SPECIES REPORT
Schiedea laui (no common name)
VERSION 1.0

Photo credit: Hank Oppenheimer, Plant Extinction Prevention Program

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Pacific Islands Fish and Wildlife Office
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EXECUTIVE SUMMARY

Schiedea laui is a short-lived perennial herb or subshrub in the pink family (Caryophyllaceae) known from the island of Moloka‘i in the Hawaiian islands. Currently, on Moloka‘i it is very rare; there are only 24 mature, 12 immature, and 32 seedlings known in a single wild population.

Schiedea laui is an endemic species that is found on the windward areas of east Moloka‘i. This species is found between the elevations of 1,097 to 1,146 meters (3,599 to 3,760 feet) growing near stream banks and inside and outside of caves. The habitat is categorized as native wet forest. The soil type is classified as rough mountainous land and is comprised of very steep slopes with numerous drainage channels.

The main threats to *Schiedea laui* are introduced ungulates, nonnative plants, landslides and flooding, hurricanes, introduced rats and slugs, small number of individuals and populations, and climate change. Conservation actions that are helping to control these threats include ungulate fencing, controlling nonnative plants, translocating individuals, seed collecting, and monitoring. There are numerous seeds in storage and propagules growing in a nursery.

We define resiliency for *Schiedea laui* based on the metric of population size. We define redundancy for *S. laui* 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 *S. laui* based on the genetic diversity and habitat variation within and among populations.

The limited geographic range, restricted habitat requirements, low populations and number of individuals have compromised the range-wide redundancy, representation, and resilience of *Schiedea laui* in the current condition. Given that there are currently only 24 mature, 12 immature, and 32 seedlings known in a single population, we evaluated the species’ resilience, redundancy, and representation as very low in the current condition. We would expect *S. laui* 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 very low.

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INTRODUCTION

Schiedea laui (no common name) is a perennial herb or subshrub in the pink family (Caryophyllaceae) and is endemic to the island of Moloka‘i in the Hawaiian Islands (Wagner et al. 2005, pp. 82–84). This species has only been known from a single population on land owned by the Nature Conservancy of Hawai‘i located within their Kamakou Preserve (Wagner et al. 2005, p. 84).

Species Report Overview

This biological report summarizes the biology and current status of *Schiedea laui* and was conducted by the U.S. Fish and Wildlife Service (Service) 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

Schiedea laui was listed as an endangered species on May 28, 2013 (78 FR 32013, USFWS 2013, p. 32015). Approximately, 2,493 ac (1,009 ha) of State land and 2,616 ac (1,059 ha) of privately owned land was designated as critical habitat for *S. laui* on the island of Moloka‘i in the montane wet ecosystem units 1, 2, and 3 (81 FR 17790, USFWS 2016a, pp. 17888 and 17906).

Methodology

We used the best scientific and commercial data available to us, including peer-reviewed literature, grey literature (government, academic, business, and industry reports), and expert elicitation. 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 *Schiedea laui*, 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 *Schiedea laui* using this definition. The Hawai‘i 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 *Schiedea laui* 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. laui*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 1; USFWS 2016b). We will evaluate the viability of our species by describing what our species needs to be resilient, redundant, and represented, and compare that to the status of our 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 *Schiedea laui*.

