess the current status and viability of *Pleomele fernaldii*, we identified population units. The classic definition of a population is a self-reproducing group of conspecific individuals that occupies a defined area over a span of evolutionary time, an assemblage of genes (the gene pool) of its own, and has its own ecological niche. However, due to information gaps, we could not assess the viability of *Pleomele fernaldii* using this definition. The Hawaiʻi and Pacific Plants Recovery Coordinating Committee revised its recovery objectives guidelines in 2011 and included a working definition of a population for plants: "a group of conspecific individuals that are in close spatial proximity to each other (i.e., less than 1,000 meters apart), and are presumed to be genetically similar and capable of sexual (recombinant) reproduction" (HPPRCC 2011, p. 1).

Based on this working definition, maps were created to display population units. In an effort to protect the sensitivity of species data, we created maps with symbol markers rather than displaying species points or polygons. We created the symbols in steps. First, we added a 500-meter buffer around each individual species point and polygon. We then dissolved all buffer areas intersecting each other into a single shape. Next, we created a centroid (i.e., point representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. Finally, the Disperse Marker tool in ArcGIS Pro was used shift symbol markers that were overlapping so they would all be visible at the scale of the map. All points and polygons were used in this process, regardless of observation date or current status (historical, current, extant, or extirpated), to represent the known range of the species.

The Report assesses the ability of *Pleomele fernaldii* to maintain viability over time. Viability is the ability or likelihood of the species to maintain populations over time, i.e., likelihood of avoiding extinction. To assess the viability of *P. fernaldii*, we use the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 1; USFWS 2016b). We evaluate the viability of our species by describing what the species needs to be resilient, redundant, and represented, and compare that to the status of the species based on the most recent information available to us.

Definitions

Resiliency is the capacity of a population or a species to withstand the more extreme limits of normal year-to-year variation in environmental conditions such as temperature and rainfall extremes, and unpredictable but seasonally frequent perturbations such as fire, flooding, and storms (i.e., environmental stochasticity). Quantitative information on the resiliency of a population or species is often unavailable. However, in the most general sense, a population or species that can be found within a known area over an extended period of time (e.g., seasons or years) is likely to be resilient to current environmental stochasticity. If quantitative information is available, a resilient population or species will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population or species, and possibly expand the range of occupancy. Thus, resiliency is positively related to population size and growth rate, and may also influence the connectivity among populations.

Redundancy is having more than one resilient population distributed across the landscape, thereby minimizing the risk of extinction of the species. To be effective at achieving redundancy, the distribution of redundant populations across the geographic range should exceed the area of impact of a catastrophic event that would otherwise overwhelm the resilient capacity of the populations of a species. In the report, catastrophic events are distinguished from environmental stochasticity in that they are relatively unpredictable and infrequent events that exceed the more extreme limits of normal year-to-year variation in environmental conditions (i.e., environmental stochasticity), and thus expose populations or species to an elevated extinction risk within the area of impact of the catastrophic event. Redundancy is conferred upon a species when the geographic range of the species exceeds the area of impact of any anticipated catastrophic event. In general, a wider range of habitat types, a greater geographic distribution, and connectivity across the geographic range will increase the redundancy of a species and its ability to survive a catastrophic event.

Representation is having more than one population of a species occupying the full range of habitat types used by the species. Alternatively, representation can be viewed as maintaining the breadth of genetic diversity within and among populations, in order to allow the species to adapt to changing environmental conditions over time. The diversity of habitat types, or the breadth of the genetic diversity of a species, is strongly influenced by the current and historic biogeographical range of the species. Conserving this range should take into account historic latitudinal and longitudinal ranges, elevation gradients, climatic gradients, soil types, habitat types, seasonal condition, etc. Connectivity among populations and habitats is also an important consideration in evaluating representation.

The viability of a species is derived from the combined effects of the 3Rs. A species is considered viable when there are a sufficient number of self-sustaining populations (resiliency) distributed over a large enough area across the range of the species (redundancy) and occupying a range of habitats to maintain environmental and genetic diversity (representation) to allow the species to persist indefinitely when faced with annual environmental stochasticity and infrequent catastrophic events. Common ecological features are part of each of the 3Rs. This is especially true of connectivity among habitats across the range of the species. Connectivity sustains dispersal of individuals, which in turn greatly affects genetic diversity within and among populations. Connectivity also sustains access to the full range of habitats normally used by the species, and is essential for re-establishing occupancy of habitats following severe environmental stochasticity or catastrophic events (see Figure 1 for more examples of overlap among the 3Rs). Another way the three principles are inter-related is through the foundation of population resiliency. Resiliency is assessed at the population level, while redundancy and representation are assessed at the species level. Resiliency populations are the necessary foundation needed to attain sustained or increasing representation and redundancy within the species. For example, a species cannot have high redundancy if the populations have low resiliency. The assessment of viability is not binary, in which a species is either viable or not, but rather on a continual scale of degrees of viability, from low to high. The health, number and distribution of populations were analyzed to determine the 3Rs and viability. In broad terms, the more resilient, represented, and redundant a species is, the more viable the species is. The current understanding of factors, including threats and conservation actions, will influence how the 3Rs and viability are interpreted for *Pleomele fernaldii.*

