Species Report for *Santalum involutum* (‘iliahi)
Version 1.0



*Santalum involutum* at the Nā Pali Coast.
Photo Credit: Kenneth R. Wood, National Tropical Botanical Garden

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U.S. Fish and Wildlife Service (USFWS). 2022. Species Report for *Santalum involutum* (‘iliahi). Version 1.0. Pacific Islands Fish and Wildlife Office, Pacific Islands Interior Region 12, Portland OR. 24 pages.

## EXECUTIVE SUMMARY

This Species Report for *Santalum involutum* was completed to assess the species' overall viability. To assess viability we used the three conservation biology principles of resiliency, representation, and redundancy. We identified the species' ecological requirements for survival and reproduction at the individual, population, and species levels, and described risk factors influencing the species' current condition.

*Santalum involutum* (ʻiliahi) is a shrub to small tree in the sandalwood family (Santalaceae) found on the island of Kauaʻi (Harbaugh et al. 2010, pp. 827–838; USFWS 2016a, p. 67806). This species is currently restricted to steep slopes along the western Nā Pali coast valleys and ridges, but was historically known to have a broader distribution which includes several sites around the northern, southern, and western regions of Kauaʻi (Wood 2015, p. 1). DNA evidence reveals that *Santalum involutum* may be of ancient hybrid origin between the white- and red-flowered Hawaiian *Santalum* clades (Harbaugh et al. 2010, entire).

The main threats to *Santalum involutum* are habitat modification and destruction by feral ungulates, habitat modification and competition by nonnative plants, fire, limited numbers of individuals and populations, climate change, inadequate regulatory mechanisms, herbivory by feral ungulates, rodents (USFWS 2016a, p. 67806) and slugs, and landslides (Wood 2015, p. 6). Conservation actions include three collections of seeds in 2014 and 2015, propagation of 18 individuals from the December 2015 seed collection (Wood 2015, pp. 12–13; NTBG 2015), and translocation of a single wild plant to Limahuli Gardens and Preserve (NTBG 2019).

Resiliency within a population is defined as a population that will show enough reproduction and recruitment to maintain or increase the numbers of individuals in the population giving the population the ability to withstand stochastic disturbance events. We can measure resiliency for *Santalum involutum* based on the metric of population size and recruitment. Redundancy is having more than one resilient population distributed across the landscape increasing the ability of a species to withstand catastrophic events. We evaluated redundancy for *S. involutum* based on the metrics of the number of populations, resilience of populations, and the distribution of the species across its range. Representation is defined as genetic and ecological diversity secured 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.

Currently, there are three known wild populations of *Santalum involutum* comprised of five sites in Kalalau, Pōhakuao, Waiolaa, Hanakoa, and Hoʻolulu, totaling five individuals. The limited geographic range, low amount of known populations, and very low number of individuals at each population have compromised the viability of *S. involutum* in the current condition. In the current condition, the overall viability of this species is very low, as we evaluated resiliency, redundancy, and representation as very low.

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## INTRODUCTION

*Santalum involutum* (ʻiliahi) is a shrub to small tree in the sandalwood family (Santalaceae) found on the island of Kauaʻi (Harbaugh et al. 2010, pp. 827–838; USFWS 2016a, p. 67806). This species is currently restricted to steep slopes along the western Nā Pali coast valleys and ridges, but was historically known to have a broader distribution which includes several sites around the northern, southern, and western regions of Kauaʻi (Wood 2015, p. 1). Hawaiʻi: Mesic Forest habitat status assessment (which includes lowland mesic forest and montane-subalpine mesic forest) (Lowe et al. 2020, entire) and the Hawaiʻi: Mesic Grasslands and Shrublands habitat status assessment (which includes lowland mesic shrubland, lowland mesic grassland, montane-subalpine mesic grassland, and subalpine mesic shrubland) (Ball et al. 2020, entire), should be referred to for further description and discussion on mesic forest and shrubland and the threats to these habitats on Kauaʻi.

### Species Report Overview

This Species Report summarizes the biology and current status of *Santalum involutum* and was conducted by Pacific Islands Fish and Wildlife Office. It is a biological report that 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, it will serve as a living document and biological foundation of other documents such as recovery plans, status in biological opinions, and 5-year reviews.

### Regulatory History

*Santalum involutum* was listed as endangered under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), as amended (ESA) on September 30, 2016 (USFWS 2016a (81 FR 67786–67860)). The recovery outline for the Hawaiian multi-island species was published on August 3, 2020 and included *S. involutum* (USFWS 2020). All federal regulatory information can be found at the following link: https://ecos.fws.gov/ecp/species/9609

### 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. To the best of our ability we use the current taxonomy at the time this report was drafted.

To assess the current status and viability of *Santalum involutum*, 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 *S. involutum* using this definition. The Hawaiʻi and Pacific Plants Recovery Coordinating Committee (HPPRCC) 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.

**Species Viability**

The Species Report assesses the ability of *Santalum involutum* 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 *S. involutum*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 1; USFWS 2016b, entire). We will evaluate the viability of a 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. Resilient 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 *Santalum involutum.*