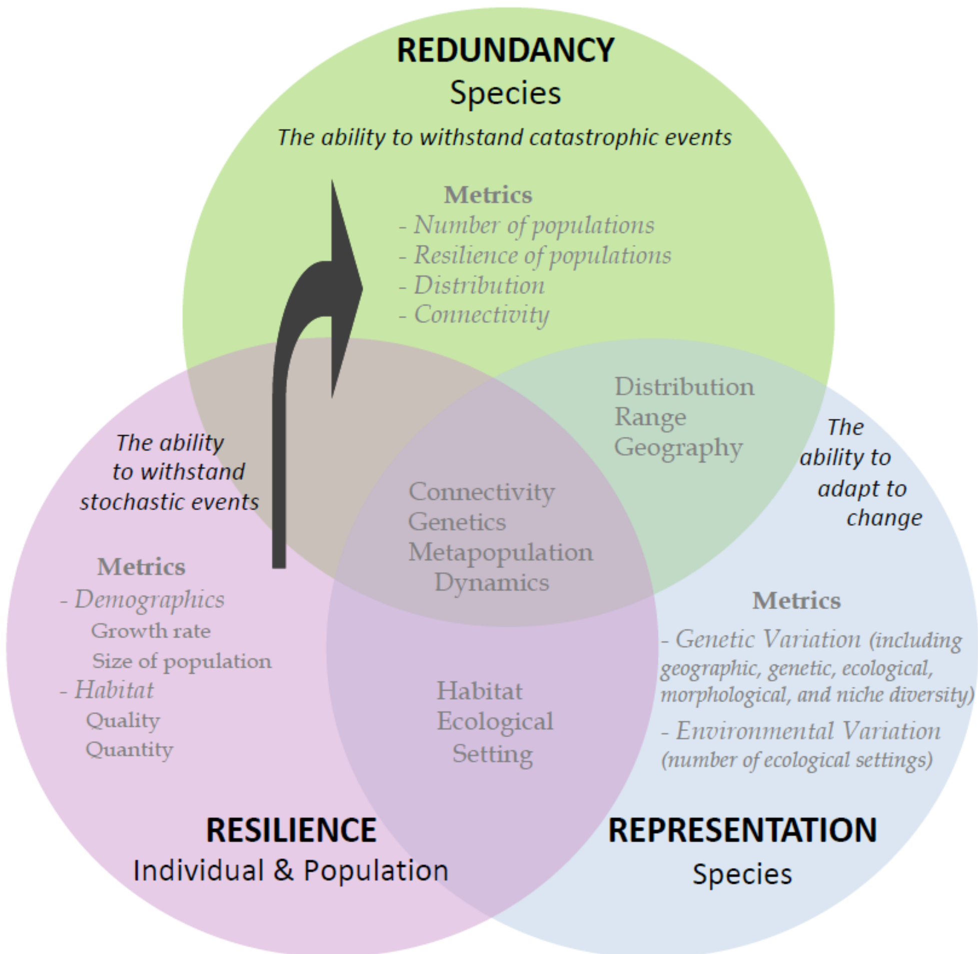

Figure 1. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs".

SPECIES' NEEDS / ECOLOGY

Species Description

Schiedea laui is a short-lived perennial herb or subshrub in the pink family (Caryophyllaceae) (Wagner et al. 2005, pp. 82-84; USFWS 2016b, p. 17809). W.L. Wagner and S.G. Weller (Wagner et al. 2005, p. 82) originally described *Schiedea laui* from a collection made in 1998 by J. Lau and S. Loo at Kamakou Preserve on Molokaʻi in the Hawaiian Islands. This species was named in honor of its discoverer, Mr. Joel Q. C. Lau, at the time employed under the Hawaiʻi Natural Heritage Program, and noted as "one of the most knowledgeable botanists of the Hawaiian flora" (Wagner et al. 2005, p. 84).

Schiedea laui is an upright to strongly ascending (sloping or leading upward) subshrub that is 5 to 15 decimeter (dm) (1.6 to 4.9 ft) tall. The stems are many-branched and glabrous (free from hair) except for the bracts (a modified leaf or scale) and sepals (each of the parts of the calyx of a flower, enclosing the petals). The internodes (a part of a plant stem between two of the nodes from which leaves emerge) are lightly purple-tinged. The leaves are opposite, narrowly ovate (oval shape, like an egg) or lanceolate (of a narrow oval shape tapering to a point at each end) to narrowly or broadly elliptic, dull green and sometimes purple-tinged. The petioles (the stalk that joins a leaf to a stem) are 0.5 to 1.1 centimeters (cm) (0.2 to 0.4 inches [in]) long. The inflorescences are terminal containing 10 to 18 flowers. The flowers are hermaphroditic (also known as "perfect", which means that each flower contains both male and female structures) and cleistogamous (flowers that do not open and are self-pollinated). The sepals are narrowly lanceolate, 4.0 to 4.5 millimeters (mm) (0.16 to 0.18 in) long, and green to sometimes purple-tinged or nearly purple throughout. The nectary base is obsolete. The capsules are narrowly ovoid (egg-shaped, with the axis widest below the middle) and approximately 4.0 to 4.5 mm (0.16 to 0.18 in) long. The seeds are orbicular-reniform (having the shape of a flat ring or disk-kidney-shaped) and approximately 1 mm (0.04 in) long (Wagner et al. 2005, p. 82).

