DOI: 10.1002/ppp3.10099

FLORA OBSCURA Plants People Planet PPP Open Access

Cyanea kuhihewa: Rediscovering one of Hawai'i's rarest trees

1 | INTRODUCTION

Oceanic island systems are generally characterized by high endemicity due to their isolation, but at the same time the unique biodiversity of many islands is currently experiencing high extinction rates, primarily due to habitat reduction and pressure from invasive weeds and predators (Barnosky et al., 2011; Bruegman, Caraway, & Maunder, 2002). With 90% of its nearly 1,400 native plants classified as endemic, Hawai'i has one of the highest levels of endemism of any floristic region of the world (Wagner, Herbst, & Lorence, 2005; Wagner, Herbst, & Sohmer, 1999).

In 1991, a team of botanists from Hawai'i's National Tropical Botanical Garden helicoptered into the headwaters of a remote towering waterfall more than 500 m above sea level in Limahuli valley on northern Kaua'i (Figure 1a,b). During their botanical exploration one of the botanists, Ken Wood, made an extraordinary discovery: 12 plants of a new species of *Cyanea* with unusually narrow linear leaves (Wichman, 1992) (Figure 1c–e).

Cyanea Gaudich. (Campanulaceae) is a genus comprised of branched and unbranched shrubs or palm-like trees, which are endemic to Hawai'i. Seventy-nine of the 85 known taxa are single island endemics. *Cyanea* species occur in mesic and wet-forest habitat and are known for their colorfully arching flowers, and for their mutualistic relationship with several genera of nectarivorous Hawaiian honeycreepers (Fringillidae, Passeriformes) that provide pollination and dispersal of the fleshy fruits (Givnish et al., 2009; Lammers & Freeman, 1986).

Although *Cyanea* is one of the most species-rich flowering plant genera in Hawai'i, nearly half of the known species are considered Endangered or Critically Endangered by the International Union for Conservation of Nature (IUCN) red list of threatened species and about 22 taxa are considered extinct in the wild (Wood, Oppenheimer, & Keir, 2019).

Only one *Cyanea* species with very narrow linear leaves was known at the time of the new *Cyanea* population discovery, namely *Cyanea linearifolia* Rock. That species was known only from the holotype collected on Kaua'i, along with a few additional specimens (Lammers, 1996), and was seen last in 1957. Consequently, *C. linearifolia* was presumed extinct probably due to the impacts of alien invasive species (Clark, 2016) and it was enthusiastically concluded that the 1991 collection represented a rediscovery of an extant population of a species presumed extinct (Wichman, 1992).

However, on subsequent comparison of Wood's specimen of the newly discovered population, with the type and other specimens of *Cyanea linearifolia*, Thomas Lammers (1996) concluded that the new finding was actually a discovery of a new species of *Cyanea*. Wood´s collection differed from *C. linearifolia* in having flat or slightly revolute leaf margins, fewer-flowered pubescent inflorescences with shorter peduncles and bracts that were longer than wide, and larger pubescent flowers (Lammers, 1996) (Figure 1c–e). The new species was named *Cyanea kuhihewa* Lammers—kuhihewa meaning "to suppose wrongly" in Hawaiian language—a reference to the confusion with *C. linearifolia* (Lammers, 1996). Based on its extremely small population size and habitat, *C. kuhihewa* was assessed and considered Critically Endangered by the IUCN red list of threatened species (Lorence, 2016).

In 1992, shortly after the discovery of *C. kuhihewa*, the devastating hurricane Iniki severely impacted all of Kaua'i and destroyed portions of the forest canopy around Limahuli. The storm was followed by an influx of alien invasive plants and animals, including rats, slugs, and plant diseases, and the single population of *C. kuhihewa* declined until the last known individual died in 2003 (Lorence, 2016; Wood, 2007).

In 2017, another team of botanists from The Nature Conservancy of Hawai'i and the National Tropical Botanic Garden, discovered a hitherto unknown population of three *C. kuhihewa* individuals in a nearby valley, uncovering a new opportunity to protect and re-establish this unique Kaua'i species. As of September 2019, this new population includes two mature and two juvenile *C. kuhihewa*, along with around 11 tiny seedlings (Wood, unpublished). Kamehameha Schools, The Nature Conservancy and the National Tropical Botanical Garden are working together to monitor and protect *C. kuhihewa* with multi-annual visits to the area. Goodnature rat traps have been set up in the area to minimize the possibility of rat predation. More than 1,000 seeds have been collected since 2017 which are stored in seed banks or are under propagation at Lyon Arboretum (O'ahu island, Hawai'i) and the National Tropical Botanical Garden. As the propagated plants mature they will be out-planted in the Upper Limahuli Preserve in the Limahuli valley on the north coast of Kaua'i, which is managed by the National Tropical Botanical Garden. Continued surveys are also being conducted in the hope of discovering additional unknown populations.

