# **Species Report for *Cyanea obtusa* (hāhā)**
Version 1.0

*Cyanea obtusa* (photo credit Hank Oppenheimer, Plant Extinction Prevention Program)

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## EXECUTIVE SUMMARY

This document presents the species report (SR) for *Cyanea obtusa* (hāhā), 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 and future condition.

*Cyanea obtusa* has a restricted range in the Hawaiian islands, occurring only on Maui. The species was previously known from both Haleakalā and Mauna Kahālāwai on Maui. The last wild individual of this species is located in the Manawainui gulch - Kahikinui region of Haleakalā (PEPP 2016; Oppenheimer pers. comm. 2019). The species is also represented by reintroduced populations in the Nakula Natural Area Reserve (NAR) on Haleakalā. Very little is known about *C. obtusa*; much of the information presented in this SR is inferred from closely-related *Cyanea* species, and we rely heavily on information from species experts. We focused our analysis on six primary threats that either significantly or potentially negatively affect the species – introduced ungulates, competition with alien plants, fire, predation (rodents, slugs and insects), limited numbers (small population dynamics and hybridization), and climate change. The synergistic effects of multiple stressors on this species have likely exacerbated declines.

Despite the fact that quality habitat is available within the historic range of *Cyanea obtusa*, no new wild populations have been discovered since 1997, with the exception of the single remaining wild individual in Manawainui gulch. There have been reports of hybrid individuals existing though (Oppenheimer 2022, pers. comm.). Therefore we cannot identify any reasonable measure of resiliency for the species. Furthermore, no additional wild populations of *C. obtusa*, distributed across any level of ecological conditions or spatial extent, are known to exist, and therefore we cannot identify any reasonable measure of genetic or ecological representation or redundancy for the species. Despite conservation efforts, there is currently only one founder line (Manawainui gulch source population) represented in controlled propagation for this species. This founder line has been reintroduced into the two areas on Haleakalā: Kahikinui (1 population) and Nakula NAR (6 populations) but these populations are not reproducing naturally, although not all reintroduced populations have been monitored since reaching maturity (Oppenheimer 2022, pers. comm.). This results in extremely low redundancy, extremely low resiliency, and extremely low representation for the species currently. Therefore, the current viability of *C. obtusa* is assessed as <u>extremely low.</u>

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## INTRODUCTION

*Cyanea obtusa* is a member of the Bellflower family (Campanulaceae) and was historically known from the wet to mesic forests of Haleakalā and Mauna Kahālāwai  on Maui (Hillebrand 1888, p. 254; HBMP 2008; Lammers 2004, p. 85-93; Wagner 1999).

### Species Report Overview

This biological report summarizes the biology and current status of *Cyanea obtusa* and was conducted by the 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

*Endangered Species Act*

In 2013 the Service determined the endangered status under the Endangered Species Act of 1973 (Act), as amended, for 38 plants and animals, including *Cyanea obtusa*, on Maui, Molokaʻi, and Lānaʻi (USFWS 2013).

*Critical habitat*

Under section 4(a)(3)(A) of the Act the Service is required to designate critical habitat to the maximum extent prudent and determinable concurrently with the publication of a final determination that a species is endangered or threatened. The Final Rule designating Critical habitat for 135 species on Molokaʻi, Lānaʻi, Maui, and Kahoʻolawe, including *Cyanea obtusa*, was published in 2016.  In this rule, a total of 14,870 acres (6,018 ha) of Critical Habitat was designated for *C. obtusa* on Maui. Ecosystem units included in unoccupied critical habitat designated for this species include Montane mesic and Lowland dry ecosystems.

Critical habitat for *Cyanea obtusa* contains the elevation, moisture regime, substrate, and canopy, subcanopy, and understory native plant species (primary constituent elements (PCEs)), identified as physical or biological features needed for species survival and recovery (USFWS 2016

**Methodology**
We used the best scientific data available to us, including peer-reviewed literature, grey literature (government, academic, and technical reports), and expert elicitation. To the best of our ability we used the current taxonomy at the time this report was drafted. Because little information is available about *Cyanea obtusa*, we also used reference material for closely related *Cyanea* species to fill in data gaps as well as using basic plant and animal biology to identify needs of individuals, populations, and species. 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. Finally, we created a centroid (i.e., point representing the center of a polygon) within each dissolved buffer area. The symbol marker represents the centroid. 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 biological report assesses the ability of *Cyanea obtusa* 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 *C. obtusa*, we used the three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs" (Figure 2; USFWS 2016). 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.

For a species to sustain populations over time it needs a sufficient number and distribution of viable populations to withstand environmental stochasticity (resiliency), catastrophes (redundancy), and changes in its environment (representation). We looked at the condition of *C. obtusa* in the context of factors that may be influencing the species as habitat loss and degradation, introduced ungulates and plants, climate change, small population dynamics, herbivory by insects, introduced slugs and snails, synergistic effects, and beneficial actions.

For purposes of this species report, a population is defined as a group of conspecific individuals that are in close proximity to each other (i.e., less than 1,000m apart, and are presumed to be genetically similar and capable of sexual (recombinant) reproduction (HPPRCC 2011). We considered historic wild and current reintroduced populations on Haleakalā (Nakula NAR, Manawainui gulch, Kahikinui FR) to be in essentially the same region of the island and not sufficiently distant that hurricane landfall (with accompanying extreme high winds and extremely heavy rainfall) on Maui would most likely substantially impact the species' populations in the region.

We consider those species with greater numbers of distributed populations, and populations with greater numbers of individuals, to be better able to withstand stochastic events. Reintroduced populations were not considered in the viability analysis if they are not recruiting naturally. We also consider that species without seeds in genetic storage or plants in nurseries and greenhouses, to be more at risk should a broadscale catastrophic event effect multiple in situ (wild and outplanted) populations. We consider smaller populations (<20 individuals) to be at greatest risk of extirpation by stochastic demographic and environmental events.

**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.

For *Cyanea obtusa*, we can measure resiliency based on metrics of population size and freedom from threats, including herbivory and introduced invasive plants. Larger populations protected from ungulates and invasive plants are better able to withstand disturbances such as random fluctuations, for example fluctuations in seed set (demographic stochasticity), variations in rainfall (environmental stochasticity), drought and other factors.