Schiedea laui is most similar in morphology to *S. nuttallii* differing by the presence of cleistogamous flowers and occurring at higher elevations in wet forest habitats, rather than mesic forests (Wagner et al. 2005, p. 84). *Schiedea laui* also does not share any unique synapomorphies (a characteristic present in an ancestral species and shared exclusively by its evolutionary descendants) with *S. nuttallii* (Wagner et al. 2005, p. 84).

The flowering periods for *Schiedea laui* are between November to January and in the months of May, June, and September (USFWS 2019, entire; U.S. National Herbarium, Smithsonian Institution 2005, entire). Fruits have been observed on the plants during the months of January and August to October (USFWS 2019, entire; National Tropical Botanical Garden 2019). A simple table displaying the fruiting and flowering cycle for this species is presented in Table 1.

Table 1. Flowering and fruiting period for *Schiedea laui* (USFWS 2019, entire; National Tropical Botanical Garden 2019, entire; U.S. National Herbarium, Smithsonian Institution 2005, entire).

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Flowering				Flowering				Flowering		Flowering	
Fruiting							Fruiting				

The breeding system of *Schiedea laui* is hermaphroditic (plants containing perfect flowers, each of which has both male and female reproductive organs; species is capable of both sexual and vegetative reproduction) and obligate autogamy through cleistogamy (Wagner et al. 2005, p. 2). Obligate autogamy means that *S. laui* is restricted to self-fertilization (flowers are self-pollinated). Cleistogamy refers to plants that produce flowers that do not open, which are developed specifically by self-pollinated flowers and does not support outcrossing (Lloyd and Schoen 1992, p. 359).

Schiedea laui produces seeds via self-fertilization and is not dependent on birds or insects for pollination. Self-fertilized plants has the reproductive benefit of always being able to make fruit and offspring in the absence of pollinators (Kalisz and Vogler 2003, p. 2939). However, self-fertilized plants are known to produce progeny that are low quality (i.e., low fitness) due to inbreeding depression (Charlesworth 2006, p. R726) and may develop abnormalities which leads to death during early seedling development (Charlesworth and Willis 2009, p. 783). Inbreeding depression is defined as "reduced survival and fertility of offspring of related individuals"

(Charlesworth and Willis 2009, p. 783) and is more noticeable in very small populations and self-fertilized plants (Charlesworth and Willis 2009, p. 785; Barrett and Kohn 1991, p. 17). Inbreeding depression also occurs when lethal or deleterious recessive alleles become homozygous (both alleles are identical at the locus [or site]) in self-fertilized plants (Barrett and Kohn 1991, p. 21). If the origin of inbreeding depression in populations of *S. laui* is centered on the presence of lethal or deleterious recessive alleles, than even fairly low rates of selfing should be able to quickly purge a population of its deleterious recessive alleles (Barrett and Kohn 1991, p. 21). Accordingly, populations of *S. laui* that have experienced a long history of inbreeding would have been able to survive past inbreeding depression.

It is suggested that plants utilizing cleistogamy, such as *Schiedea laui*, uses this breeding system as a way to adapt to the high elevations and very wet habitats that it occupies. In very wet environments, the use of autogamy helps to reduce the time rain may interact with pollen, so that the rain does not wash away pollen from the flowers or allow pollen to open when it is not ready (Wagner et al. 2005, p. 26).

Seed dispersal mechanisms for *Schiedea laui* are unknown (Wagner et al. 2005, p. 28). However, we can assume that seed dispersal for *S. laui* would follow its close relative, *Schiedea jacobii*, which also grows in wet forest habitats. Seeds of *S. jacobii* are formed in a capsule and ultimately dispersed from open capsules after they have matured on the plant (Wagner et al. 2005, p. 28). Therefore, seeds fall and germinate near the parent plant.

In addition, seeds of *Schiedea laui*, and other species in *Schiedea*, are known to exhibit some sort of dormancy which is most likely an adaptive characteristic that allows the seeds to be developed during the end of the winter wet season. This dormancy will delay germination of the seeds until the winter rainy season begins (Wagner et al. 2005, p. 24), allowing for the higher survival of recruitments with increased water availability during the rainy season.

We do not have information about how long seeds of *Schiedea laui* will remain viable. Other life history information is currently unknown, including information on plant growth stages and the length of time it takes to flower. The potential lifespan of *S. laui* is apparently short at less than 10 years.