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.
© 2020 National Tropical Botanical Garden. *Plants*, *People*, *Planet* published by John Wiley & Sons Ltd on behalf of New Phytologist Trust.

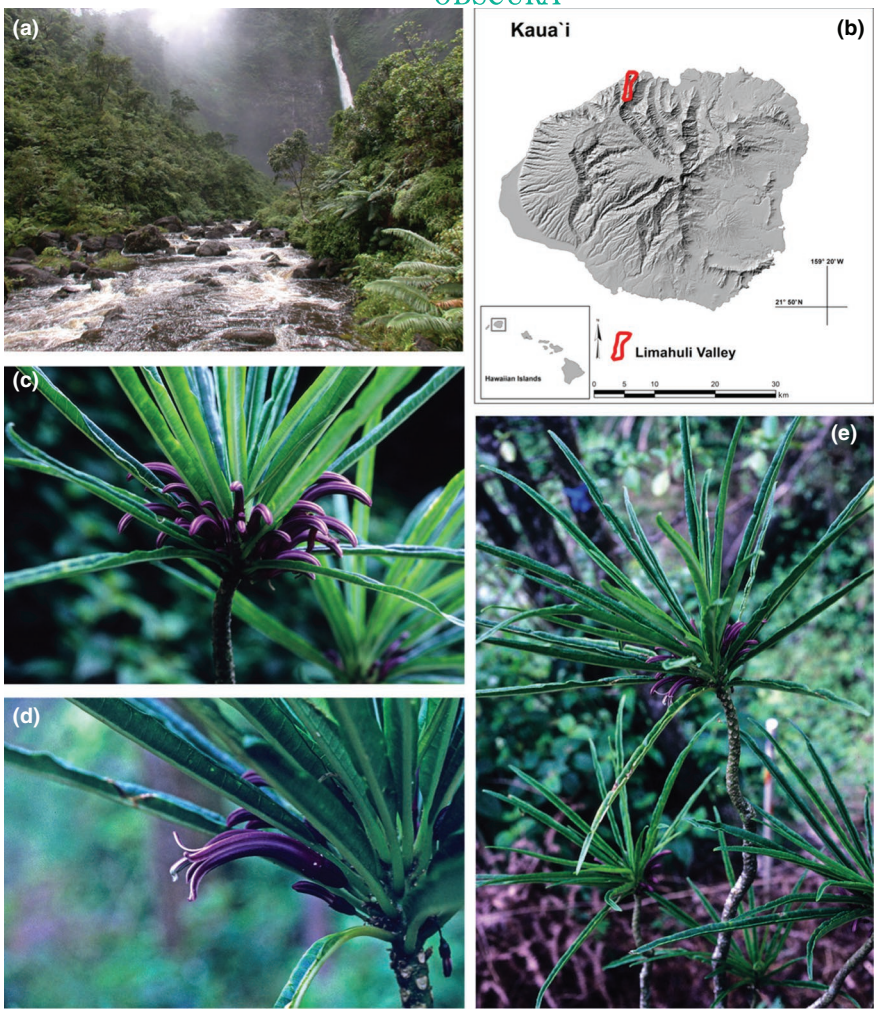

FIGURE 1 *Cyanea kuhihewa* Lammers. (a) Habitat North shore Kaua'i. (b) Map of Kaua'i showing Limahuli Valley. (c–e) Habit and flowers. Photographs and map (a,b) by Ken Wood; (c-e) by David Lorence

2 | THE UNIQUE HAWAIIAN FLORA

Cyanea is one of six genera of Hawaiian lobeliads, which are a group of circa 126 species in the bellflower family, Campanulaceae, all of which are endemic to Hawai'i, and considered to be one of the most spectacular examples of adaptive radiation in plants (Givnish et al., 2009). The origin of this group has been debated because morphological data indicate multiple independent colonization events. However, based on molecular phylogenetic data, the Hawaiian lobeliads likely arrived at the Hawaiian islands by a single-dispersal event about 13 million years ago (Givnish et al., 2009). Accelerated speciation and adaptive radiation in habitat, followed by changes in elevation and flower-tube length in *Cyanea*, resulted in Hawaiian lobeliads being the most species-rich single-origin radiation of plants resolved on any single oceanic island or archipelago, making them a model case for understanding island speciation (Givnish et al., 2009; Lammers, 2007).