**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.

For genetic diversity we have not identified specific genetic differences among wild populations, but consider populations > 1,000 meters (m) apart to be genetically distinct. We evaluate ecological representation based on the number of ecosystem types where *Cyanea obtusa* occurs.

**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.

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 *Cyanea obtusa.*

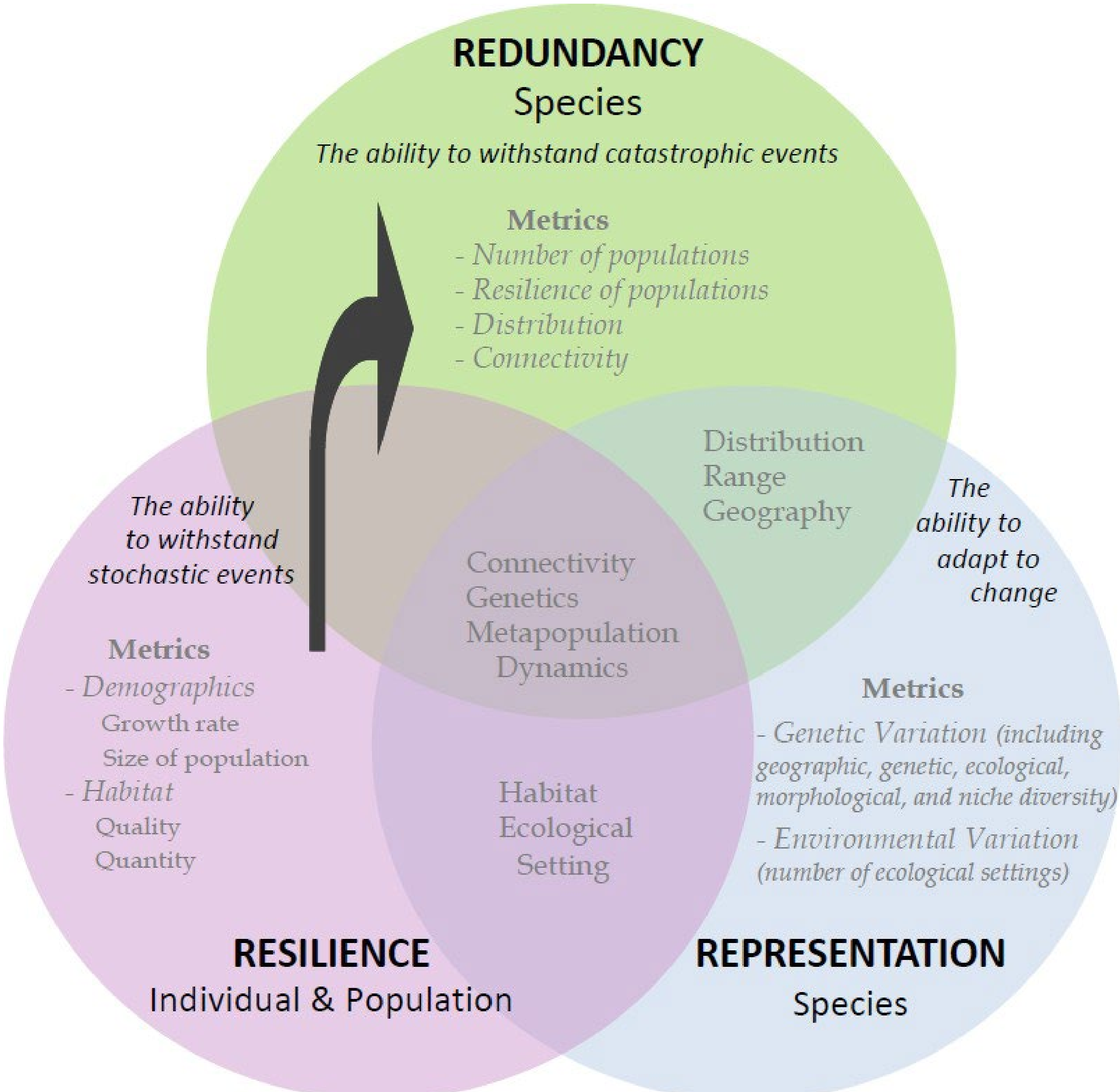


Figure 2. The three conservation biology principles of resiliency, redundancy, and representation, or the "3Rs"

**SPECIES' NEEDS / ECOLOGY**

**Species Description**

*Cyanea obtusa* (hāhā), is a shrub endemic to Maui and in the bellflower family (Campanulaceae), approximately 2 to 5 meters (m) (6.6 to 16 feet (ft)) tall, with branched and pubescent stems. Leaves are oblong to oblanceolate, with blades 15 to 30 centimeters (cm) (6 to 12 inches (in)) long and 4 to 9 cm (1.6 to 3.5 in) wide, with the upper surface green and sparsely pubescent, and the lower surface pale green and densely pubescent. Inflorescences are 6 to 12-flowered, densely pubescent, and with peduncles 20 to 50 millimeters (mm) (0.8 to 2.0 in) long. The hypanthium is obovoid, with narrowly triangular calyx lobes 1 to 2 mm (0.04 to 0.08 in) long. The corolla is

purplish to cream, where the wild plants have flowers observed that are white with magenta and purple stripes and reintroduced plants have flowers that are more cream in color, 30 to 36 mm (1.2 to 1.4 in) long, 1.5 to 3 mm (0.06 to 0.12 in) wide, and is also densely pubescent.
(Lammers 1999, p. 458). Fruits of reintroduced individuals are reported to be pale yellow-orange colored (Oppenheimer 2022, pers. comm.) It should be noted that the fruit and flower colors were from observations of only a few specimens.

**Taxonomy**
*Cyanea obtusa* was described by Hillebrand and was recognized as a distinct taxon in Lammers (1999) and Wagner and Herbst (2003), the most recently accepted Hawaiian plant taxonomy.