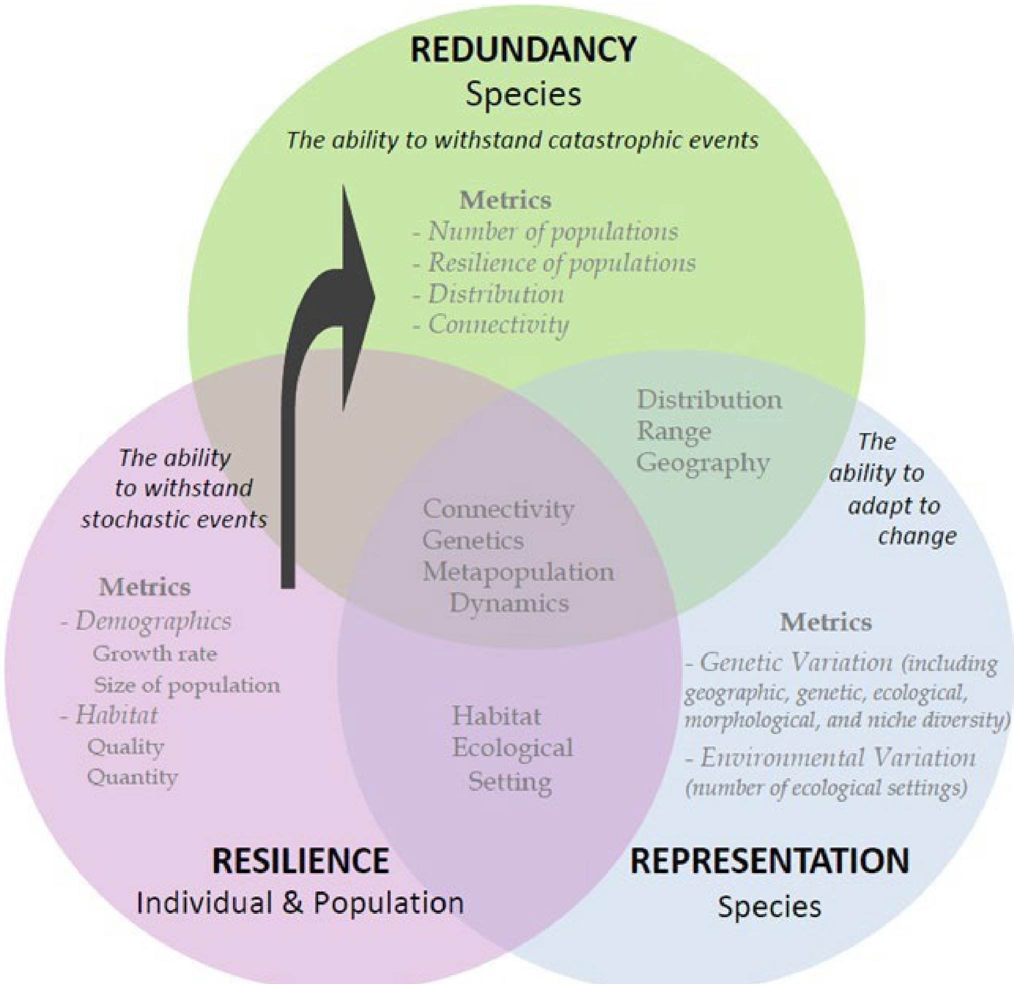

Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs".

SPECIES NEEDS / ECOLOGY

Species Description

This species was first described as *Pleomele fernaldii* by Harold St. John in 1947 (St. John 1947, pp. 39–42) and listed as Endangered under this taxonomic name (USFWS 2013, entire). The isotype was collected from the south ridge of Holopoe [Hulopoʻe] Gulch on Lānaʻi (University of Michigan Library Digital Collections 2019, entire). Otto Degener mistakenly named the species *Pleomele lanaiensis*, but did not officially publish the name (Degener and Degener 1971, p. 9). Wagner et al. (1999, p. 1352) considered *P. lanaiensis* a synonym of *P. fernaldii*.

Phylogenetic analysis of chloroplast DNA, as well as differences in floral morphology and diurnal flowering pattern, indicate that Hawaiian *Pleomele* species are a distinct group; this group has been alternatively treated as the genus *Chrysodracon* (Lu and Morden 2014, pp. 92–98), but based on new genetic analyses, *Chrysodracon* is now considered a subgenus nested within the genus *Dracaena* (Jankalski 2008, pp. 17–21; Takawira-Nyenya 2018, p. 265). Thus, the new combination for this species is *Dracaena fernaldii* in the most recent taxonomic treatment in the checklist of Hawaiian flora (Smithsonian Institution 2023, entire). This taxonomic change does not affect the range or endangered status of this species. This species will be referred as *Dracaena fernaldii* throughout the following sections of this Species Report.

Dracaena fernaldii is a tree 19 to 26 ft (6 to 8 m) tall, usually few branched. Its leaves are spirally clustered toward the ends of branches and are long and strap-like, 6.7 to 15.7 inches (in) (17 to 40 centimeters [cm]) long, 0.5 to 0.9 in (1.2 to 2.3 cm) wide, gradually tapering in the upper one-third. Panicles (branched inflorescences with hanging flowers on the second branches) are slender, slightly waxy, about 9.4 to 17.3 in (24 to 44 cm) long, the lower lateral branches about 1.9 to 4 in (5 to 10 cm) long, stalks 3.1 to 5.1 in (8 to 13 cm) long, and abruptly recurved. Flower petals are greenish-yellow and 0.9 to 1.2 in (23 to 30 millimeters [mm]) long. Berries are bright red, about 0.3 to 0.47 in (8 to 12 mm) long containing 1 to 3 seeds (Wagner et al. 1999, pp. 1351–1352).