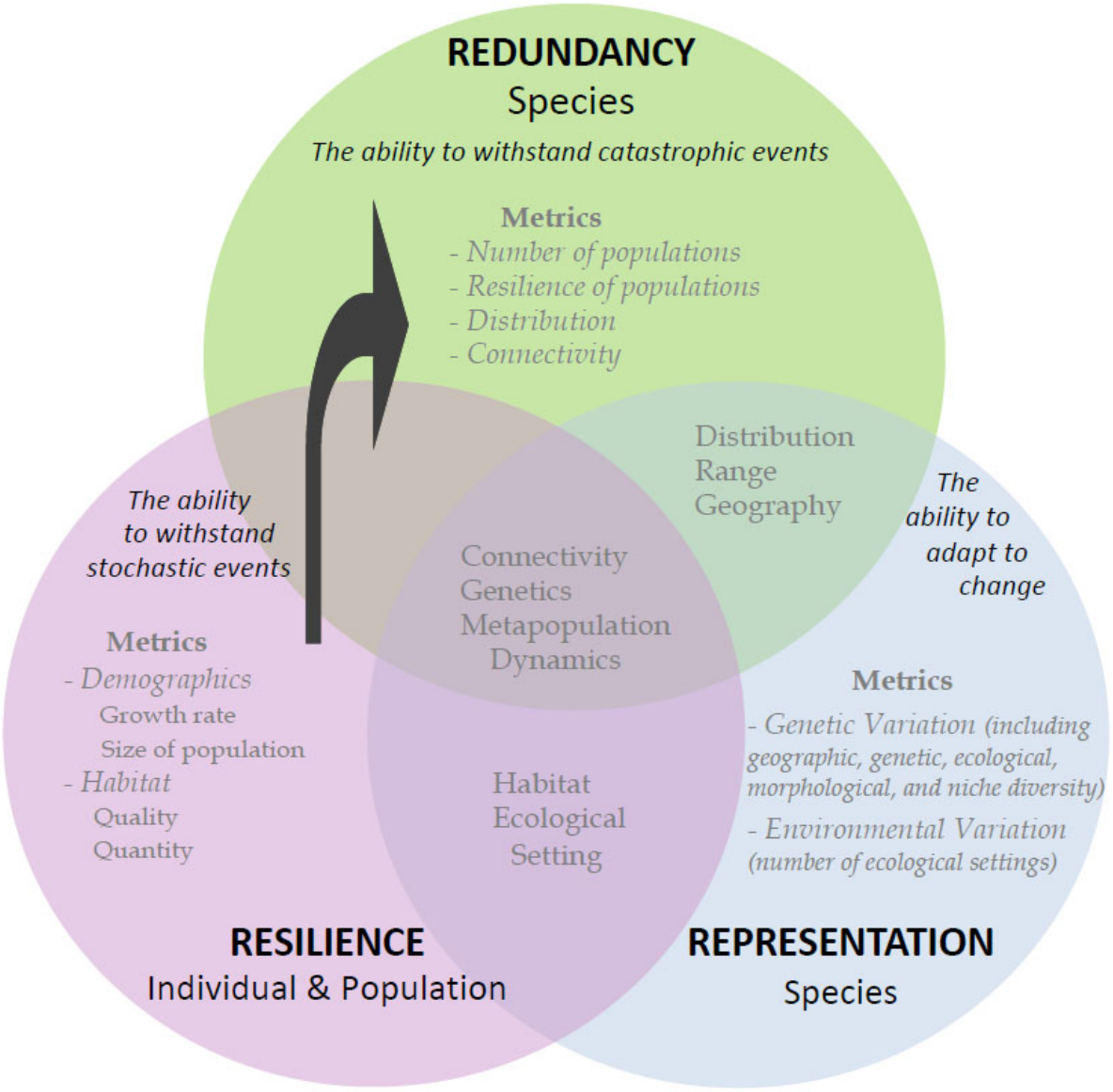



Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs".

## SPECIES ECOLOGY

### Species Description

*Santalum involutum* (ʻiliahi) is a shrub to small tree in the sandalwood family (Santalaceae) found on the island of Kauaʻi (Harbaugh et al. 2010, pp. 827–838; USFWS 2016a, p. 67806) (Figure 2). Trees range from 6 to 33 feet (ft) (2 to 10 meters [m]) tall with the tree trunks ranging a black-brown to a dark brown color with a brown-red tinge. This species is well-branched with stems being lax and of a red-brown color; leaves are medium green to light green. The corolla ranges in color from cream to white-green and turns to a reddish color with age (Figure 3A).

Fruits are red to purple. During various site visits flowers were present in February and fruits were present from January to April (Wood 2015, pp. 10–13).

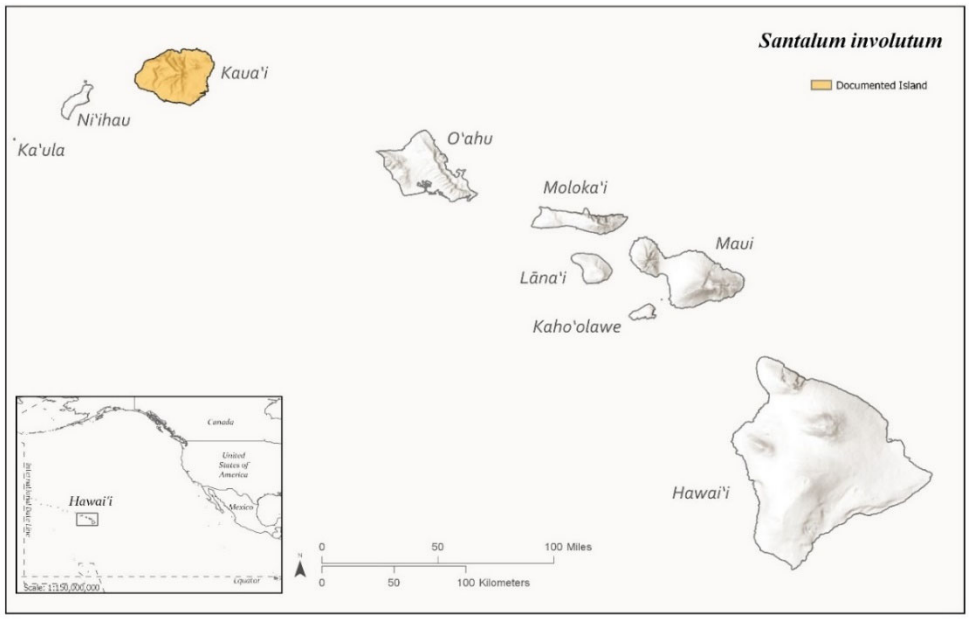



Figure 2. Map of the Hawaiian Islands showing from which islands *Santalum involutum* is known.