**Historic Distribution and Assessment of Viability**
*Cyanea obtusa* was first described in 1888 by Hillebrand. Kahālāwai In the absence of the threats that arrived with human occupation of the island, the species likely had more resilient populations. Historically, the species was likely pollinated by members of the honeyeater family (Meliphagidae), by native honeycreepers (Drepanididae) (a majority of which are now extinct), as well as by generalist honeycreepers, which still exist today but no longer overlap in range with *C. obtusa.* At that time Hillebrand first described *Cyanea obtusa* in 1888, the species was only documented in the mesic forest on Haleakalā. Over the next 100 years, at least seven other occurrences were documented. At the time of listing, one population was known, consisting of one wild individual.

**Recent Range**
The known range of *Cyanea obtusa* was from Haleakalā and Mauna Kahālāwai on Maui (Hillebrand 1888, p. 254; HBMP 2008; Medieros et al. 1986). This includes the mesic forests of Makawao, and Manawainui gulch in the Kahikinui region of Haleakalā, where it was rediscovered in 1996 after being presumed extinct for 70 years. The species was known from the Ulupalakua on Haleakalā and from the mesic forests of Paplaua-Manawainui, Pohakea, and Waikapu on Mauna Kahālāwai . It was also known from the wet to mesic forests (wet cliff subtype) of Panaewa on Mauna Kahālāwai (Table 1; Figure 3).

Table 1. Known locations of wild populations

| Name | Geographic Location | Population Type | Number Individuals | Last seen in the wild |
|---|---|---|---|---|
| Ulupalakua (A) | Haleakalā | Wild | no data | 1888* |
| Manawainui gulch – Kahikinui (B) | Haleakalā | Wild | 1+ | 2016 |
| Makawao (C) | Haleakalā | Wild | 5-10+ | 1997+ (only C. elliptica observed since 1997) |
| Makawao (D) | Haleakalā | Wild | no data | 1919* |
| Papalaua-Manawainui (E) | Mauna Kahālāwai | Wild | 0 | before 1998* |

| | | | | |
|---|---|---|---|---|
| Pohakea * (E) | Mauna Kahālāwai | Wild | 1+ | 2001+ (only hybrids since 2009)* |
| Waikapu (F) | Mauna Kahālāwai | Wild | no data | 1800* |
| Panaewa (G) | Mauna Kahālāwai | Wild | 1+ | 1972 |

PEPP 2016-2019; HBMP 2008*; NTBG 2009; DLNR 1989; Hank Oppenheimer pers. comm. 2019+

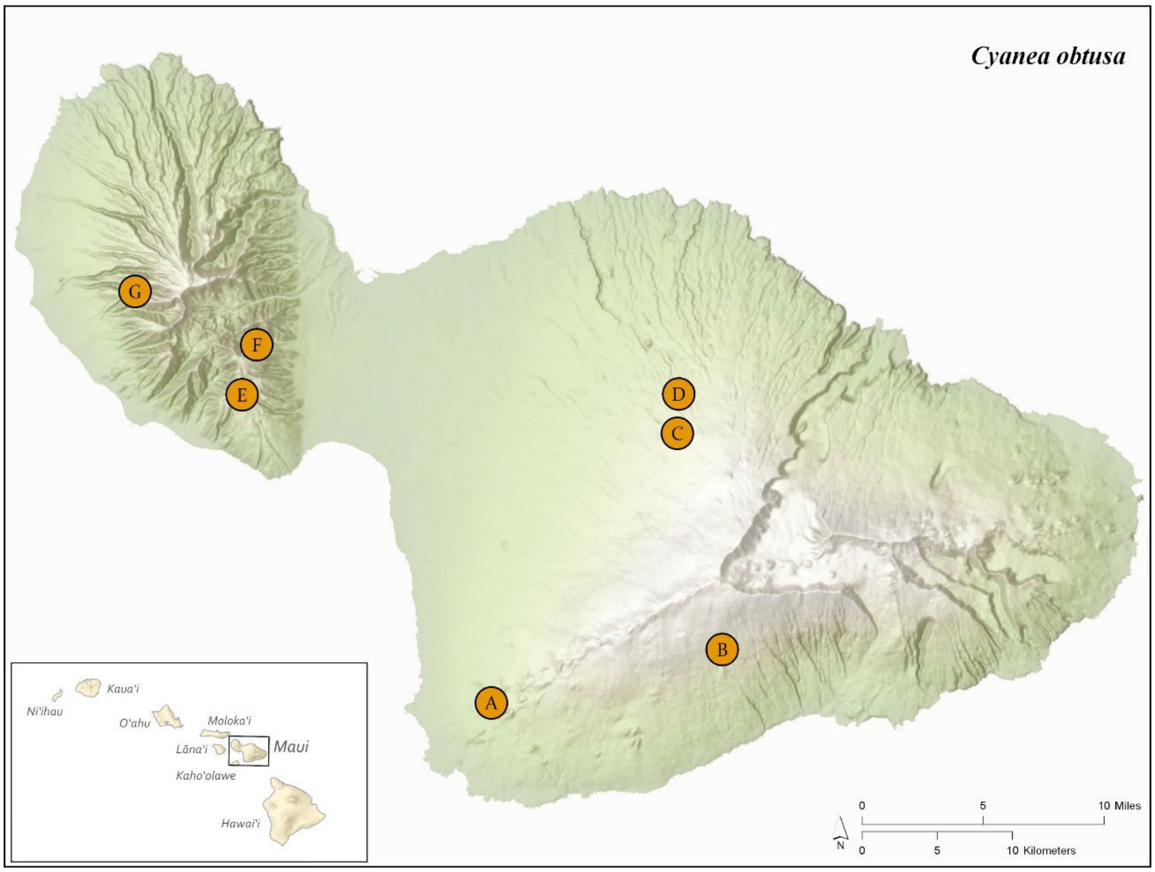


Figure 3. Known range of *Cyanea obtusa* on Maui

**Individual Needs**

*Phenology and Reproduction*

The specific life history characteristics of *Cyanea obtusa* have not been studied extensively. Little is known about the phenology and reproduction of *Cyane*a species, except the time of flowering and fruiting. *Cyanea obtusa* has been observed in flower in September, and fruits observed from October to December (Oppenheimer 2022, pers. comm.). Flowering of similar *Cyanea* species have been observed between early summer and early fall, with fruit peaking between December and May (Lammers 2004, p. 85-93; NTBG 2009a, p. 1; NTBG 2009b, p.1;

PEPP 2010-2018; Oppenheimer pers comm. 2019). There is evidence nectarivorous (animals that feed on nectar) Hawaiian forest birds (many now extinct) were important pollinators of *Cyanea* and other lobeliads, and frugivorous (animals that feed on fruit) Hawaiian forest birds (many now also extinct) were important seed dispersers (Lunau 2004, p. 210; Jennings et al. 2015, p. 4).