The flowering periods for *Dracaena fernaldii* are in the spring through summer with variation observed between sites located in drier and wetter sites and dependent on if it has been a wet or dry year. Fruit has been collected in the fall season when they have matured but could be collected until January (Oppenheimer 2019, pers. comm.). A simple table displaying the fruiting and flowering cycle for this species is presented in Table 1.

Table 1. Flowering and fruiting period for *Dracaena fernaldii* (Oppenheimer 2019, pers. comm.).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
	Flowers										
Fruit								Fruit			

Since the breeding system of *Dracaena fernaldii* is unknown, we used the general study conducted by Sakai et al. (1995, p. 2524) to make inferences for this species. Sakai et al. (1995, p. 2524) studied the colonists of the flora of the Hawaiian islands to determine the breeding system of the colonist's lineage, the assumed breeding system of the colonist, the breeding system of the current species, the assumed pollinator of the colonists, and the assumed dispersal method. According to Sakai et al. (1995, p. 2524) the presumed breeding system of both the colonist and current species are monomorphic, the assumed breeding system of the colonist was hermaphroditic, and the breeding system of the current species is hermaphroditic. The assumed pollinator of the colonist was insect and the assumed original long distance dispersal method was internally by birds. Based on the results of this study, we assume that the breeding system for *Dracaena fernaldii* is hermaphroditic, thus this species is capable of both sexual and vegetative reproduction. Additionally, we assume that the fleshy fruits of this species may be dispersed internally by birds through ingestion (Figure 2).

Figure 2. Fleshy fruits of *Dracaena fernaldii* (Photo credit: Hank Oppenheimer, Plant Extinction Prevention Program).

Figure 3. Yellowish flowers of *Dracaena fernaldii* (Photo credit: Hank Oppenheimer, Plant Extinction Prevention Program).

Similarly, the large bell shaped flowers that are yellowish in color (see Figure 3) and dark colored berries tend to favor the relationship with birds for pollination and seed dispersal of *Dracaena* species (Lu 2012, p. 171).

We do not have information about how long the species' seeds remain viable or under what conditions they germinate. However, we do know that *Dracaena fernaldii* has very low seed storage potential as the seeds are recalcitrant (i.e., desiccation-sensitive [do not withstand drying for frozen storage] and not storable by conventional methods) (Chau et al. 2019, p. 12; Keir and Weisenberger 2014, p. 62). Therefore, seeds of *D. fernaldii* require alternate *ex situ* storage methods. Other life history information is currently unknown, including information on plant growth stages, longevity, and the length of time it takes to flower. The potential lifespan of *D. fernaldii* is apparently long-lived at more than 10 years.

Habitat Conditions

Historically, *Dracaena fernaldii* has been known throughout Lāna‘i on both the leeward and windward sides. Currently, *D. fernaldii* is found from Hulopo‘e and Kunoa Gulches southeast to Waiakeakua and Puhi‘elelu Ridge (St. John 1947, pp. 39–42; USFWS 2019, entire; PEPP 2008, p. 75) in two population units called Lōpā-Wai‘opa-Haua and Kapōhaku-Kaunoa- Ho‘oki‘o, which refers to the geographic reference areas they fall within (Figure 4). This species is typically found between the elevations of 1,608 to 3,051 ft (490 to 930 m) in the gulches and cliff faces of remnant dry forest, mesic forest, and mesic grassland and shrubland (Wagner et al. 1999, p. 1352; USFWS 2019, entire; National Tropical Botanical Garden 2019; Oppenheimer 2019, pers. comm.).

Dracaena fernaldii occurs on privately owned lands that were purchased by Larry Ellison in 2012 (Pūlama Lāna‘i 2019, p. 2). Pūlama Lāna‘i was established to manage, preserve, and protect the land and natural resources on Lāna‘i (Pūlama Lāna‘i 2019, p. 2). The population units are not all fenced and ungulates are still found within the fences (Oppenheimer 2019, 2022, pers. comm.). At the Lōpā-Wai‘opa-Haua population unit, the habitat types where *D. fernaldii* is found are classified as wet forest, mesic forest, and mesic grasslands and shrublands. At the Kapōhaku-Kaunoa-Ho‘oki‘o population unit, the habitat type is identified as wet forest (USFWS 2019, entire). Therefore, based on these habitat types we will be referencing the Habitat Status Assessments for wet forest (Clark et al. 2019, entire), mesic forest (Lowe et. al. 2019, entire), and mesic grasslands and shrublands (Ball et al. 2019, entire) to describe the habitat needs for this species.

Lōpā-Wai‘opa-Haua

Geospatial reference information for the population unit located at Lōpā-Wai‘opa-Haua (A in Figure 4) includes observations that were last made between 2006 and 2008. This population unit is located within soil types classified as rough mountainous land and rock outcrop. Rough mountainous land is comprised of very steep slopes with numerous drainage channels (USFWS 2019, entire; Foot et al. 1972, p. 119). The soil layer in rough mountainous land is very thin and found in the first 10 in (25 cm) of the ground layer. Rock outcrop is defined as regions that have more than 90 percent of the surface layer composed of visible bedrock (Foote et al. 1972, p. 119). Soils of rock outcrop consists of basalt and andesite (Foote et al. 1972, p. 119).