Revisionary studies in the Hawaiian red-flowered sandalwoods which were based on molecular data and supported by morphological analysis were conducted by Harbaugh et al. (2010, entire) resulting with several taxonomic changes. Six species with four varieties of *Santalum* in Hawai‘i were recognized where previously there were only four recognized species with five varieties (Wagner et al. 1999, pp. 1218–1223). Species in Hawai‘i are considered to be the result of two colonization events, which include four species and two varieties within the red-flowered section *Solenantha* Tuyama (i.e., *Santalum freycinetianum* Gaudich., *S. haleakalae* Hillebr. var. *haleakalae*, *S. haleakalae* var. *lanaiense* (Rock) Harbaugh, *S. involutum* H. St. John, and *S. pyrularium* A. Gray); along with two species with two varieties from the white-flowered section *Hawaiiensia* Skottsb. (i.e., *S. ellipticum* Gaudich., *S. paniculatum* Hook. & Arn. var. *paniculatum*, and *S. paniculatum* var. *pilgeri* (Rock) Stemmerm.). *Santalum freycinetianum* as currently described is restricted to O‘ahu as the previously recognized variety *pyrularium* was elevated to species and restricted to Kaua‘i. In addition, *S. involutum* was resurrected from *S. pyrularium* to the species level (Harbaugh et al. 2010, entire; Wood 2015, p. 2).

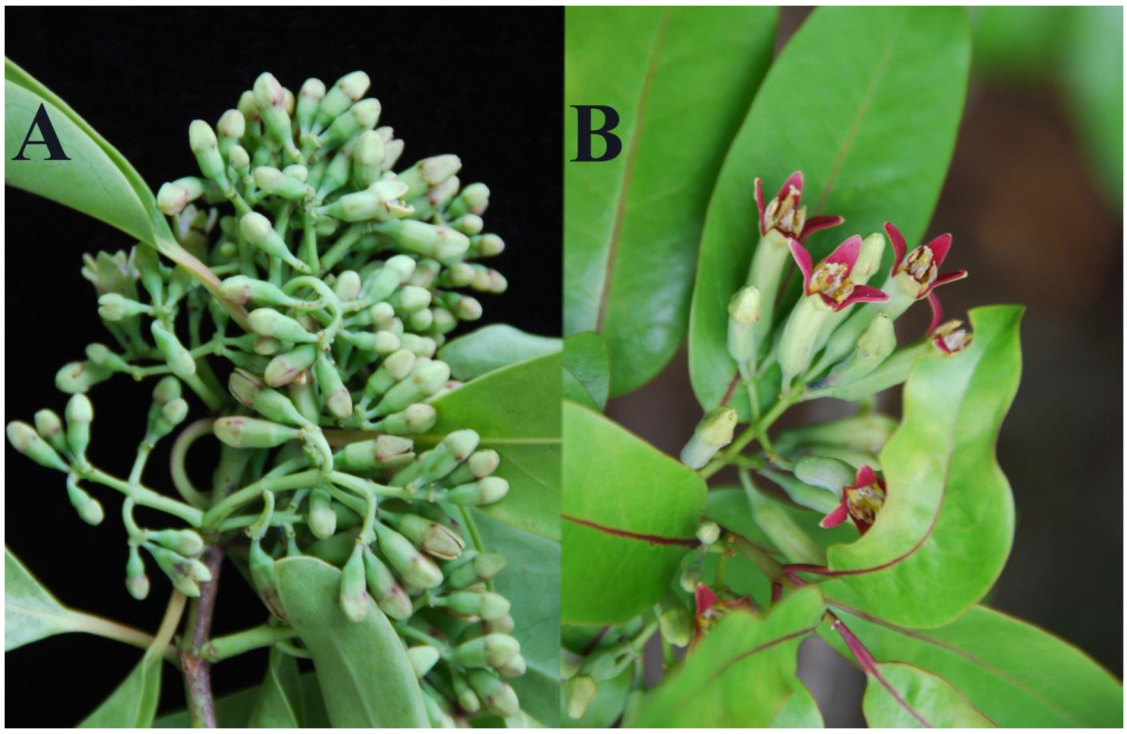



Figure 3. A. Flowers of *Santalum involutum* and B. *S. pyrularium* (Wood 2015, p. 3).

*Santalum involutum* and *S. pyrularium* are both endemic to Kauaʻi . These species are genetically distinct from each other and phylogenetic evidence, utilizing both nrDNA and cpDNA data, indicates that *S. pyrularium* (Figure 3B) has evolved from a separate colonization event belonging to the previously mentioned red-flowered clade, whereas *S. involutum* is more closely related to the white-flowered *S. ellipticum* clade. *Santalum involutum* may be of ancient hybrid origin between the white- and red-flowered Hawaiian *Santalum* clades (Harbaugh et al. 2010, entire). Morphologically, *S. involutum* differs from the more common *S. pyrularium* in its shorter campanulate, white to greenish flowers (occasionally purple-red), and its weeping habit with involuted (in-rolled) leaves (Harbaugh et al. 2010, entire; Wood 2015, p. 2).

**Individual Needs**

Our understanding of the life history of *Santalum involutum* is limited. The life stages (seeds, seedlings, immature plants, and flowering plant) of *S. involutum* may likely require similar resources. Habitats where populations occur receive 66 to 95 inches (in) (1,666 to 2,421 millimeter [mm]) of annual rainfall (Wood 2015, pp. 10–13; NTBG 2017). Competition with other species (including native plants) and/or nonnative invasive species can limit seedlings, immature plants, and flowering plants from getting water, soil, and sunlight that they need.

*Santalum involutum* has been historically observed around lowland *Acacia* (koa) and/or *Diospyros* (lama) mesic forests and exposed ridges of Waipā, Wainiha, and Hanakāpīʻai (northern Kauaʻi) (Wood 2015, pp. 10–13). A new population was observed in the mesic shrubland habitat of Hoʻolulu in 2017 (NTBG 2017). Currently, *S. involutum* is only known to occur along the northwestern Nā Pali coast valleys and ridges of Hanakoa and Waiolaa, Kalalau, and Pōhakuao, and the mesic shrubland of Hoʻolulu. *Santalum involutum* occurs in lowland

mesic forest dominated by *Diospyros* spp. (lama), *Metrosideros polymorpha* (ʻōhiʻa), and/or *Acacia koa* (koa) and in mesic shrubland dominated by *Diospyros* spp. (lama) and *Nestegis* spp. (olopua). The National Tropical Botanical Garden (NTBG) botanists have also observed individuals around steep mesic ridges dominated by matting ferns of *Dicranopteris linearis* (uluhe) and *Diplopterygium pinnatum* (uluhe lau nui) (Wood 2015, pp. 10–13; NTBG 2017).