**Population Needs**

Population size affects population viability through genetic health. Small populations have lower levels of genetic diversity (heterozygosity), which reduces the capacity of a population to respond to environmental change. Inbreeding depression may result, leading to reduced longevity and fecundity and overall population fitness (Darvill et al. 2006, p. 602).
Thus, population viability requires occupying areas with a diversity of environmental conditions (spatial heterogeneity) to ensure populations are secure despite year-to-year variations in climatic variables, such as temperature and precipitation. Similarly, spatial heterogeneity increases the likelihood of long-term metapopulation persistence (Hanski 1999, p. 28). In spatially heterogeneous populations, it is unlikely that the entire population will contemporaneously experience the same environmental conditions, thus ensuring that not all individuals comprising a population will fail due to unfavorable conditions.

Historically, populations of *Cyanea obtusa* were known from mesic ecosystems between 1300-1830 m (Wagner et al 1999a). Characteristics of these habitat types are found in Table 2 and are further described in the Hawaiian Habitat Assessments (HSA) for these ecosystems (Peʻa et al. 2019, *in press*; Ball et al. 2019, *in press*; Nelson et al. 2019, *in press*; Lowe et al. 2019, *in press*).

The population size required to support a viable population is likely variable across spatial scales and is unknown for *Cyanea obtusa*. However, generally speaking, the larger the population, the more genetically healthy and thus the more robust to extirpation.

Another important aspect of population viability is connectivity between populations to ensure out-crossing of unrelated reproductive individuals and connectivity among populations to maintain within-population genetic diversity. Lastly, the degree of spatial heterogeneity across the population area reduces the chances of all populations failing concurrently due to poor environmental conditions, and thus, is important for long-term persistence of the species.

Table 2. Characteristics of current ecosystems where *Cyanea obtusa* occurs/occurred

| **Current HSA Ecosystem** | **Island(s)/Region** | **Elevation (m)*** | **Precipitation (cm)*** |
|---|---|---|---|
| Mesic forest | Maui/ Haleakalā and Mauna Kahālāwai | 30-2,000 m | 100-380 cm |
| Wet forest and shrublands (wet cliff subtype) | Maui/ Mauna Kahālāwai | 200-900 m | 250-500 cm |

*m= meters; cm=centimeters

**Synopsis of Species' Ecological Needs**
Viability is the likelihood that a species will sustain populations over time. To do this, *Cyanea obtusa* needs a sufficient number and distribution of self-sustaining populations to withstand environmental stochasticity (resiliency), adapt to changes in its environment (representation), and withstand catastrophes (redundancy) (Table 3).

Table 3. Ecological requirements for species-level viability in *Cyanea obtusa*

| 3Rs | Requisites of long-term viability | Description |
|---|---|---|
| Resiliency (able to withstand stochastic events) | Interconnected, healthy populations across a diversity of climatic conditions | Populations with:<br>1) large $N_e$, sufficient number of individuals in close proximity to ensure pollination (out-crossing)<br>2) connectivity between populations, and<br>3) spatial heterogeneity; high connectivity among populations dispersed across diverse climatic conditions (spatial heterogeneity) |
| Representation (to maintain evolutionary capacity) | Maintain adaptive diversity of the species | Healthy populations distributed across areas of unique adaptive diversity (i.e., ecoregions, ecosystems) |
| | Maintain evolutionary processes | Maintain evolutionary drivers - gene flow, natural selection, genetic drift - to mimic historical patterns |
| Redundancy (to withstand catastrophic events | Sufficient distribution of healthy populations | Sufficient distribution to guard against catastrophic events wiping out portions of the species adaptive diversity, i.e., to reduce covariance among populations |
| | Sufficient number of healthy populations | Adequate number of healthy populations to buffer against catastrophic losses of adaptive diversity |

**Species' Needs / Ecology**
The native Hawaiian bird-pollinated flora of Hawaiʻi is primarily composed of six lobeliad genera, including *Cyanea*, collectively containing approximately 126 species (Givinish et al. 2009, p. 407). Historically, these genera were believed to have been pollinated by different species of specialist nectarivorous birds, the Hawaiian honeycreepers (Drepanidae) and honeyeaters (Meliphagidaae) (Lunau 2004, pp. 209-210). The most striking coadaptation in *Cyanea* with nectivorous Hawaiian forest birds is the corolla tube length, ranging from 15 to 85 mm (0.6 to 2.3 in), and the curvature of the corolla tube, traits that seem to have coevolved to bill size and shape of pollinating birds (Lunau 2004, p. 210). Since human colonization of Hawaiʻi, both nectarivorous birds and native plant species that depend on them for pollination have undergone wide-scale declines and extinctions (Cory et al. 2015, p. 255). The Hawaiian honeyeaters are now extinct and only two of the five specialist nectarivorous Hawaiian honeycreepers that coevolved with lobeliads remain (Cory et al. 2015, p. 256). Surviving honeycreepers are now limited to high elevations (above approximately 5,000 ft) and do not overlap with the distribution of most populations of the *Cyanea*

species in this SR (Cory et al. 2015, p. 256). Furthermore, many species of frugivorous Hawaiian forest birds that dispersed *Cyanea* fruits also are now extinct (Lunau 2004, p. 210; Jennings et al. 2015, p. 4). It is possible that introduced frugivores could potentially disperse fruit as they do for other native plants (Oppenheimer 2022, pers. comm.).