Habitat Conditions

Schiedea laui is an endemic species to the Waikolu drainage on Moloka‘i (Wagner et al. 2005, p. 82). This species is found between the elevations of 1,097 to 1,146 meters (m) (3,599 to 3,760 ft) in the wet forest (National Tropical Botanical Garden 2019; Wagner et al. 2005, p. 82). The wild population is located in a cave along a narrow stream corridor at the base of a waterfall (Wagner et al. 2005, p. 82). This species is typically found in the wet forests and we will be referencing the Habitat Status Assessment for wet forests (Clark et al. 2019, entire) to describe the habitat needs for this species.

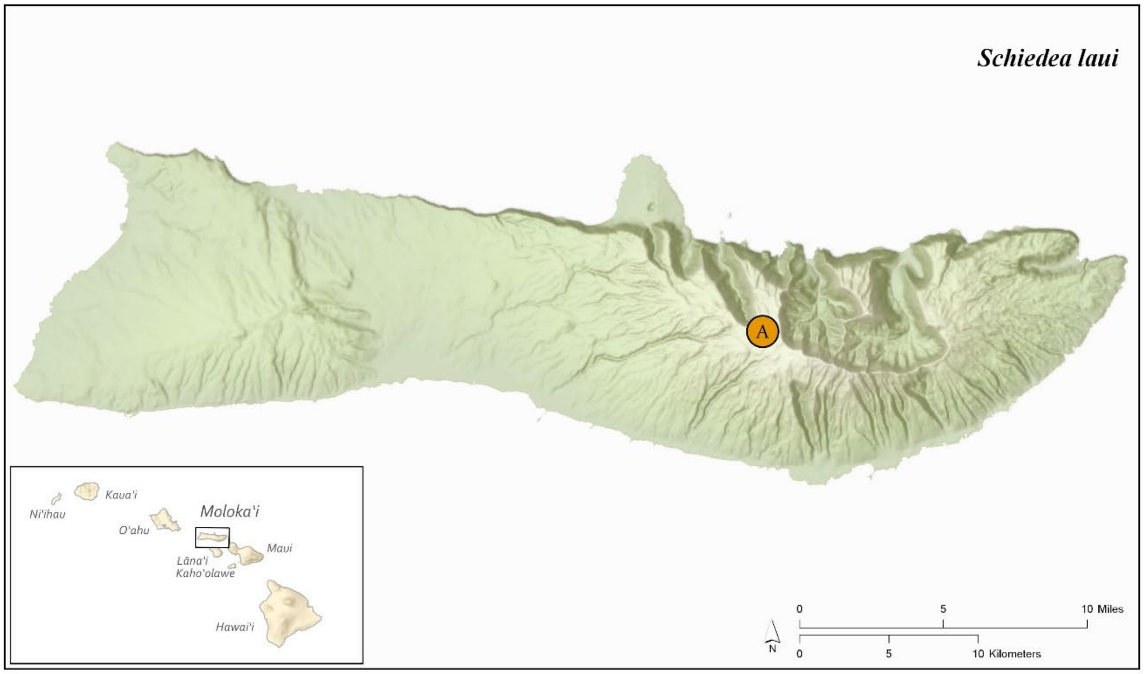

Figure 2. Distribution of *Schiedea laui* on Molokaʻi.

Schiedea laui is currently located within the Kamakou Preserve, which is co-managed by The Nature Conservancy of Hawaiʻi and the East Molokaʻi Watershed Partnership (The Nature Conservancy of Hawaiʻi [TNCH] 2012, p. 3) (Figure 2, A refers to Kamakou Preserve). Kamakou Preserve is located in the east Molokaʻi mountains and encompasses 2,633 ac (1,066 ha). This preserve was established in 1982, through a perpetual conservation easement with Molokaʻi Ranch, to safeguard endemic forest bird habitat (TNCH 2012, p. 3). The East Molokaʻi Watershed Partnership is a volunteer program comprised of private, state, and federal landowners and agency partners to protect and conserve the most intact remnant native forests and watershed areas on the East Molokaʻi Mountains.

At the wild population, the soil type is classified as rough mountainous land (50 to 100 percent slope) and is comprised of very steep slopes with numerous drainage channels (Foote et al. 1972, p. 119). The soil layer in this soil type is very thin and found in the first 25 cm (10 in) of the ground layer.

Near the wild population, the average annual temperature is approximately 56.3 degrees F in February to 63.0 degrees F in August (Giambelluca et al. 2014). The mean annual rainfall is 2989 mm (118 in) (Giambelluca et al. 2013). Most of the rainfall occurs during the months of November through March, with October being the driest month (164.4 mm [6.5 in]) and January the wettest (375.5 mm [14.8 in]) (Giambelluca et al. 2013).