Tree species associated with *Santalum involutum* in lowland forest and shrubland communities of the Nā Pali coast include combinations of the following: *Acacia koa* (koa), *Antidesma platyphyllum* (hame), *Bobea elatior* (ʻahakea), *Chrysodracon aurea* (halapepe), *Coprosma waimeae* (pilo), *Diospyros sandwicensis* (lama), *D. hillebrandii* (lama), *Dodonaea viscosa* (ʻaʻaliʻi), *Elaeocarpus bifidus* (kalia), *Flueggea neowawraea* (mēhamehame), *Ilex anomala* (kāwaʻu), *Kadua affinis* (manono), *Melicope clusiifolia* (alani), *Metrosideros polymorpha* var. *glaberrima* (ʻōhiʻa), *Nestegis sandwicensis* (olopua), *Ochrosia kauaiensis* (hōlei), *Pandanus tectorius* (haha), *Pisonia sandwicensis* (kaulu), *Pittosporum glabrum* (hōʻawa), *Planchonella sandwicensis* (kaulu), *Pritchardia napaliensis* (loulu), *Psychotria greenwelliae* (kōpiko), *P. mariniana* (kōpiko), *Psydrax odorata* (alaheʻe), *Pteralyxia kauaiensis* (kaulu), *Pteridium aquilinum* subsp. *decompositum* (kilau) *Rauvolfia sandwicensis* (hao), Syzygium *sandwicensis* (pāʻihi), *Wilkesia gymnoxiphium* (iliau), *Wikstroemia oahuensis* (akia), *Xylosma hawaiiense* (aʻe), and *Zanthoxylum dipetalum* (kāwaʻu) (Wood 2015, pp. 10–13; NTBG 2017).

Shrubs, herbs, and vines of these habitats where *Santalum involutum* occur include *Artemisia australis* (hinahina), *Bidens sandwicensis* (koʻokoʻolau), *Dianella sandwicensis* (ʻukiʻuki), *Dubautia microcephala* (naʻenaʻe), *Euphorbia celastroides* var. *hanapepensis* (ʻakoko), *E. eleanoriae* (ʻakoko), *Freycinetia arborea* (ʻieʻie), *Kadua flynnii* (manono), *Leptecophylla tameiameiae* (pūkiawe), *Lipochaeta* spp. (nehe), *Lobelia niihauensis* (Niʻihau lobelia), *Peucedanum sandwicensis* (makou), *Santalum freycinetianum* (ʻiliahi), and *Scaevola procera* (naupaka) (Wood 2015, pp. 10–13; NTBG 2017).

Fern species that co-occur with *Santalum involutum* include *Cibotium nealiae* (hapuʻu), *Dicranopteris linearis* (uluhe), *Diplazium sandwichianum* (hōʻiʻo), *Diplopterygium pinnatum* (uluhe lau nui), *Doodia* kunthiana (pāmoho), *Nephrolepis exaltata* var. *hawaiiensis* (kupukupu), and *Sphenomeris chinensis* (palaʻa). Grasses and sedges that are associated with *S. involutum* include *Carex meyenii, C. wahuensis, Eragrostis variabilis* (ʻemoloa), and *Panicum lineale* (hākonakona) (Wood 2015, pp. 10–13; NTBG 2017).

Individuals of *Santalum involutum* were found between 804 to 3,264 ft (245 to 995 m) on moderate to steep slopes (58 to 119 percent slopes) (Wood 2015, pp. 10–13; NTBG 2017). Soil type consists of rough mountainous land (Foote et al. 1972, p. 119). We can assume that these habitat characteristics are required for individuals to grow and become reproductive.

**Population Needs**

A resilient population is an interconnected, healthy population with enough high quality habitat to maintain survival and reproduction in spite of disturbance. To be resilient, *Santalum involutum* would need a large number of individuals in close proximity to ensure pollination (out-crossing) within and among populations. Suitable habitat for *Santalum involutum* is based on known locations of the species. Lowland mesic forest habitat is relatively stable to decreasing in size

and quality as threats are present (Lowe et al. 2020, pp. 8–22) and mesic grasslands and shrublands are decreasing in size and species diversity as threats are present (Ball et al. 2020, pp. 2–3) as described below in the Factors Influencing Viability Section.

**Species Needs and Ecology**
In order for a species to be redundant and represented, it would need to have multiple populations occurring throughout the known range of the species, representing all known ecological and genetic diversity.

Redundancy is having multiple resilient populations distributed across the landscape to withstand catastrophic events, thereby minimizing the risk of extinction of the species. We are using the metrics of the number of resilient populations and the species distribution across the landscape to measure redundancy of *Santalum involutum*. There are 5 known wild individuals of *S. involutum* at five sites representing three populations within a 1.23 square mile area.

Representation is having more than one resilient population of a species representing all ecological and genetic diversity within the species, and occupying the full range of habitat types used by the species, thereby, sustaining the species' ability to adapt to change. We evaluated representation of *Santalum involutum* on how many resilient populations occupy the known ecological variation found at populations, in lieu of no known morphological or genetic variation of individuals among populations. This species occur in two habitat types, lowland mesic forest and mesic shrubland.

## FACTORS INFLUENCING VIABILITY

**Threats**
The immediate and potential threats to the viability of *Santalum involutum* include the habitat modification and destruction by feral ungulates, habitat modification and competition with nonnative plants, fire, limited numbers of individuals and populations, climate change, inadequate regulatory mechanisms, herbivory by introduced ungulates, rodents (USFWS 2016a, p. 67806; USFWS 2020, p. 12) and slugs, and loss of substrate due to either or both landslides or flooding (Wood 2015, p. 6). Further discussion on the impacts these threats have to mesic forest and shrubland habitats can be found in Hawai‘i: Mesic Forests habitat status assessment (Lowe et al. 2020, pp. 13–17) and the Hawai‘i: Mesic Grasslands and Shrublands habitat status assessment (Ball et al. 2020, pp. 12–16).