Members of the taxon in Hawaiʻi have well developed fleshy fruits, a feature commonly found in plants requiring birds for dispersal (Carlquist 1980, p. 96)

## FACTORS INFLUENCING VIABILITY

### Threats and Conservation Actions

***Threats***

The immediate and potential extrinsic and intrinsic threats facing *Cyanea obtusa* include the destruction and adverse modification of habitat by feral ungulates (hoofed mammals), competition with alien plants, fire, herbivory and seed predation by introduced rodents, insects, and slugs, limited numbers (hybridization), and climate change. These threats are summarized in Table 4.

Table 4. Summary of Threats to *Cyanea obtusa* (Maui PEPP 2016-2018)

| **Feral Ungulates (Browsing/ Trampling)** | **Alien Plants** | **Fire** | **Insects** | **Slugs** | **Rodents** | **Limited Numbers*/risk of hybridization** | **Climate change** |
|---|---|---|---|---|---|---|---|
| X | X | X | P | X | X | X [1,2] / P | P |

X=Immediate and significant threat
P= Potential Threat
*No more than 40 individuals and/or fewer than 10 populations

1 No more than 40 individuals
2 Fewer than 10 populations

### Extrinsic Threats

*Degradation of native ecosystems*

The native plants of the Hawaiian Islands evolved in the absence of mammalian predators, browsers, or grazers. Many of the native species have lost unneeded defenses against threats such as mammalian predation and competition with aggressive, weedy plant species that are typical of continental environments (Loope 1992, p. 11; Gagne and Cuddihy 1999, p. 45; Wagner et al. 1999, pp. 3-6). For example, Carlquist (in Carson 1974, p. 29) notes ``Hawaiian plants are notably free from many characteristics thought to be deterrents to herbivores (toxins, oils, resins, stinging hairs, coarse texture)." Native Hawaiian plants are therefore highly vulnerable to the impacts of introduced mammals and alien plants. In addition, species restricted and adapted to highly specialized locations are particularly vulnerable to changes (from nonnative species, hurricanes, fire, and climate change) in their habitat (Carlquist and Cole, in Carson 1974, pp. 28-29; Loope 1992, pp. 3-6; Stone 1989, pp. 88-95; Ball et al. 2019, *in press*; Lowe et al. 2019, *in press*; Nelson et al. 2019, *in press*; Peʻa et al. 2019, *in press*).

*Browsing and trampling by introduced ungulates*

Non-native ungulates (feral pigs, goats, cattle, and axis deer) are a threat to the ecosystems known to support *Cyanea obtusa* (Ball et al. 2019, *in press*; Lowe et al. 2019, *in press*; Nelson et al. 2019, *in press*; Pe‘a et al. 2019, *in press*). The effects of these nonnative animals include the destruction of vegetative cover that may lead to treefall and landslides; trampling of plants and seedlings; consumption of native vegetation; 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; Wagner et al. 1999a). All of these impacts lead to the subsequent conversion of native plant communities to plant communities dominated by nonnative species.

*Competition with Invasive plants*

Nonnative plants are a threat to the ecosystems known to support *Cyanea obtusa* (Ball et al. 2019, *in press*; Lowe et al. 2019, *in press*; Nelson et al. 2019, *in press*; Pe‘a et al. 2019, *in press*). Invasive plants observed to threaten habitat and reintroduced populations include: *Bocconia frutescens* (plume poppy), *Ageratina adenophora* (sticky snakeroot), *Cenchrus clandestinum* (kikuyu grass), *Melinus minutiflora* (molasses grass), *Rubus rosifolius* (thimbleberry), and *Sphaeropteris cooperi* (Australian tree fern) (PEPP 2016-2018; Oppenheimer 2022, pers. comm.). 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). The most-often cited effects of nonnative plants on native plant species are displacement through competition. Competition may be for water or nutrients, or it may involve allelopathy (chemical inhibition of other plants) (Smith 1985 *in* Cuddihy and Stone 1990, p. 74). Nonnative plants may also displace native species by preventing their reproduction, usually by shading and taking up available sites for seedling establishment (Vitousek et al. 1987 *in* Cuddihy and Stone 1990, p. 74).

*Fire*

Fire is a primary threat to the dry and mesic grasslands and shrublands and the mesic forest ecosystems (Ball et al. 2019, *in press*; Lowe et al. 2019, *in press;* Pe‘a et al. 2019*, in press*). *Cyanea obtusa* is adversely impacted by fire primarily in the lowland mesic grassland and shrubland system and in the montane mesic forest ecosystems because individuals of this species, or its known habitat, is located in or near areas that were burned in previous fires or in areas at risk for fire (USFWS 2016). Between the years 2007 and 2010, wildfires burned more than 8,650 ac (3,501 ha) on Mauna Kahālāwai (Shimogawa 2010, in litt.; Honolulu Advertiser 2010, in litt.). In 2007, a fire that started along Honoapiilani Highway on the south coast of Mauna Kahālāwai burned a total of 1,350 ac (546 ha), encroached into the West Maui Natural Area Reserve (Panaewa section), and placed at risk habitat known to support *C. obtusa* (HDLNR 1989, pp. 53- 63). There have also been wildfires in the Kahikihui region, which is closest to the last wild individual of *Cyanea obtusa* (Oppenheimer 2022, pers. comm.). Loss of mesic forest and dry and mesic grassland and shrubland ecosystems due to fire, decreases representation and redundancy of ecosystems that support the species.

*Climate change (drought/storms)*

Changing climate is considered a primary threat to ecosystems known to support *Cyanea obtusa* (Ball et al. 2019, *in press*; Lowe et al. 2019, *in press*; Nelson et al. 2019, *in press*; Pe‘a et al.

2019, *in press*). The species has limited environmental tolerances, limited 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 habitats. These impacts include long periods of decline in annual precipitation resulting in a reduction in moisture availability, an increase in drought frequency and intensity, and a self-perpetuating cycle of nonnative plants (such as nonnative grasses adapted to fire and dry conditions) intruding and displacing native plant communities.

In a climate change vulnerability study, *Cyanea obtusa* was found to have a med-high level of vulnerability to predicted climate change (Fortini et al. 2013, p. 84). Findings of the study showed an increase in vulnerability from wet to dry ecosystems, with dry systems being most at risk (Fortini et al. 2013, p. 37).