The habitat of *Schiedea laui* on Molokaʻi is described as a wet forest with mixed *Metrosideros polymorpha* and *Cheirodendron trigynum* subsp. *trigynum* (U.S. National Herbarium, Smithsonian Institution 2005, entire). Associated native species include *Asplenium lobulatum*, *Asplenium macraei*, *Dryopteris sandwicensis*, *Vandenboschia davallioides*, *Cyrtandra hawaiensis*, *Cyrtandra procera*, *Hymenasplenium unilaterale*, *Hydrangea arguta*, *Coprosma* sp., *Cyanea solenocalyx*, *Dicranopteris linearis*, *Cibotium glaucum*, *Machaerina* sp., *Sadleria* sp., and *Freycinetia arborea* (U.S. National Herbarium, Smithsonian Institution 2005, entire; National Tropical Botanical Garden 2019, entire).

Individual Needs
The chromosome number for *Schiedea laui* is unknown (Wagner et al. 2005, p. 82).

When comparing the results from the phylogeny of *Schiedea* with species habitats, *S. laui* has been identified as a species that has transitioned out of the mesic environment and into the wet environment with its root ancestor identified as *S. jacobii* (Wagner et al. 2005, p. 24).

The life cycle of *Schiedea laui* 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 *S. laui* 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 this individual, than the species is highly resilient.

In summary, the individual needs of *Schiedea laui* includes growing near streams inside and outside of caves in the wet forest habitats on Molokaʻi. The soil type that *S. laui* may occupy is classified as rough mountainous land and is comprised of very steep slopes with numerous drainage channels and very shallow soils. *Schiedea laui* is able to self-pollinate and the flowers are hermaphroditic, thus it contains both male and female structures. Because individuals of *S. laui* are self-pollinated, they also need sufficient space and suitable habitat for recruitment to occur so that parent plants can be replaced. Otherwise, individuals could blink out as a result of stochastic events.

Population Needs
Suitable habitat for *Schiedea laui* occurs in the wet forests on the windward sides of eastern Molokaʻi as described in the Habitat Conditions section above. The seeds of *S. laui* are dispersed naturally through gravity and simply fall beneath the parent plants. This species is self-pollinated and does not require pollinators. Sufficient suitable habitat and space is needed for self-pollinated plants such as *S. laui*, to facilitate recruitment and replacement of individuals and prevents populations from blinking out as a result of stochastic events.

Species' Needs / Ecology
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 valleys found in

east Moloka'i would have isolated populations from each other, allowing for higher representation and redundancy within the species.

Schiedea laui was first described in 2005 by W.L. Wagner and S.G. Weller (Wagner et al. 2005, p. 82). The type specimen was collected by J. Lau and S. Loo in a single location within the Kamakou Preserve on Moloka'i in 1998 (Wagner et al. 2005, p. 82). When it was first found in 1998, there were 16 mature individuals and 1 immature individual observed along with additional seedlings (no number provided) (U.S. National Herbarium, Smithsonian Institution 2005, entire). The known historic distribution and range for this species included the windward areas of east Moloka'i in the Waikolu and Hanalilolilo drainages (Wagner et al. 2005, pp. 82–84). On Moloka'i, only one population from a single location was known to occur in the past 20 years (Wagner et al. 2005, p. 82; USFWS 2019, entire). Although this species was noted from only one location, it is likely that other populations existed but were not found due to the lack of systematic surveys in this remote area of Moloka'i.

FACTORS INFLUENCING VIABILITY

Threats and Conservation Actions

Introduced Ungulates

Threat - Introduced pigs (*Sus scrofa*) are a threat to *Schiedea laui* because they can be highly destructive to the native vegetation in the habitats suitable for the species, and 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 and damage vegetation below (Cuddihy and Stone 1990, pp. 63–64; USFWS 2013, p. 32041; Bakutis 2019, pers. comm., p. 2). Additionally, disturbance of soils by feral pigs from rooting, which can create fertile seedbeds for nonnative plants (Cuddihy and Stone 1990, p. 65). While rooting in the earth in search of invertebrates and plant material, pigs directly impact native plants and individuals of *S. laui* by disturbing and destroying vegetative cover, and trampling plants and seedlings of *S. laui*. Pigs may also reduce or eliminate plant regeneration by damaging or eating seeds and seedlings of *S. laui*.