*Herbivory by rodents and slugs*
Herbivory on fruits and seeds by rats (*Rattus* spp.) negatively affects the remaining individuals of *Santalum involutum* (Wood 2015, p. 6; USFWS 2016a, p. 67806; USFWS 2020, p. 12). Rats impact native plants by eating seeds, flowers, leaves, roots, and other plant parts, and can substantially affect regeneration (Atkinson and Atkinson 2000, p. 23). Herbivory by nonative slugs is a threat to populations of *S. involutum* (Wood 2015, p. 6). Slugs are known to consume leaves, stems, flowers, including entire seedlings and new vegetative growth (USFWS 2016a, p. 67841; USFWS 2020, p. 12).

*Herbivory and habitat modification and destruction by introduced ungulates*

Introduced pigs (*Sus scrofa*), goats (*Capra hircus*), and Columbian black-tailed deer (*Odocoileus hemionus columbianus*) are a threat to the ecosystems known to support *Santalum involutum* (Wood 2015, p. 6; USFWS 2016a, pp. 67806, 67836–67837; USFWS 2020, p. 12). The effects of these nonnative animals include the destruction of vegetative cover, herbivory and trampling of plants and seedlings, soil disturbance, dispersal of alien plant seeds on hooves and coats and through the spread of seeds in feces, and creation of open, disturbed areas conducive to further invasion by nonnative pest plant species (Cuddihy and Stone 1990, p. 94). All of these impacts lead to the subsequent conversion of native plant communities to plant communities dominated by nonnative species.

*Habitat modification and competition with invasive plants*
Nonnative plants are a threat to the mesic forest and shrubland habitats that support *Santalum involutum* (Ball et al. 2020, pp. 12–13; Lowe et al. 2020, p. 14). Invasive plants observed to threaten habitat include *Adiantum hispidulum* (rough maidenhair fern), *A. raddianum* (Delta maidenhair ferm), *Ageratina riparia* (creeping croftonweed), *Andropogon glomeratus* (bushy breadgrass), *Buddleja asiatica* (dog tail), *Elephantopus mollis* (tobacco weed), *Erigeron karvinskianus* (Mexican daisy), *Hedychium gardnerianum* (kahili ginger), *Kalanchoe pinnata* (air plant), *Lantana camara* (lantana), *Melia azedarach* (chinaberry tree), *Melinis minutiflora* (molasses grass), *Miconia crenata* (Koster's curse), *Nephrolepis multiflora* (Asian swordfern), *Oplismenus hirtellus* (basketgrass), *Paspalum conjugatum* (Hilo grass), *Plantago lanceolata* (ribwort), *Pluchea carolinensis* (sourbush), *Psidium guajava* (common guava), *Rubus argutus* (blackberry), *R. rosifolius* (thimbleberry), *Setaria parviflora* (marsh bristlegrass), *Spathoglottis plicata* (ground orchid), *Sphaeropteris cooperi* (Australian tree fern), *Sporobolus indicus* (smut grass), *Stachytarpheta jamaicensis* (Jamaica vervain), and *Thelypteris dentata* (downy maiden fern) (Wood 2015, pp. 10–13; NTBG 2017). These alien plant species modify the availability of light, alter soil-water regimes, modify nutrient cycling, and alter fire regimes which affects native 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).

*Habitat destruction and modification by fire*
Alteration of fire regimes represents an ecosystem-level change caused by the invasion of nonnative grasses (D'Antonio and Vitousek 1992, p. 73; Ball et at 2020, p. 13; Lowe et al. 2020, p. 14). Beginning in the late 18th century, Europeans and Americans introduced alien grasses for pasturage and ranching (D'Antonio and Vitousek 1992, p. 67). Although fires were historically infrequent in mountainous regions, extensive fires have occurred in the last half of the 20$^{th}$ century in lowland mesic areas, leading to grass-fire cycles that convert forest to grasslands (D'Antonio and Vitousek 1992, p. 77). Successive fires that burn farther into native habitat destroy native plants and remove habitat for native species by altering microclimate conditions to conditions favorable to alien plants. Fire can destroy dormant seeds of these species as well as the plants themselves, even in steep or inaccessible areas. Other nonnative plants such as *Micronia crenata* (Koster's curse) rapidly outcompete native plants and dominate areas opened by fire (USFWS 2016a, p. 67806).

*Landslides or flooding*
Mesic forests are susceptible to hurricanes, high winds, and landslides, all of which may affect vegetation by altering succession and creating conditions more favorable to invasive species

growth, resulting in an altered vegetation community (Hillberg et al. 2018, p. 1). One of the most sensitive climatic components for mesic forests is water availability as a function of precipitation, soil moisture, drought, air temperature, and presence of trade winds. For example, reduced or increased water availability can directly alter vegetation composition and distribution in these communities by favoring growth and germination of invasive plants with higher tolerance for drier or wetter conditions (Hillberg et al. 2018, p. 1).

Storms, flooding, and landslides can destroy mesic forests, altering succession in areas with poor drainage or on steep ridges and valleys. Storms can exacerbate habitat modification and alteration caused by introduced ungulates and nonnative plants, causing additional or more extensive landslides and rockfalls (Walker 1999, p. 32; Restrepo and Vitousek 2001, pp. 409–410; Lowe et al. 2020, p. 17).

*Climate change (drought/storms)*
Climate change may pose a threat to *Santalum involutum*. Fortini et al. (2013, entire) conducted a landscape-based assessment of climate change vulnerability for native plants of Hawai‘i 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. An assessment was not conducted on *S. involutum* but was conducted on *S. ellipticum* and *S. paniculatum,* which are found in the same habitat type as *S. involutum*. Assessments concluded that both species are vulnerable to the impacts of climate change, with a vulnerability score of 0.39 and 0.111, respectively (on a scale of 0 being not vulnerable to 1 being extremely vulnerable to climate change).