Oceanic island systems are generally characterized by high endemicity due to their isolation. With its wide range of bioclimatic zones, abundance of freshwater and sunlight critical to life, and lack of natural predators, Hawai'i developed into one of the major "hot spots" on Earth for plant endemism (Brooks et al., 2002; Steinbauer et al., 2016). With 90% of the nearly 1,400 native plants classified as endemic, Hawai'i has one of the highest levels of endemism of any floristic region of the world (Wagner et al., 2005, 1999). Just like the *Cyanea*, many of these species are uniquely adapted to, and dependent on, their natural habitats, and are critical components of the local ecosystem.

3 | A HAWAIIAN EXTINCTION CRISIS

In addition to its distinction as a global hotspot of endemism, Hawai'i has also recently been presented as a global extinction capital (Humphreys, Govaerts, Ficinski, Nic Lughadha, & Vorontsova, 2019), with about 134 native Hawaiian plant species reported extinct since the 1840s (Bruegmann et al., 2002; Wood et al., 2019). In comparison to continental sites, these species have an exceptionally slim chance of ever being rediscovered (Humphreys et al., 2019). Nearly 240 Hawaiian plant species, 34 *Cyanea* species among them, are considered to have fewer than 50 individuals left in the wild, which is a criteria for a plant being considered Critically Endangered according to the IUCN red list of threatened species (IUCN, 2020; Plant Extinction Prevention Program, 2019) highlighting a more general ongoing extinction crisis in Hawai'i. There are several reasons for this endangerment, including habitat destruction, loss of pollinators and seed

dispersers, invasive plants and animals, introduced diseases, and climate change (Barnosky et al., 2011; Bruegmann et al., 2002; Lammers & Freeman, 1986).

4 | CONSERVING THE UNKNOWN

Hawai'i shares this pattern of decline and extinction with other island groups and many of these threatened species will not survive without extensive management, including habitat protection, restoration, and control of invasive weeds, animals and diseases (Bruegmann et al., 2002). In addition, carefully monitored ex situ conservation in seed banks and through propagation in living collections, as well as out-planting, can contribute to conserve genetically healthy populations of these species (Fant et al., 2016). Governmental, non-governmental organizations, and botanical gardens, must work together to address the extinction crisis. In Hawai'i, this is being implemented though the Hawai'i Conservation Alliance, which is a partnership of organizations and agencies working together to provide unified leadership, advocacy, and collaborative action to conserve and restore native ecosystems and the unique biodiversity of the islands of Hawai'i (Hawai'i Conservation Alliance, 2020). Successful conservation schemes are dependent on knowing and understanding the flora, however, several of the world's most biodiverse countries and island systems are still lacking thorough floristic investigation, prohibiting formal assessment of threatened species, as well as meta-analyses of changes in floristic patterns (Lack, 2012). When considering the extremely narrow endemicity and rarity of many island species, taxonomic confusion such as that surrounding *C. kuhihewa*, as alluded to by its name, may indeed be a serious impediment for assessing and improving the conservation status of a species.

5 | CONCLUDING REMARKS

The flora of Hawai'i is a hotspot of endemism, but the uniquely adapted native flora is highly vulnerable to disturbance, and losing just a few populations may mean losing one or more species. *C. kuhihewa* is one of about 85 taxa in this genus of charismatic Hawaiian lobeliads, most of which are uniquely adapted to a single island or are even narrower endemics from a single mountain or valley. About half of the genus is considered threatened, most of them with fewer than 50 individuals remaining in the wild. Reports of rediscovery of species previously thought to be extinct are always encouraging news, and we may still be able to safeguard *C. kuhihewa* through the ongoing combination of monitoring, weed and predator control, seed-banking, propagation, and out-planting.

KEYWORDS

campanulaceae, conservation, extinction, habitat destruction, invasive weeds, island speciation, Lobelioideae

ACKNOWLEDGEMENTS

Kamehameha schools and The Nature Conservancy of Hawai'i supported the fieldwork that led to the rediscovery of *C. kuhihewa* in 2017. Fondation Franklinia is thanked for financial support for the conservation of *C. kuhihewa* under the project Endangered Endemic Trees of Kaua'i project number 2020-4.