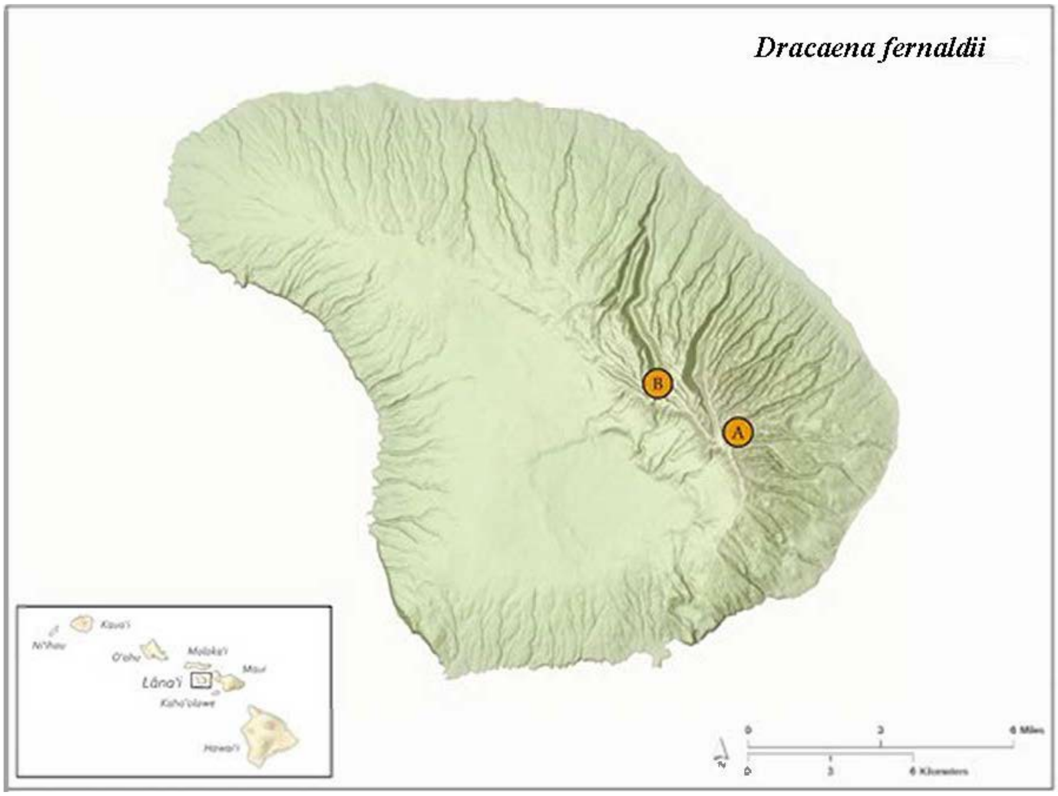

Figure 4. Distribution and Population Units of *Dracaena fernaldii* on Lānaʻi (A, refers to Lōpā-Waiʻopa-Haua, B is Kapōhaku-Kaunoa-Hoʻokiʻo; USFWS 2019, entire).

The average annual temperature is approximately 63.9 degrees F; in February the average temperature is 60.5 degrees F and in August the temperature is 67.6 degrees F. The mean annual rainfall is 29.5 in (750.5 mm). Most of the rainfall occurs during the months of November through March, with July being the driest month (1.1 in [27.88 mm]) and January being the wettest (4.2 in [105.9 mm]) (Giambelluca et al. 2014, entire).

The habitat of *Dracaena fernaldii* at Lōpā-Waiʻopa-Haua is described as a mixed mesic forest. Associated native plant species may include *Myrsine lessertiana*, *Nestegis sandwicensis*, *Metrosideros polymorpha*, and *Diospyros sandwicensis* (National Tropical Botanical Garden 2019, entire).

Kapōhaku-Kaunoa-Hoʻokiʻo

Geospatial reference information for the population unit located at Kapōhaku-Kaunoa-Hoʻokiʻo (B in Figure 4) includes observations that were last observed between 2006 and 2008. This population unit is located within soil types classified as rough mountainous land, Kahanui silty clay (3 to 20 percent slopes), and rock outcrop (USFWS 2019, entire). Rough mountainous land is comprised of very steep slopes with numerous drainage channels. The soil layer in rough mountainous land is very thin and found in the first 10 in (25 cm) of the ground layer. Rock outcrop is defined as regions that have more than 90 percent of the surface layer composed of visible bedrock. Soils of rock outcrop consists of basalt and andesite (Foote et al. 1972, p. 119).

The average annual temperature is approximately 64.7 degrees F; in February the average temperature is 61.3 degrees F and in August the temperature is 68.4 degrees F. The mean annual rainfall is 31.5 in (892.8 mm). Most of the rainfall occurs during the months of November through March, with July being the driest month (1.3 in [35.2 mm]) and January being the wettest (4.5 in [115.9 mm]) (Giambelluca et al. 2014, entire). The habitat of *Dracaena fernaldii* at Kapōhaku-Kaunoa-Hoʻokiʻo is described as wet forest (USFWS 2019, entire). Associated native plant species may include *Myrsine* spp., *Metrosideros polymorpha*, and *Dicranopteris linearis* (Oppenheimer 2019, pers. comm.).

Individual Needs

The chromosome number for *Dracaena fernaldii* is unknown.