*Limited numbers of individuals and populations*
There are current and ongoing threats to this species due to factors associated with limited numbers of individuals and populations (USFWS 2016a, pp. 67806; USFWS 2020, p. 12). Species that are endemic to single islands are inherently more vulnerable to extinction than are widespread species, because of the increased risk of genetic bottlenecks, random demographic fluctuations, climate change effects, and localized catastrophes such as hurricanes, landslides, rockfalls, drought, and disease outbreaks (Pimm et al. 1988, p. 757; Mangel and Tier 1994, p. 607). These problems are further magnified when populations are few and restricted to a small geographic area (low redundancy), and when the number of individuals in each population is small (low resiliency), such as with *Santalum involutum*. Populations with these characteristics face an increased likelihood of stochastic extinction due to changes in demography, the environment, genetics, or other factors (Gilpin and Soulé 1986, pp. 24–34). A single, stochastic event can result in the extinction of an entire species, if all the representatives of that species are concentrated in a single area (low redundancy). In addition, small, isolated populations often exhibit reduced levels of genetic variability (low representation), which diminishes the species' capacity to adapt and respond to environmental changes, thereby lessening the probability of long-term persistence and lowering its resiliency (e.g., Barrett and Kohn 1991, p. 4; Newman and Pilson 1997, p. 361; USFWS 2016a, p. 67806). Small, isolated populations of plants also are more susceptible to reduced reproductive vigor due to ineffective pollination, inbreeding depression, and hybridization due to low representation. The problems associated with small population size and vulnerability to random demographic fluctuations or natural catastrophes are further magnified by synergistic interactions with other threats, such as those discussed above.

*Inadequate regulatory mechanisms*
*Inadequate Habitat Protection*
Nonnative feral ungulates pose threat to *Santalum involutum* through destruction and degradation of the species' habitat and herbivory but regulatory mechanisms are inadequate to address this threat (USFWS 2016a, pp. 67806, 67843–67846). The State of Hawai'i provides game mammal (feral pigs, goats, black-tailed deer) hunting opportunities on 17 State-designated public hunting areas on the island of Kaua'i (Anderson et al. 2007, in litt.; HDLNR 2010, in litt.). However, the State's management objectives for game animals range from maximizing public hunting opportunities (e.g., "sustained yield") in some areas to removal by State staff, or their designees, in other areas (State of Hawai'i, H.A.R. 13-123).

*Introduction of Nonnative Plants and Insects*
Currently, four agencies are responsible for inspection of goods arriving in Hawai'i (USFWS 2016a, pp. 67806, 67843–67846). The Hawai'i Department of Agriculture (HDOA) inspects domestic cargo and vessels and focuses on pests of concern to Hawai'i, especially insects or plant diseases. The U.S. Department of Homeland Security-Customs and Border Protection (CBP) is responsible for inspecting commercial, private, and military vessels and aircraft and related cargo and passengers arriving from foreign locations (USFWS 2016a, pp. 67806, 67843-67846). The U.S. Department of Agriculture-Animal and Plant Health Inspection Service-Plant Protection and Quarantine (USDA-APHIS-PPQ) inspects propagative plant material, provides identification services for arriving plants and pests, and conducts pest risk assessments among other activities (HDOA 2009, p. 1). The Service inspects arriving wildlife products, enforces the injurious wildlife provisions of the Lacey Act (18 U.S.C. 42; 16 U.S.C. 3371 *et seq*.), and prosecutes CITES (Convention on International Trade in Wild Fauna and Flora) violations. The State of Hawai'i allows the importation of most plant taxa, with limited exceptions (USFWS 2016a, pp. 67806, 67843–67846). It is likely that the introduction of most nonnative invertebrate pests to the State has been and continues to be accidental and incidental to other intentional and permitted activities. Many invasive weeds established on Hawai'i have currently limited but expanding ranges. Resources available to reduce the spread of these species and counter their negative ecological effects are limited. Control of established pests is largely focused on a few invasive species that cause significant economic or environmental damage to public and private lands, and comprehensive control of an array of invasive pests remains limited in scope (USFWS 2016a, pp. 67806, 67843–67846).

**Conservation Actions**
*National Tropical Botanical Garden (NTBG)*
The NTBG's focus is on identifying, documenting, understanding, and conserving the rich diversity of tropical plants and their habitats. Their collections (living, herbarium, and library) provide valuable resources. The NTBG's conservation initiatives include collecting expeditions throughout Hawai'i and the Pacific region to identify plant species that are at risk of extinction, to collect seeds and plant material for propagation and conservation in the living collections, ecological restoration of degraded habitats, protecting the endemic species that still exist, and reintroducing species which have not survived on their own (*https://ntbg.org/science*). The NTBG conducts surveys and monitors plant populations, control threats, collect propagules, and conduct outplantings for these rare endangered plants. The NTBG botanists have conducted

extensive surveys for *Santalum involutum* where wild populations were known to exist historically. Three seed collections of *S. involutum* at Pōhakuao have been made by NTBG staff, in August of 2014 and in January and December of 2015 (Wood 2015, p. 7; NTBG 2015). Eighteen seeds from the December 2015 collection were propagated in January of 2016. A single wild plant was collected at Pōhakuao in 2018 and translocated into their Limahuli Gardens and Preserve (NTBG 2019).

*Plant Extinction Prevention Program (PEPP)*
The Plant Extinction Prevention Program (PEPP) supports conservation of plant species by securing seeds or cuttings (with permission from the State, Federal, or private landowners) from the rarest and most critically endangered native species for propagation and translocation. The PEPP focuses on species that have fewer than 50 plants remaining in the wild including *Santalum involutum*. Funding for this program is from the State of Hawai‘i, Federal agencies (e.g., Service), and public and private grants (*http://pepphi.org*). The PEPP botanists conduct surveys and monitors plant populations, control threats, collect propagules, and conduct outplantings for these rare endangered plants. The PEPP botanists have conducted extensive surveys for *Santalum involutum* where wild populations were known to exist historically.

*State of Hawai‘i*
The State of Hawai‘i owns and manage locations where known populations of *Santalum involutum* occur (Hono O Nā Pali Natural Area Reserves and Nā Pali Coast State Wilderness Park). The mission of the State of Hawai‘i Department of Land and Natural Resources, Division of Forestry and Wildlife (DLNR-DOFAW) is to responsibly manage and protect watersheds and native ecosystems. Both DOFAW and the Division of State Parks manage and protect cultural resources and provide outdoor recreation while facilitating partnerships, community involvement, and education (https://dlnr.hawaii.gov/dofaw; https://dlnr.hawaii.gov/dsp). No plants are protected by fencing and no rodent control program is occurring at sites where *S. involutum* is located. The DLNR-DOFAW botanist works closely with the PEPP and the NTBG botanists on rare plant management.