Conservation action - The wild and reintroduced populations of *Schiedea laui* on Moloka'i are fenced and the fences are monitored for breeches (Plant Extinction Prevention Program [PEPP] 2018, p. 19; TNCH 2012, p. 8–11).

Landslides and Flooding

Threat - Landslides and flooding adversely impact the habitats and individuals of *Schiedea laui* by destabilizing substrates, damaging and destroying individual plants, and altering hydrological patterns, which result in habitat destruction or modification and changes to native plant and animal communities. Field survey data presented by the Plant Extinction Prevention (PEP) Program (2015, p. 160; Bakutis 2019, pers. comm., p. 2) suggest that catastrophic flooding or landslides are possible at one population of *S. laui* located along a narrow stream corridor in the Kamakou Preserve.

Nonnative Plants
Threat - Invasive plant species are a threat to *Schiedea laui* 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). Potential invasive plant species may include *Rubus argutus* (blackberry), *Psidium cattleyanum* (strawberry guava), *Chaetogastra herbacea* (glorybush), and *Miconia crenata* (Koster's curse) (TNCH 2012, p. 15).

Conservation action - Weeds are controlled around the reintroduced population at PēpēʻŌpae Stream within the Kamakou Preserve (PEPP 2018, p. 19). Weed control also occurs within the Kamakou Preserve by the Nature Conservancy (TNCH 2012, p. 15-17).

Hurricanes
Threat - Hurricanes destroy native vegetation, the habitat and may kill individuals of *Schiedea laui* by opening the canopy and thus modifying the availability of light, and creating disturbed areas conducive to invasive 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). Therefore, natural disasters such as hurricanes are particularly devastating to this species.

Introduced Rats
Threat - Introduced rats (*Rattus* sp.) are a threat to this species (USFWS 2013, p. 32053; Bakutis 2019, pers. comm., p. 2). 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 - None.

Introduced Slugs
Threat - Introduced slugs are a threat to this species (USFWS 2013, p. 32054; Bakutis 2019, pers. comm., p. 2). Predation by introduced slugs impact individuals of *Schiedea laui* through mechanical damage, destruction of plant parts, and mortality (USFWS 2013, p. 32054).

Conservation action - None; label requirements for slug pesticides restrict their application as populations of *S. laui* are located too close to streams and waterways to apply slug pesticides.

Small Number of Individuals and Populations
Threat - *Schiedea laui* faces the threat of limited numbers as it is known from only a single population on Molokaʻi. *Schiedea laui* may experience: (1) reduced reproductive vigor due to ineffective pollination or inbreeding depression; (2) reduced levels of genetic variability, leading to diminished capacity to adapt and respond to environmental changes, thereby lessening the probability of long-term persistence; and (3) a single catastrophic event may result in extirpation of remaining populations and extinction of the species. In particular, the wild individuals of

Schiedea laui are facing imminent threats from flooding and landslides because of their location in a grotto (Bakutis 2019, pers. comm., p. 2).

Conservation action - The PEP Program 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 (*http://pepphi.org*). The PEP Program focuses on species that have fewer than 50 plants remaining in the wild. Funding for this program is from the State of Hawaiʻi, Federal agencies (e.g., Service), and public and private grants. The PEP Program conducts these activities for *S. laui:* collect, monitor, and translocate (PEPP 2017, pp. 45, 209; PEPP 2016, p. 44, 212; PEPP 2015, p. 35, 160).

In 2018, there are hundreds of seeds of *Schiedea laui* in storage and numerous plants in living collections. The Lyon Arboretum Seed Conservation Laboratory reported more than 12,700 seeds in storage from thirteen accessions representing the wild and reintroduced populations from Kamakou Preserve (Lyon Arboretum 2018). The Lyon Arboretum Micropropagation Laboratory reported more than 1,100 containers of propagules collected from Hanalilolilo representing 15 founders (Lyon Arboretum 2018).

The National Tropical Botanical Garden (2018) has more than 650 seeds of *Schiedea laui* in storage collected from Hanalilolilo.

The Olinda Rare Plant Facility (2018) has 153 potted plants of *Schiedea laui* in their nursery for both *in-situ* and *ex-situ* purposes. They have propagated 21 individuals for future reintroduction efforts at Hanalilolilo (Olinda Rare Plant Facility 2018).