The life cycle of *Dracaena fernaldii* is based on what is known about the species and is like most plants, seeds become seedlings, then become vegetative plants, and then flowering plants. The life stages (seed, seedlings, vegetative, and flowering plants) of *D. fernaldii* require very similar resources. At the seed stage, the seeds must be removed from the fruit that is located on the mother plant, and the seeds must be deposited onto soil. The seed needs an unknown amount of precipitation, soil, and sunlight for an unknown number of hours per day to germinate. Competition with other species (including native plants) and/or nonnative invasive species can limit seedlings, vegetative plants, and flowering plants from getting water, soil, and sunlight that they need. Vegetative and flowering plants need the same important resources such as an unknown amount of precipitation during the spring and winter months, soil, and sunlight. If all of the resource needs are met for each individual, then the populations are highly resilient.

In summary, the individual needs of *Dracaena fernaldii* include growing near gulches and cliff faces in the wet forest, mesic forest, and mesic grassland and shrubland habitats on Lānaʻi. The soil type that *D. fernaldii* may occupy is classified as rough mountainous land, rock outcrop, and Kahanui silty clay (3 to 20 percent slopes). *D. fernaldii* is a hermaphroditic species, thus it is capable of both sexual and vegetation reproduction.

Population Needs

The population structure of *Dracaena fernaldii* consists of two population units containing more than 1,000 individuals that are mostly older mature trees. A few seedlings have been observed in the wild, but these are within fenced areas protected from ungulates (Oppenheimer 2019, pers. comm.). A healthy population consists of abundant individuals within habitat patches of adequate area and quality to maintain survival and reproduction in spite of disturbance. The current wild population of *D. fernaldii* does not have a healthy population structure as it does not contain all age class stages.

Suitable habitat for *Dracaena fernaldii* occurs in the wet forest, mesic forest, and mesic grassland and shrubland habitats on the leeward and windward sides of Lānaʻi as described in the Habitat Conditions section above. The seeds of *D. fernaldii* are dispersed by frugivorous birds through ingestion. The pollinators are endemic nectar-feeding birds, the honeycreepers, and insects. With the loss of native forest birds in the lower elevations due to avian malaria and avian pox, we assume that cross pollination within and among populations is not occurring or is very limited.

Additionally, seeds of this species are no longer being dispersed by native forest birds through ingestion, though seeds may be dispersed by introduced birds (Oppenheimer 2022, pers. comm.).

HISTORIC CONDITION

Historically, in the absence of invasive species threats that arrived with human occupation of the islands, this species likely had more resilient populations. The steep gulches and ridges found on Lānaʻi would have isolated populations from each other, allowing for higher representation and redundancy within the species.

Historically, *Dracaena fernaldii* was likely pollinated by the ʻiʻiwi (*Drepanis coccinea*), a native honeycreeper that is now extinct on Lānaʻi, as well as by the ʻapapane (*Himatione sanguinea*), also a honeycreeper, which still may exist today but may no longer overlap with the range of *D. fernaldii* (Banko and Banko 2009, pp. 35-36). However, the last time ʻapapane was observed on Lānaʻi was a few years ago (Oppenheimer 2019, pers. comm.). Similarly, the likely seed dispersers of *D. fernaldii* were the olomaʻo or Molokaʻi Thrush (*Myadestes lanaiensis rutha*), a honeycreeper that is now extinct on Lānaʻi (Banko and Banko 2009, pp. 30, 35). Prior to their reduction in range and/or extinction, the pollinators and seed dispersers as identified above would have been able to maintain the connectivity between populations (representation) and maintain the range of the species (redundancy and resiliency) as one large, continuous meta-population.

Dracaena fernaldii was first described in 1947 by Harold St. John (St. John 1947, pp. 39–42). The known historic distribution and range for this species included nine locations throughout the leeward and windward areas of Lānaʻi at Puʻu Kilea, Kaiholena Ridge, Kaʻa, Kaʻena, Kānepuʻu, and Kapano Gulch (St. John 1985, p. 179; Figure 5).

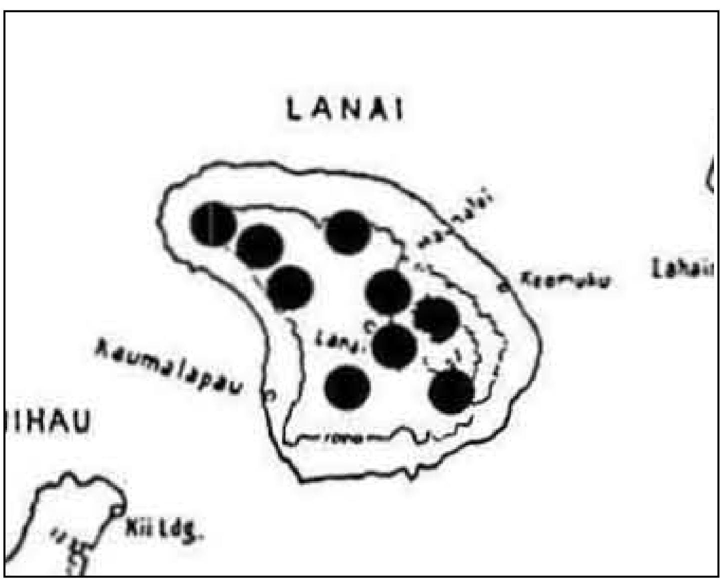

Figure 5. Historic distribution of *Dracaena fernaldii* on Lānaʻi adapted from St. John (1985, p. 189).