*Rodents*

Invasive rodents (*Rattus rattus* and *Mus musculus*) are a prominent stressor for vegetation in the ecosystems that support *Cyanea obtusa* (Pe‘a et al. 2019, *in press*; Lowe et al. 2019, *in press*; Ball et al. 2019, *in press*; Nelson et al. 2019, *in press*). All three species of rat (black, Norway, and Polynesian) have been reported to adversely impact many endangered and threatened Hawaiian plants (Stone 1985, p. 264; Cuddihy and Stone 1990, pp. 67–69). Rodents damage plant propagules, seedlings, and native trees, which changes forest composition and structure (Cuddihy and Stone 1990, p. 67). Black rats strip bark from some native plants, and are known to eat the fleshy stems and fruits of plants in the bellflower family (Tomich 1986; Cuddihy and Stone 1990, p. 68-69; J. Lau, pers. comm. 1994). Stem damage to other *Cyanea* species by rats has been reported in the wet forests of Kaua‘i and in the mesic montane forests on the island of Hawai‘i (Jack Jeffrey, Service, pers. comm. 1995). To date, there has been no natural recruitment observed in reintroduced populations of *C. obtusa*. Rat traps were deployed seasonally around the last wild individual during flowering and fruiting to prevent damage to the plants (Oppenheimer 2022, pers. comm.). Because rodents are known to damage fruits and stems of other *Cyanea* species, we consider rodent herbivory to be a threat to the species, reducing its representation and resiliency.

*Insects*

Introduced insect species are a negative stressor on ecosystems supporting *Cyanea obtusa* (Pe‘a et al. 2019, *in press*; Lowe et al. 2019, *in press*; Ball et al. 2019, *in press*) There is a serious threat of widespread impacts of feeding or defoliation of native plants from alien insects which may even reduce the geographic range of some species (Cuddihy and Stone 1990, p. 71). Alien insect predation on native insects affects pollination of native plant species (Cuddihy and Stone 1990, p. 71). Significant changes in nutrient cycling processes because of large numbers of alien invertebrates may also result in changes to the composition and structure of ecosystems (Cuddihy and Stone 1990, p. 73). To date, there has been no natural recruitment observed in reintroduced populations of *C. obtusa*. Studies are needed to determine if alien insects are influencing recruitment of the species.

*Predation by non-native snails and slugs*

The health of ecosystems supporting *Cyanea obtusa*, particularly mesic forests, are affected by introduced herbivores, including non-native slugs and snails (Lowe et al. 2019, *in press*). Nonnative snails and slugs are found in mesic forest ecosystems where *C. obtusa* occurs and are considered to be a threat to seedling recruitment by the PEPP program (PEPP 2010- 2019). Predation by nonnative snails and slugs adversely impacts native plant species through mechanical damage, destruction of plant parts, and mortality. Joe and Daehler (2008, p. 252) found that native Hawaiian plants are more vulnerable to slug damage than nonnative plants. In particular, they found that a similar species of *Cyanea* (*Cyanea superba*) had a 50 percent higher mortality when exposed to slugs when compared to individuals of the same species that were protected within slug exclosures. Research investigating slug herbivory and control methods shows that slug impacts on seedlings of a similar *Cyanea* spp. resulted in up to 80 percent seedling mortality (U.S. Army Garrison 2005, p. 3-51). Herbivory by introduced snails and slugs on *C. obtusa,* results in reduced resiliency of the species.

**Intrinsic threats**

*Small population dynamics*

There are current and ongoing threats to this species due to factors associated with small numbers of populations and individuals. There is only one wild individual known and it was last observed in 2016 (Oppenheimer pers. comm. 2019).

These threats are exacerbated by this species inherent vulnerability to extinction from stochastic events (low resiliency and redundancy) at any time because of its endemism, small numbers of individuals and populations, and restricted habitats. With only seven reintroduced populations of 40 or fewer total individuals, reduced reproductive vigor and extinction due to stochastic events, such as hurricanes or landslides, are also threats to *Cyanea obtusa.*

*Limited Number of Individuals and Populations*

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 very small geographic area (low redundancy), and when the number of individuals in each population is very small (low resiliency). 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). Very 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.

We consider the limited numbers of populations and few individuals (<40) within these to be a serious and ongoing threat to *Cyanea obtusa*. In addition, the species has only one wild individual remaining (Oppenheimer pers. comm. 2019) and is only represented by seven reintroduced populations (none of which are naturally recruiting), from one founder line. The species is planted in a narrow region on Haleakalā making it susceptible to threats from habitat degradation or loss by erosion, flooding, landslides, or tree falls, or a combination of these, because of its limited distribution in the mesic forest ecosystem and in locations with steep terrain (USFWS 2013; PEPP 2009, pp. 23–24, 49–58). Rare species 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.

*Hybridization*
Hybridization adversely impacts *Cyanea obtusa* through reduced representation, and may lead to its extinction as a genotypically distinct species. On Haleakalā, *C. obtusa* is known from one wild individual, but only hybrids between *C. obtusa* and the more abundant *C. elliptica* are known from Mauna Kahālāwai  populations (Oppenheimer 2022, pers. comm.). Natural hybridization is a frequent phenomenon in plants and can lead to the formation of new species (Orians 2000, p. 1,949), or sometimes to the decline of species "through genetic assimilation or introgression" (Ellstrand 1992, pp. 77, 81; Levin et al. 1996, pp. 10-16; Rhymer and Simberloff 1996, p. 85). Hybridization, however, is especially problematic for rare species like *C. obtusa* that come into contact with species that are abundant or more common (Rhymer and Simberloff 1996, p. 83).

*Endemism*
The historic distribution of *Cyanea obtusa* is poorly understood, however, the topography of Maui, with many watersheds separated by cliffs and other steep terrain has contributed to speciation in the Maui *Cyanea.* While endemism is not a threat, per se, it increases the species' vulnerability to other threats. For example, climate change could further reduce the amount of potential habitat, or a single prolonged drought or catastrophic rainfall and flooding could increase mortality throughout the species range decreasing its redundancy and representation.