In 2009, the PEP Program began translocating this species within the Kamakou Preserve on Molokaʻi (PEPP 2009, p. 107–109). In 2010, approximately 92 individuals were reintroduced within the Kamakou Preserve in approximately three sites (two sites at Hanalilolilo and one site at upper Kamakou) (PEPP 2010, p. 108–109). In 2011, 58 individuals were reintroduced at Hanalilolilo (PEPP 2011, p. 168).

Translocations by site
PēpēʻŌpae Stream (PEP) — In 2015, the 75 reintroduced individuals at PēpēʻŌpae Stream that were previously reintroduced was monitored and only 68 individuals were relocated and noted as healthy (USFWS 2019, entire). In January 2016, only 62 previously reintroduced individuals were monitored (USFWS 2019, entire). In June 2016, an additional 67 individuals of *Schiedea laui* were reintroduced (PEPP 2016, p. 212). As of 2019, there is only one reintroduction site at PēpēʻŌpae Stream containing 24 mature individuals that are reproductive and producing lots of seeds (Bakutis 2019, pers. comm., p. 2).

PēpēʻŌpae Bog (PEP) — In July 2015, 52 individuals were reintroduced (USFWS unpublished data). In December 2015, the previously reintroduced individuals were monitored and noted in healthy condition with a few individuals starting to flower (USFWS unpublished data). Currently, the status of these reintroduced individuals is unknown.
Hanalilolilo (HAN) — In 2010 and 2012, there were 16 reintroduced individuals that were healthy and some flowering (USFWS unpublished data). In 2017, the population at Hanalilolilo

was monitored and contained 44 reintroduced individuals (PEPP 2017, p. 209). During that same visit, seeds were collected from that population (PEPP 2017, p. 209). Currently, all of the reintroduced individuals at Hanalilolilo has died as of August 2019 (Bakutis pers. comm. 2019, p. 2).

West Kawela (KAW) — In August 2015, 22 individuals were reintroduced at West Kawela and they were all vegetative (non-flowering) plants (USFWS unpublished data). In November 2015, all reintroduced individuals were noted as healthy and a few were producing flowers (USFWS unpublished data). In September 2016, only 18 of the 22 individuals were noted as healthy (USFWS unpublished data). As of July 2019, there are only five reintroduced individuals remaining (Bakutis pers. comm. 2019, p. 2).

Kawela Stream (KAW) — In 2016, the Kawela Stream reintroduced population of 20 individuals was monitored and noted as healthy (PEPP 2016, p. 212). In 2017, this population was revisited and two plants were noted as dead (PEPP 2017, p. 209). Currently, there are only six reintroduced individuals remaining (Bakutis pers. comm. 2019, p. 2).

Currently, there are two reintroduction sites at Kawela and Pēpē‘Ōpae Stream located within the Kamakou Preserve, which contain approximately 35 individuals (Bakutis, pers. comm. 2019, pp. 1-2). In particular, the Pēpē‘Ōpae Stream site is fenced and has been pig-free for more than two years. Weed control also occurs at this site by the Nature Conservancy (PEPP 2018, p. 19). The forest at the Pēpē‘Ōpae Stream site is high quality and intact, composed of approximatley 95 to 100 percent native plant community (PEPP 2018, p. 19).

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 *Schiedea laui* 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). Because the specific and cumulative effects of climate change on *S. laui* are presently unknown, we are not able to determine the magnitude of this possible threat with confidence.

Increased inter-annual variability of ambient temperature, precipitation, and hurricanes, would provide additional stresses on the habitat and to this species because *Schiedea laui* 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, *S. laui* already has limited environmental tolerances, ranges, restricted habitat requirements, small population sizes, and low numbers of individuals. 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).

CURRENT CONDITION

Description

Following the discovery of 19 individuals of *Schiedea laui* in 1998, a follow-up survey and monitoring trip in 2000 to the wild site was only able to relocate 9 individuals with a few immature plants and seedlings (Wagner et al. 2005, pp. 90–92). By 2006, only 13 plants were seen (PEPP 2007, p. 57). In 2010, there were 24 to 34 individuals in the same location in Kamakou Preserve (Bakutis 2010, pers. comm.). In 2014, there were 24 mature, 7 immature individuals, and 13 seedlings at the wild population (USFWS 2019, entire). Currently, this wild population was last monitored in July 2019 and there were 24 mature, 12 immature individuals, and 32 seedlings (Bakutis 2019, pers. comm.). As noted above, the number of individuals fluctuates from year to year, but there has never been more than 50 wild mature individuals known at a given time.