FACTORS INFLUENCING VIABILITY

Threats and Conservation Actions

Introduced Ungulates
Threat: Introduced axis deer (*Axis axis*) and mouflon sheep (*Ovis gmelini musimon*) are threats to *Dracaena fernaldii* because these introduced ungulates can be highly destructive to the native vegetation in the habitats suitable for the species. They also contribute to erosion by eating young trees and young shoots of plants before they can become established, creating trails that damage native vegetative cover, promoting erosion by destabilizing substrate and creating gullies that convey water, and dislodging stones from ledges that can cause rockfalls and landslides which damage vegetation below (Cuddihy and Stone 1990, pp. 63–64). Additionally, axis deer and mouflon sheep are known to consume native vegetation and thus may consume *D. fernaldii* when foraging for food, trample roots and seedlings of *D. fernaldii*, accelerate erosion in the areas occupied by this species, and promote the invasion of nonnative plants that will outcompete this species for space, water, light and nutrients (USFWS 2013, pp. 32042, 32052). Also, axis deer likely rub their antlers on the trunks of *D. fernaldii*, which could eventually kill the trees (Oppenheimer 2022, pers. comm.).

Conservation action: The two population units containing *Dracaena fernaldii* are not all fenced, and ungulates are still present within these fences (Oppenheimer 2019, 2022, pers. comm.). Therefore, individuals of *D. fernaldii* are not protected from the damaging impacts caused by feral ungulates.

Nonnative Plants
Threat: Invasive plant species are a threat to *Dracaena fernaldii* as they have the ability to compete with the species for water, space, nutrients, and light. Invasive nonnative plant species are responsible for modifying the availability of light; altering soil-water regimes; modifying nutrient cycling; altering the fire regime affecting native plant communities; and ultimately, converting native-dominated plant communities to nonnative plant communities (Smith 1985, pp. 180–181; Cuddihy and Stone 1990, p. 74; D'Antonio and Vitousek 1992, p. 73; Vitousek et al. 1997, p. 6). Some of the major invasive plant species include *Psidium cattleyanum* (strawberry guava), *Morella faya* (firetree), *Leptospermum scoparium* (tea tree), *Hedychium gardnerianum* (Himilayan ginger), *Melinis minutiflora* (molasses grass), *Miconia crenata* (Koster's curse), *Cinnamomum burmanii* (padang cassia), *Tibouchina herbacea* (cane tibouchina), and *Rubus rosifolius* (thimbleberry) (PEPP 2008, p. 75; Oppenheimer 2019, 2022, pers. comm.).

Conservation action: The Maui Nui Plant Extinction Prevention Program controls invasive plant species around individuals of *Dracaena fernaldii* within the Lōpā-Wai‘opa-Haua population unit only (Oppenheimer 2019, pers. comm.). Pūlama Lāna‘i also controls invasive plants in upper ‘Āwehi Gulch (Oppenheimer 2022, pers. comm.).

Drought
Threat: Dracaena fernaldii may be directly affected by drought and its habitat may also be affected by droughts, which are not uncommon in the Hawaiian Islands (Oppenheimer 2019, pers. comm.). Drought causes the direct loss of individuals due to death. In addition, drought causes the loss or degradation of habitat due to death of individual native plants, as well as an

increase in forest and brush fires. Additional information related to the stressors of drought to the mesic forest and mesic grassland and shrubland habitats as it relates to changes in water availability and vegetation composition can be found in Lowe et al. 2019 (p. 14) and Ball et al. 2019 (p. 14–15). These threats are serious and have the potential to occur at any time, although their occurrence is not predictable.

Conservation action: none.

<u>Fire</u>
Threat: Dracaena fernaldii is at risk of the negative impacts by fire because individuals of this species or its habitat are located in or near areas that were burned in previous fires (USFWS 2013, pp. 32044, 32049). The threat from fire is serious and ongoing because fire damages and destroys native vegetation, including dormant seeds, seedlings, and juvenile and adult plants (D’Antonio and Vitousek 1992, pp. 70, 73–74; Tunison et al. 2002, p. 122).

In addition, fire is a threat to the mesic forest and mesic grassland and shrubland habitats occupied by this species. Direct and indirect consequences of fire to the mesic forest and mesic grassland and shrubland habitats can be found in the respective Habitat Status Assessments (Lowe et al. 2019, pp. 16–17; Ball et al. 2019, pp. 16–17). As a result of fire, many nonnative invasive plants, particularly fire-tolerant grasses, outcompete native plants and inhibit their regeneration. Successive fires that burn farther and farther into native habitat destroy native plants and remove habitat for native species by altering microclimatic conditions and creating conditions favorable to nonnative plants. The threat from fire is unpredictable but is increasing in frequency in ecosystems that have been invaded by nonnative, fire-prone grasses (Lowe et al. 2019, pp. 16–17; Ball et al. 2019, p. 17).

Conservation action: none.

<u>Hurricanes</u>
Threat: Hurricanes destroy native vegetation and habitat for *Dracaena fernaldii* by opening the canopy and thus modifying the availability of light, and creating disturbed areas conducive to invasion by nonnative pest species. Gaps in the canopy also allow for the establishment of nonnative plants, which may be present as plants or as seeds incapable of growing under shaded conditions (USFWS 2013, p. 32045). Because *D. fernaldii* persists in relatively low numbers and in restricted ranges, natural disasters, such as hurricanes, are particularly devastating to this species.

Conservation action: none.

<u>Rats</u>
Threat: Introduced rats (*Rattus* spp.) are a threat to this species (USFWS 2013, p. 32053). Plants with fleshy fruits are particularly susceptible to rat predation, including *Dracaena fernaldii*. Rats impact native plants by eating seeds, flowers, leaves, roots, and other plant parts (Atkinson and Atkinson 2000, p. 23), and can seriously affect regeneration.