*Lack of genetic diversity*
The relative dearth of genetic diversity (low representation) and high levels of inbreeding expected for rare *Cyanea* species may be partly due to few founders and isolated populations historically (low redundancy), or lack of genetic diversity may have occurred recently because of an absence of honeycreepers and honeyeaters, important pollinators of *Cyanea* and other Lobeliads (Jenning et al. 2015, p 1), insect pollinators or fruit dispersing forest birds. A lack of genetic diversity may reduce the potential to adapt to new or existing diseases and parasites, extreme weather, and climate changes. Low genetic diversity may also limit fertilization and seed production resulting in low resiliency.

*Pollinator deficiency*
*Cyanea* and other lobelioids appear to have coevolved with Hawaiian honeycreepers (Drepanididae) and honeyeaters (Meliphagidae), both which served as pollinators (Lunau 2004, p. 210). We currently do not have information on the role of insect pollinators in *Cyanea* spp. With the complete disappearance of honeyeaters and surviving honeycreepers now limited to high elevation areas and little overlap with the *Cyanea* spp. in this SR, these *Cyanea* species may suffer from reduced opportunities for outcrossing and potential in-breeding and in-breeding depression resulting in reduced representation. In an attempt to assess if lobelioid species can produce viable

seeds in the absence of pollinators, two pollination treatments were applied to two Hawaiian lobelioid species, *Clermontia kakeana* and *Cyanea angustifolia*, in single populations of each species on Oʻahu (Cory et al. 2015, p. 256). In each lobelioid species, mean seed counts were not significantly different in fruits resulting from open-pollinated and pollinator-excluded flowers. This suggests that both species are capable of autogamy and can produce seeds in the absence of pollinators and/ if in-breeding depression may be a threat due to pollinator deficiency. It is possible that this species may still produce viable seeds without out-crossing, as viable seed has been produced from a single wild plant (Oppenheimer 2022, pers. comm.).

*Population fragmentation and isolation*
An important factor for long-term management of *Cyanea* species is the effective pollination range of its pollinators. For purposes of population management we estimate that genetically diverse individuals should be not more than about 1,000 m for high fertilization rates to occur. Population fragmentation and isolation of individuals results in reduced representation and may decrease the likelihood of successful reproduction as the progeny of small colonies are too closely related to fertilize each other and lack of pollinators prevent genetic exchange among isolated colonies.

**Other threats**
*Inadequate Regulatory Mechanisms*
Current biosecurity regulations and existing funding is not sufficient to prevent the ongoing impact from introduced species which pose a threat to ecosystems that support *Cyanea obtusa* (Peʻa et al. 2019, *in press*; Lowe et al. 2019, *in press*; Ball et al. 2019, *in press*; Nelson et al. 2019, *in press*). With no change in current conservation management parameters, threats from established pests (e.g., nonnative ungulates, weeds, and invertebrates) are expected to continue into the future (Peʻa et al. 2019, *in press*; Lowe et al. 2019; *in press*; Ball et al. 2019, *in press*; Nelson et al. 2019, *in press*). Existing State and Federal regulatory mechanisms are not preventing the introduction into Hawaii of nonnative species or the spread of nonnative species between islands and watersheds (USFWS 2016).

**Conservation Efforts**
*State Reserves*
A mesic forest ecosystem containing reintroduced populations of *Cyanea obtusa* is found within the State's Nakula Natural Area Reserve (NAR) on Haleakalā (Lowe et al. 2019, *in press*). The Nakula NAR was formally established in 2011 from lands withdrawn from the Kahikinui Forest Reserve (FR). The 1,500 acre (ac) (607 hectare (ha)) Reserve was created to protect leeward Haleakalā mesic koa (*Acacia koa*) forest and natural communities, including rare and endangered plants and animals. Management activities within the NAR include forest restoration, native species restoration (plants and animals), invasive species control (ungulates and weeds), mammalian predator control, fire prevention, and response to non-native insects and disease (DLNR 2015, pp. 1-2). Mesic forest ecosystem management efforts help to increase resiliency and representation of reintroduced *C. obtusa* populations within the NAR. Fences have also been constructed at the Kahakuloa Game Management Area on Mauna Kahālāwai where individuals of *C. obtusa* occurred in the late 1990's (Maui Pineapple Company, Ltd. 1999).

*Watershed Partnerships*

The Leeward Haleakalā Watershed Restoration Partnership (LHWRP) manages lands where reintroduced populations of *Cyanea obtusa* occur. Most of the ongoing conservation management actions undertaken by the LHWRP, and also with the State of Hawaii Department of Forestry and Wildlife (DOFAW), addresses threats to upland habitat from nonnative species (e.g., feral ungulates, nonnative plants) and may include fencing, ungulate removal, nonnative plant control, and outplanting of native, as well as rare native, species on lands within the partnership (HAWP 2018; Lowe et al. 2019, *in press*). These efforts help to increase resiliency and representation of *C. obtusa* populations occurring within the LHWRP watershed partnership area.

*Plant Extinction Prevention Program (PEPP)*

The State of Hawaii's Plant Extinction Prevention (PEPP) Program collects, propagates, and outplants species with <50 plants remaining in the wild, including *Cyanea obtusa* (PEPP 2019). In addition to evaluating the viability of PEPP populations, staff conduct fencing, weed control, and predator control (slugs, rodents) at sites where *C. obtusa* and other PEPP species have been reintroduced (Table 5). The PEPP program has reintroduced 7 populations of *C. obtusa*, but natural recruitment has not been observed at these sites (Table 6). Botanists with the program also conduct extensive surveys for rare plant species in areas where wild populations were known to exist historically (Maui PEPP 2018, pp. 37-47; Table 1). Staff adhere to strict biosanitation protocols developed by the PEPP program which includes removal of invasive plants, animals, or pathogens through the decontamination of vehicles, helicopters, tools, equipment, supplies, clothes, hands, etc. to prevent introduction or infestations of contaminants to protected plant populations and sites (PEPP 2017, p.1) Efforts by the PEPP program helps to increase the resiliency, representation and redundancy of this species.