Currently, there are at least two reintroduction sites at Kawela and Pēpē‘Ōpae Stream located within the Kamakou Preserve, which contain approximately 35 individuals (Bakutis 2019, pers. comm.). Please refer to the *Threats and Conservation Efforts* section above for a more detailed description of the reintroduction efforts for this species. No naturally recruited individuals have been observed from the reintroduction sites.

Overall, the number of wild individuals for *Schiedea laui* is relatively stable but fluctuates from year to year. The only known wild population continues to survive for the last 20 years since it was discovered in 1998.

This species is known to occupy wet forest habitats. 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 *Schiedea laui* 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, flooding and landslides, rats, slugs, and low numbers.

Suitable habitat for *Schiedea laui* occurs in the wet forests on the windward sides of eastern Moloka‘i as described in the *Habitat Conditions* section above. Seeds of *S. laui* are dispersed naturally while it matures on the plant, therefore, its range and distribution is limited by its natural seed dispersal mechanism. Based on this species current breeding system of self-fertilization and very low population size, *S. laui* may be experiencing some level of inbreeding depression; therefore, the survival and fertility of its offspring may be low as is witnessed in the fluctuating population sizes from year to year.

Metrics for Resiliency, Redundancy, and Representation

Resiliency is the capacity of a population (or a species) to withstand stochastic disturbance events. We define resiliency for *Schiedea laui* based on the metric of population size.

Redundancy is defined as the ability of a species to withstand catastrophic events and is measured by the number of populations, connectivity, and distribution of the populations throughout the range of *Schiedea laui*. We define redundancy for *S. laui* 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 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.

Resiliency

For *Schiedea laui* 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 *S. laui* 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. Currently, there is only a single population of *S. laui* containing 24 mature and 12 immature individuals in the wild. The number of individuals have fluctuated over recent years but it has never gotten to more than 50 mature individuals in the wild. The confined range, diminished number of populations, and low total number of individuals have reduced the population and species resilience.

Additionally, the location of this single population near a stream and waterfall increases the potential for landslides, rockfalls, or flooding, which in turn damages or destroys individuals of *Schiedea laui* and its habitat. These events could eliminate this single isolated population that persist in low numbers and a limited geographic range, resulting in reduced resilience of this species and population. Our evaluation of resiliency on the population and species level is <u>very low</u>.

Redundancy

We define redundancy for *Schiedea laui* based on the metrics of the number of populations, resilience of populations, and the distribution of the species across its range. Currently, there is only a single known population for this species. The distribution of this species has not changed and is still very narrow and confined to the native wet forest habitat along stream corridors in east Moloka‘i. The resiliency on both the species and population levels are very low in the current condition. Additionally, the location of this single population near a stream and waterfall increases the potential for landslides, rockfalls, or flooding, which in turn damages or destroys individuals of *S. laui* and its habitat. These events could eliminate this single isolated population that persist in low numbers and in a limited geographic range, resulting in reduced redundancy for this species. The confined range, diminished number of populations, and low total number of individuals have reduced the redundancy of *S. laui*. Therefore, the evaluation of redundancy is <u>very low</u> in the current condition.

Representation
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 is no difference in the habitat occupied by *Schiedea laui*; it still occurs in the wet forest habitat, which is representative of its historical geographical and ecological distribution. Each of the physical or biological features described in the wet forest habitat in which the species occurs are essential to this species to retain its geographical and ecological distribution across the habitat that it occurs in. Each physical or biological feature is also essential to retaining the genetic representation that allows this species to successfully adapt to the environmental conditions in the wet forest habitat. Genetic and environmental diversity is not secured throughout the range of this species as only a single population is known. The remaining population is likely fragmented both physically (due to extensive habitat degradation) and functionally (due to self-fertilization and low genetic diversity). Therefore, the evaluation of representation is very low in the current condition.

Species Viability Summary
On the population level *Schiedea laui* has very low resiliency and on the species level it has very low redundancy and representation; therefore, the overall viability of this species is very low in the current condition (Table 2). Some redundancy and representation are maintained in *ex-situ* seed storage facilities, rare plant nurseries, and in the reintroduced population, but no reintroduced individuals resulting from these efforts have been documented to be naturally recruiting in the wild yet.

Table 2. Current viability of *Schiedea laui.*

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

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