Conservation action: Rat control conducted and maintained by Pūlama Lānaʻi, which occurs near populations of seabirds, other rare plants, and tree snails in areas also occupied by individuals of *Dracaena fernaldii* benefit this species (Oppenheimer 2019, 2022, pers. comm.).

Regeneration
Threat: Lack of, or low levels of, regeneration (reproduction and recruitment) in the wild has been observed and is a threat to *Dracaena fernaldii* (USFWS 2013, p. 32059; Oppenheimer 2019, pers. comm.). Although there are currently approximately several hundred to 1,000 individuals, very little recruitment has been observed at the known locations over the past 10 years (Oppenheimer 2008, pers. comm.). Recently, seedlings of *D. fernaldii* have only been observed at one site which has been protected from ungulates (Oppenheimer 2019, pers. comm.).

Conservation action: none.

Loss of Native Pollinators and Seed Disperser Agents
Threat: Loss of native pollinators (affecting seed set) and seed disperser agents are a threat to *Dracaena fernaldii* (Oppenheimer 2019, pers. comm.). Although, *Dracaena fernaldii* is regularly observed with viable seed during sporadic monitoring by field botanists, the loss of native nectar-feeding birds that aid in pollination and seed dispersal may have contributed to the decline of this species (Oppenheimer 2022, pers. comm.). Many native nectar-feeding passerine birds, which have acted as pollinators have become extinct or declined drastically from historic levels. This is largely caused by avian malaria, the most important avian disease affecting the native forest birds of Hawaiʻi. For the most part avian malaria has restricted these native forest birds to the upper elevations, where average temperatures are too cold for mosquitoes (which are the vectors of avian malaria), and *Plasmodium relictum* (the parasite that causes avian malaria) to persist. With an increase in avian malaria at higher elevations, it is likely that most or all of the bird-pollinated species could be lost if the birds are lost to these or other threats.
Conservation action: none.

Climate Change
Threat: Changes in environmental conditions that may result from global climate change include increasing temperatures, decreasing precipitation, and increasing storm intensities (Intergovernmental Panel on Climate Change (IPCC) 2014, pp. 6–11). The consequent impacts on *Dracaena fernaldii* are related to changes in microclimatic conditions in the species habitat. These changes may lead to the loss of native species associated in this species habitat due to direct physiological stress, the loss or alteration of habitat, or changes in disturbance regimes (e.g., droughts, fire, storms, and hurricanes).

Increased inter-annual variability of ambient temperature, precipitation, and hurricanes would provide additional stresses on the habitat and to this species because *Dracaena fernaldii* is highly vulnerable to disturbance and related invasion of nonnative species. The probability of this species to go extinct as a result of such factors increases when its range is restricted, habitat decreases, and population numbers decline (IPCC 2014, pp. 6–11). Currently, *D. fernaldii* already has limited environmental tolerances, ranges, and small population sizes. Therefore, we would expect this species to be particularly vulnerable to projected environmental impacts that may result from changes in climate and subsequent impacts to its habitat (e.g., Pounds et al. 1999, pp. 611-612; Benning et al. 2002, pp. 14246–14248, Giambelluca et al. 2008, pp. 13–18).

Additionally, Fortini et al. (2013, pp. 85, 96) conducted a landscape-based assessment of climate change vulnerability for native plants of Hawaiʻi using high resolution climate change projections. Climate change vulnerability is defined as the relative inability of a species to display the possible responses necessary for persistence under climate change. The assessment concluded that *Dracaena fernaldii* is highly vulnerable to the impacts of climate change with a vulnerability score of 0.969 (on a scale of 0 being not vulnerable to 1 being extremely vulnerable to climate change). In addition, this species has no overlap between current and future climate envelopes and is unlikely to tolerate expected changes in climate at its current location. This limitation means this species must either endure in suitable microrefugia within its current envelope or move to newly available climate-compatible areas to avoid extinction.

Conservation action: none.

<u>General Conservation Actions</u>
Monitoring of *Dracaena fernaldii* has occurred as recently as April of 2019 (Oppenheimer 2019, pers. comm.). Since this species is not on the PEP Program's priority list as there are more than 50 individuals in the wild, monitoring of this species occurs sporadically. Therefore, other sites containing individuals of *D. fernaldii* has not been revisited for more than 10 years (Oppenheimer 2019, pers. comm.).

There are no seeds in seed storage for *Dracaena fernaldii*. As mentioned in the Species Needs / Ecology Section above, the seeds of this species are recalcitrant and cannot be stored using conventional seed banking methods (Chau et al. 2019, p. 12; Keir and Weisenberger 2014, p. 62). There are no plants growing in rare plant nurseries serving as living collections for *D. fernaldii*. Seeds collected in January of 2019 by the PEP Program has been given to the staff of Pūlama Lānaʻi for propagation at their nursery (Oppenheimer 2019, pers. comm.). The status on whether these seeds have germinated is unknown.

CURRENT CONDITION

Description
In 1999, *Dracaena fernaldii* was known from three populations totaling 200 to 2,000 individuals (USFWS 2005, p. 2; Oppenheimer 2008, pers. comm.). In 2008, there were several dozen individuals observed within the Kapōhaku-Kaunoa-Hoʻokiʻo population unit; however, the entire population unit was not surveyed (PEPP 2008, p. 75). When this species was listed in 2013, there were several hundred to perhaps as many as 1,000 individuals (USFWS 2013, p. 32025). Currently, that total estimate still stands; there are more than 1,000 wild individuals of *D. fernaldii* (Oppenheimer 2019, pers. comm.). However, very little recruitment has been observed at these remaining populations (Oppenheimer 2008, pers. comm.; Oppenheimer 2019, pers. comm.).