Table 5. Management actions at PEPP reintroduction sites

| **Pop ref code** | **Location (E Maui)** | **Last census** | **Fenced** | **Ungulates present** | **Other Threats** | **Habitat Management** |
|---|---|---|---|---|---|---|
| MA-PAI | Waiopai Nakula NAR | +2016 *2017 | X | No | Rats, slugs | Weed control |
| MA-MNG | Manawainui gulch (Kahikinui) | 2015-16 | X | Yes | Rats, slugs | Weed control |

(PEPP 2016-2018)

Table 6. Reintroduced populations of *Cyanea obtusa*

| **Population reference code (Founder lines)** | **Location Haleakalā** | **Last obs.** | **Number of populations** | **Number ind. per site** | **Total number ind.** | **Natural recruitment?** |
|---|---|---|---|---|---|---|
| MA-PAI | Waiopai Nakula NAR | +2016 *2017 | 6 | 4-9 | 34 | No |
| MA-MNG | Manawainui gulch | 2018 | 1 | 4 | 4 | No |

(PEPP 2016-2018)

*Olinda Rare Plant Facility (ORPF) and Lyon Arboretum*
*Cyanea obtusa* had been successfully propagated at the Olinda Rare Plant Facility (ORFP) where one reference collection (founder line) was maintained (1 plant) for the purpose of controlled propagation. There are currently no reference collections of *C. obtusa* in genetic storage at ORPF, but it is represented by 49 explants in micropropagation at Lyon Arboretum's Micropropagation Laboratory (Lyon Arboretum 2022) (low representation).

Table 7. *Cyanea obtusa* reference populations in controlled propagation, seed storage and micropropagation

| Population Reference Code (ref site) | Reference Location | Seed Storage (Lyon Arboretum) | Micropropagation (Lyon Arboretum) | Propagation (Olinda Rare Plant Facility) |
|---|---|---|---|---|
| MA-MNG | Manawainui gulch (East Maui) | - | X | - |

Source: ORPF 2018, Lyon Arboretum 2022

## CURRENT CONDITION

### Current Status

Currently, this species is known from one wild individual last observed in the mesic forest ecosystem of Haleakalā in 2016 (Table 8; Oppenheimer pers. comm. 2019). Botanists continue to search the potentially suitable habitat near the last known locations for this species (PEPP 2019). It is also known from seven reintroduced populations composed of one founder line, totaling approximately 38 individuals (none of which are naturally recruiting), all on Haleakalā (Table 6; PEPP 2019). There is one founder line (Manawainui gulch) represented in micropropagation (1 plant) at Lyon Arboretum's Micropropagation Laboratory (Table 7).

Table 8. Location of wild *Cyanea obtusa*

| Name | Ecosystem type | Pop. type | Number of pops. | Region | Number individuals | Date of last census/obs. |
|---|---|---|---|---|---|---|
| MA-MNG | Mesic forest | Wild | 1 | Haleakalā (Kahikinui) | 1 | 5/2016 |

PEPP Report 2016-2019, Oppenheimer 2022, pers. comm.

### Description of Current Condition

There is only one wild *Cyanea obtusa* remaining (PEPP 2019; Oppenheimer pers. comm. 2019; Table 8). There are seven reintroduced populations, totaling approximately 38 plants, none of which are naturally recruiting. All of the reintroduced populations occur on Haleakalā in the mesic forests of Kahikinui and in the Nakula NAR (PEPP 2016-2019; Oppenheimer pers. comm. 2019). The number of plants in each reintroduced population ranges from 4-9 per site (Table 6). The species is represented in controlled propagation by one founder line in an ex situ collection at Lyon Arboretum's Micropropagation Laboratory.

***Resiliency***: Currently, we know of only a single wild individual. The seven reintroduced populations total 38 plants or fewer (avg. 4-9 individuals per site), none of which are naturally recruiting, and therefore not yet supporting the resiliency of the species. The single remaining wild population has the potential to be eliminated by a single stochastic event, such as grazing by ingress feral ungulates, erosion, treefall, storm events with heavy rainfall, fire, or herbivory by rats and slugs. The wild individual of *Cyanea obtusa* is also vulnerable to impacts of erosion and flooding because it occurs along a steep gulch (Oppenheimer pers. comm. 2019). These ongoing threats make it more difficult for the species to recover from other stochastic environmental and demographic events. Although there are outplanted populations in suitable habitat, these populations face the same ongoing threats as the single wild individual. One founder line exists in an ex situ collection at the Lyon Arboretum's Micropropagation Laboratory that may be used for propagation and outplanting to recover wild and outplanted populations affected by stochastic events. Threats from slugs and rats are ongoing and may impact success of outplantings. Therefore, the current resiliency for the species is assessed as extremely low.

***Representation***: We consider representation for *Cyanea obtusa* to be extremely low because there is only one population with a single individual which occurs in a narrow geographic region on Haleakalā. Reintroduced populations are not naturally recruiting. It is also represented in only one ecosystem type, mesic forest. Whatever genetic variation previously existed within and among populations has likely been lost since it is not well represented in ex-situ populations.

***Redundancy***: We consider redundancy for *Cyanea obtusa* to be extremely low because only one wild individual remains on Haleakalā. This individual is at imminent risk of extirpation from a single extreme weather event. All seven reintroduced populations (none of which are naturally recruiting), face the same risk of extirpation due to current threats. The *ex-situ* population is extremely limited and therefore is not considered to provide substantial support to the species redundancy.

***Species Viability Summary***

The current condition for *Cyanea obtusa* in terms of redundancy, representation, and resiliency is extremely low. *C. obtusa* persists with only a single wild individual and less than 40 individuals within seven reintroduced populations (none of which are naturally recruiting) which is composed of a single founder line. Reintroduced populations are composed of between 4-9 individuals each.

The remaining wild plant and each of the seven reintroduced populations are all at imminent risk of extirpation due to ongoing threats, and stochastic and catastrophic events. *C. obtusa* is distributed in only one ecosystem type (mesic forest) on Haleakalā. The geographic distribution for this species is narrow, which does not provide protection against catastrophic events such as hurricanes and flooding. *C. obtusa* is only represented as one founder line in micropropagation.. Table 9 provides a summary of the current status for *C. obtusa.*

Table 9. *Cyanea obtusa* current status: resiliency, representation, and redundancy

| **Resiliency** | **Representation** | **Redundancy** |
|---|---|---|
| Extremely Low | Extremely Low | Extremely Low |

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Personal Communication

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