*Regulatory Actions*
*Endangered Species Act* (ESA)
The Service in 2016 determined endangered status under the ESA, as amended, for 49 species on 2016 including *Santalum involutum* (USFWS 2016a, pp. 67806, 67843–67846). The primary purpose of the ESA is the conservation of endangered and threatened species and the ecosystems upon which they depend. The ultimate goal of such conservation efforts is the recovery of these listed species, so that they no longer need the protective measures of the ESA. Conservation measures provided to species listed as endangered or threatened under the ESA include recognition of threatened or endangered status, recovery planning, requirements for Federal protection, and prohibitions against certain activities. The ESA encourages cooperation with the States and requires that recovery actions be carried out for all listed species. The ESA and its implementing regulations in addition set forth a series of general prohibitions and exceptions that apply to all endangered wildlife and plants. For plants listed as endangered, the ESA prohibits the malicious damage or destruction on areas under Federal jurisdiction and the removal, cutting, digging up, or damaging or destroying of such plants in knowing violation of any State law or regulation, including State criminal trespass law. Certain exceptions to the prohibitions apply to

agents of the USFWS and State conservation agencies. The USFWS may issue permits to carry out otherwise prohibited activities involving endangered or threatened wildlife and plant species under certain circumstances. With regard to endangered plants, a permit must be issued for scientific purposes or for the enhancement of propagation or survival. For federally listed species unauthorized collecting, handling, possessing, selling, delivering, carrying, or transporting, including import or export across State lines and international boundaries, except for properly documented antique specimens of these taxa at least 100 years old, as defined by section 10(h)(1) of the Act, is prohibited. Damaging or destroying any of the listed plants in addition is violation of the Hawai‘i State law prohibiting the take of listed species. The State of Hawai’i’s endangered species law (HRS, Section 195-D) is automatically invoked when a species is federally listed, and provides supplemental protection, including prohibiting take of listed species and encouraging conservation by State government agencies. *S. involutum* occurs on non-Federal lands.

## CURRENT CONDITION

### Historical Condition

*Pre-human Habitat Distribution*

Mesic forests were more extensive historically, particularly in the lowlands, and contained inclusions of native grasslands and shrublands throughout the areas they occurred. Lowland mesic forests were widely distributed historically across a broad range in the main Hawaiian Islands and across multiple watersheds containing high quality subunits with a wide range of species and diversity. Mesic shrublands were more extensive historically and occurred as inclusions within mesic and dry forests; it is likely that shrublands and forests were found together throughout the lowlands. Species richness was considered low to moderate so although it was composed entirely of native vegetation, it may not have been species rich. However, the large size of these habitat in the main Hawaiian Islands made it resilient to stochastic events like flooding or minor fires. We refer you to the Pre-Human Condition section of the Habitat Status Assessments for mesic forest and mesic shrubland (Ball et al. 2020, pp. 2–3; Lowe et al. 2020, pp. 6–8) for further discussion on the habitat characteristics for where this species occurred.

*Historic Trends of* Santalum involutum

Historically, *Santalum involutum* has never been common, as reflected by the sparingly few vouchers collected. Historical collections consists of Wainiha Valley, *Fosberg and Sachet 13946* (BISH); west of Wai‘oli-Waipā Ridge in koa forest, *Christensen 69* (BISH); Lumaha‘i-Wainiha Ridge, sides of ridge, *Christensen 182* (BISH); Wahiawā, edge of Kanaele Bog, *St. John 26766* (BISH); Wainiha Valley 1 1/8 mile in from last house, *Christensen 121* (BISH); and Nā Pali Coast, Hanakāpī‘ai Ridge E. of stream, *Christensen 57* (BISH) (Wood 2015, p. 13).

More recent surveys have located three populations consisting of five sites, totally approximately 5 individuals of *Santalum involutum*. In the Nā Pali Coast State Wilderness Park, the population at Kalalau (Population A on Table 1) consisted of 50 individuals when observed in 2007; only one individual was observed in 2012. The population at Pōhakuao-Hanakoa-Waiolaa (B on Table 1) consists of three sites: 100 individuals were observed at Pōhakuao in 1992, but a single individual was observed in 2014; 50 individuals were observed at Hanakoa in 2014, but one individual was observed in 2015; and a single individual was observed at Waiolaa in 2015

(Wood 2015, pp. 10–13). A single individual was observed at Hoʻolulu in 2017 (NTBG 2017) (Table 1, Figure 4).

Table 1. Known wild population units of *Santalum involutum.*

| **Population** | **Population Map Letter** | **Extant** | **Last Observation Date** | **Estimated Number of Individuals** |
|---|---|---|---|---|
| Kalalau | A | Y | 2012 | 1 |
| Pōhakuao-Hanakoa-Waiolaa | B | Y | 2015 | 3 |
| Hoʻolulu | C | Y | 2017 | 1 |