There are no confirmed reintroductions for this species (Oppenheimer 2019, pers. comm.). Overall, the number of wild individuals of *Dracaena fernaldii* is decreasing. The distribution of *D. fernaldii* has shrunk as it is no longer as widely distributed across the island as it was in the past. The species is no longer found in the lower elevations and dry forest habitats. With the loss of these historic populations, there are now only two population units of *D. fernaldii* found on Lānaʻi indicating a highly reduced range, and loss of redundancy and representation.

The diversity of habitats occupied by this species has been reduced when compared to those occupied in the past; it is no longer found within the dry forest habitat (USFWS 2019, entire). The current condition of the wet forest habitat type can be found in the Hawaiian Islands Wet Forest Habitat Status Assessment report by Clark et al. (2019, pp. 7–9). In summary, the quality of the native wet forest habitat type in the current condition has declined as a result of feral ungulates, residential and agricultural development, invasion of nonnative plant species, and fragmentation due to agricultural practices for food crops (Clark et al. 2019, pp. 9–11). Similarly, the extent and range of the native wet forest habitat type has not changed in the current condition, except for the lowland wet forest habitat type which has declined substantially (Clark et al. 2019, p. 7).

Because of these factors, currently the amount of suitable habitat located in the native wet forest habitat type that can be occupied by *Dracaena fernaldii* is limited in size and highly degraded. Therefore, there is less suitable habitat for this species to currently occupy and persist, in addition to dealing with threats from introduced ungulates, invasive plants, drought, fire, rats, lack of regeneration, and loss of native pollinators and seed disperser agents.

Suitable habitat for *Dracaena fernaldii* occurs in the wet forests, mesic forest, and mesic grassland and shrubland on the leeward and windward sides of Lānaʻi as described in the Habitat Conditions section above. Seeds of *D. fernaldii* are dispersed internally by birds through ingestion and pollinated by native honeycreepers. With the loss of native forest birds due to avian malaria and avian pox, we assume that cross pollination within and among populations is not occurring or is very limited. Additionally, seeds of this species are no longer being dispersed by native forest birds through ingestion; therefore, seeds drop and germinate not too far from their parent plants. Though, introduced birds could possibly disperse the seeds of these species into other habitats. The ability for this species to occupy a wide range of habitats is dependent on its seed disperser agent, which are very few in numbers or not existent.

Resiliency

Resiliency is the capacity of a population (or a species) to withstand stochastic disturbance events. We define resiliency for *Dracaena fernaldii* based on the metric of population size. For *Dracaena fernaldii* to maintain viability, the population must be resilient, meaning they must have healthy, stable populations and good quality and quantity of habitat. We determined resiliency for *D. fernaldii* based on the metric of the number of populations for this species. Populations are resilient if there are large number of populations with abundant individuals. This species has gone through reductions in its range (scarcely found within the dry forest) and declines in the number of populations and individuals in recent times. Currently, there are only two population units of *D. fernaldii* known containing more than 1,000 wild individuals. There is no population structure for this species; only old mature trees are known. In addition, low to lack of regeneration has been noted for this species. Very few seedlings have been observed in the wild and have only been found in places where they are protected from ungulates. Therefore, our evaluation of resilience of the population (for both population units) and the species level is <u>low</u>.

Redundancy

We define redundancy for *Dracaena fernaldii* based on the metrics of the number of populations, resilience of populations, and the distribution of the species across its range. Currently, there are only two known population units for this species. The distribution of this species has narrowed and is now confined to the native wet forest, mesic forest, and mesic grassland and shrubland habitats on east Lānaʻi. Also, the species range has shrunk with the loss of or very few individuals found within the dry forest habitat. The resiliency on both the species and population levels are low in the current condition. Therefore, the evaluation of redundancy is <u>very low</u> in the current condition. The narrow distribution of this species and limited numbers of individuals makes it vulnerable to withstand catastrophic events.

Representation

Representation is defined as unique traits represented throughout multiple populations across the range of the species. We can measure representation based on the genetic diversity and habitat variation within and among populations. Using the best available scientific data, there are no differences in species morphology and genetic diversity. In the Habitat Conditions section above, we assessed that there are no differences in the habitats occupied by *Dracaena fernaldii.* Genetic diversity is slightly secured throughout the range of the species, as there are two known wild population units, but these units are vulnerable to catastrophic events. The remaining population units are likely fragmented both physically (due to extensive habitat degradation), and functionally (due to the loss of pollinators and possibly dispersal agents). Therefore, the evaluation of representation is <u>low</u> in the current condition.

Species Viability Summary

On the population level, *Dracaena fernaldii* has low resiliency and on the species level it has low redundancy and representation; therefore, the overall viability of this species is <u>low</u> in the current condition (Table 2). Redundancy and representation are not maintained in *ex situ* seed storage facilities, rare plant nurseries, or in reintroduced populations as none of these actions have been conducted for this species. Therefore, these cannot be considered in the current viability assessment for this species.

Table 2. Current viability of *Dracaena fernaldii.*

The 3Rs	**Resiliency**	**Redundancy**	**Representation**	**Overall Viability**
Current Condition	Low	Very low	Low	Low

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