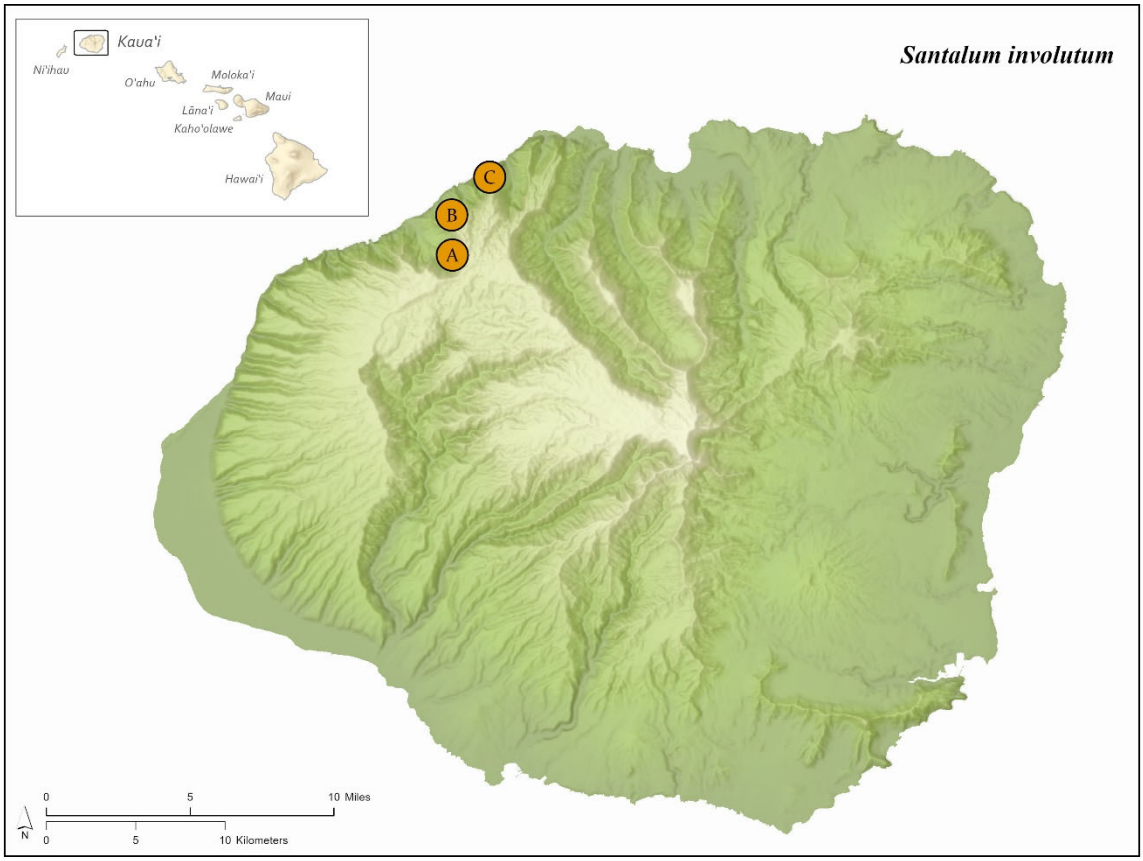



Figure 4. Distribution of *Santalum involutum* on Kauaʻi.

**Current Condition**

Mesic forests have decreased in quality and quantity on Kauaʻi and throughout the Hawaiian chain. Much of the lowland mesic forests have since been converted to pasture, military, or agricultural use, or have been lost to urbanization or fire. Intensive human disturbance in the lowlands has resulted in the majority of intact native mesic forests remaining only at higher elevations. Many areas in the lowland mesic forest zone have been cleared for timber logging,

and have been invaded by invasive grasses brought in by early ranchers to support grazing animals (Lowe et al. 2020, p. 8).

Mesic grasslands and shrublands experienced similar decreases in quality and quantity. This habitat was cleared for agriculture by the Hawaiians. By the time of European contact in the late 1700s most of the native mesic communities below 2500 ft (760 m) had been converted from forest, woodlands, and shrublands to open grasslands. Native lowland mesic communities, including grasslands and shrublands have been further converted to pasture, military, or agricultural use, or have been lost to urbanization or fire. It is estimated that less than ten percent of the original native vegetation in lowland areas of the Hawaiian islands currently remain. The majority of remaining native mesic grasslands and shrublands are found today at higher elevations and in areas where development, agriculture, and grazing have not been as intensive (Ball et al. 2020, p. 9). We refer you to the Current Condition section of the Habitat Status Assessments for mesic forest (Lowe et al. 2020, pp. 8–12) and for mesic grasslands and shrublands (Ball et al. 2020, p. 9) for further discussion on the habitat needs for this species.

## SPECIES VIABILITY SUMMARY

### Resiliency

For *Santalum involutum* to maintain viability, the populations must be resilient. The definition of resiliency is the ability of the population to withstand stochastic events, meaning they must have healthy, stable populations, good quality and quantity of habitat.

We determine resiliency for *Santalum involutum* based on the metrics of the population size. Three populations consisting of five sites contain a total of 5 individuals. In the Nā Pali Coast State Wilderness Park, the population at Kalalau (Population A on Table 1) consists of one individual. The population at Pōhakuao-Hanakoa-Waiolaa (B on Table 1) consists of three sites: a single individual at Pōhakuao, a single individual at Hanakoa, and a single individual at Waiolaa (Wood 2015, pp. 10–13). A single individual was observed at Hoʻolulu in 2017 (NTBG 2017). No populations are within fenced areas and are therefore exposed to feral ungulates; no rodent control program exist in these locations. Therefore, the resiliency *S. involutum* on the species level is very low in the current condition due to the very low number of individuals at the three populations.

### Redundancy

We evaluate redundancy for *Santalum involutum* based on the metric of the distribution of the populations and amount of populations across the range of the species. Currently, there are three populations of *S. involutum*; all populations have very low resiliency, are geographically close (within a 1.23 square mile area), and therefore increasing the risk of a single catastrophic even contributing to the extinction of the species. Therefore, redundancy in the current condition is very low, due to its limited native range and population resiliency.

### Representation

We define representation for *Santalum involutum* based on the genetic diversity and habitat variation within and among the populations as well as on the metric of connectivity among populations. It is unknown if there is any connectivity between populations, or whether there

were more individuals in the past to more strongly connect these sites and populations. The level of genetic diversity within and among these three populations is unknown, and there are no known morphological differences among the sites as well, but little data is available. Three individuals are represented in *ex situ* seed storage, and a single wild plant was translocated into Limahuli Gardens and Preserve. Therefore, the genetic structure of the species is not secured. Two populations are located in lowland mesic forest habitat while the Hoʻolulu population is found in mesic shrubland habitat. As this individual is located in a little warmer and wetter habitat and is at lower elevation than the other two populations, it may contain unique traits not represented by the other two populations. The representation is very low in the current condition.

**Species Viability Summary**

The current condition of *Santalum involutum* is described as having three populations that are confined to a narrow geographic range of the Nā Pali coast lowland mesic forest and shrubland habitats. Currently, two populations consist of a single individual each. The population at Kalalau and at Pōhakuao-Hanakoa-Waiolaa have experienced massive declines in individual numbers. Limited representation is maintained in *ex situ* seed storage, propagated plants, and a single wild plant translocated into Limahuli Gardens and Preserve. As this species has very low resiliency, representation, and redundancy in the current condition, the overall viability of this species is very low.

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