Nina Rønsted
Kenneth R. Wood

National Tropical Botanical Garden, Kalaheo, HI, USA

Correspondence
Nina Rønsted, National Tropical Botanical Garden, 3530 Papalina Road, Kalaheo, Kaua'i, HI 96741, USA.
Email: nronsted@ntbg.org

ORCID

Nina Rønsted https://orcid.org/0000-0002-2002-5809

REFERENCES

Barnosky, A. D., Matzke, N., Tomiya, S., Wogan, G. O. U., Swartz, B., Quental, T. B., … Ferrer, E. A. (2011). Has the Earth's sixth mass extinction already arrived? *Nature*, *471*, 51–57. https://doi.org/10.1038/nature09678

Brooks, T. M., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A. B., Rylands, A. B., Konstant, W. R., … Hilton-Taylor, C. (2002). Habitat loss and extinction in the hotspots of biodiversity. *Conservation Biology*, *16*, 909–923. https://doi.org/10.1046/j.1523-1739.2002.00530.x

Bruegmann, M. M., Caraway, V., & Maunder, M. (2002). A safety net for Hawaii's rarest plants. *Endangered Species Bulletin*, *27*, 8–11.

Clark, M. (2016). Cyanea linearifolia. The IUCN Red List of Threatened Species 2016: e.T91172297A91172324. https://doi.org/10.2305/IUCN.UK.2016-2.RLTS.T91172297A91172324.en

Fant, J. B., Havens, K., Kramer, A. T., Walsh, S. K., Callicrate, T., Lacy, R. C., … Smith, P. P. (2016). What to do when we can't bank on seeds: What botanic gardens can learn from the zoo community about conserving plants in living collections. *American Journal of Botany*, *103*, 1541–1543. https://doi.org/10.3732/ajb.1600247

Givnish, T. J., Millam, K. C., Mast, A. R., Paterson, T. B., Theim, T. J., Hipp, A. L., … Sytsma, K. J. (2009). Origin, adaptive radiation and diversification of the Hawaiian lobeliads (Asterales: Campanulaceae). *Proceedings of the Royal Society B: Biological Sciences*, *276*, 407–416. https://doi.org/10.1098/rspb.2008.1204

Hawai'i Conservation Alliance. (2020). Retrieved from http://www.hawaiiconservation.org, accessed January 16th, 2020.

Humphreys, A. M., Govaerts, R., Ficinski, S. Z., Nic Lughadha, E., & Vorontsova, M. S. (2019). Global dataset shows geography and life form predict modern plant extinction and rediscovery. *Nature Ecology and Evolution*, *3*, 1043–1047. https://doi.org/10.1038/s41559-019-0906-2

IUCN (2020). *The IUCN red list of threatened species*. Retrieved from https://www.iucnredlist.org, accessed January 16th, 2020.

Lack, W. (2012). Flora projects – A never ending synthesis. In W. Lack, & K. Grotz (Eds.), *Flora's treasures – Recording the green world* (pp. 10–11). Berlin: Botanisches Museum Berlin-Dahlem.

Lammers, T. G. (1996). A new linear-leaved *Cyanea* (Campanulaceae: Lobelioideae) from Kaua i, and the "re-discovery" of *Cyanea linearifolia*. *Brittonia*, *48*, 237–240. https://doi.org/10.2307/2807820

Lammers, T. G. (2007). *World checklist and bibliography of Campanulaceae*. Kew: Royal Botanical Gardens.

Lammers, T. G., & Freeman, C. E. (1986). Ornithophily among the Hawaiian Lobelioideae (Campanulaceae): Evidence from floral nectar sugar compositions. *American Journal Botany*, *73*, 1613–1619. https://doi.org/10.1002/j.1537-2197.1986.tb10913.x

Lorence, D. H. (2016). Cyanea kuhihewa. The IUCN Red List of Threatened Species 2016: e.T80230488A115511187. https://doi.org/10.2305/IUCN.UK.2016-1.RLTS.T80230488A80230494.en

Steinbauer, M. J., Field, R., Grytnes, J.-A., Trigas, P., Ah-Peng, C., Attorre, F., … Beierkuhnlein, C. (2016). Topography-driven isolation, speciation and a global increase of endemism with elevation. *Global Ecology and Biogeography*, *25*, 1097-1107.

Plant Extinction Prevention Program. (2019). PEP species list, March 7th, 2019. Retrieved fromhttp://www.pepphi.org, accessed November 3rd, 2019.

Wagner, W. L., Herbst, D. R., & Lorence, D. H. (2005). Flora of the Hawaiian Islands website. Retrieved from http://botany.si.edu/pacificislandbiodiversity/hawaiianflora/index.htm, accessed November 3rd, 2019.

Wagner, W. L., Herbst, D. R., & Sohmer, S. H. (1999). *Manual of the flowering plants of Hawai`i. Revised Edition*. Bishop Museum Special Publications 97. Honolulu: University of Hawaii Press.

Wichman, C. (1992). *Cyanea linearifolia*: Exciting rediscovery of "extinct" plant. *Bulletin of the National Tropical Botanical Garden*, *22*, 39–41.

Wood, K. R. (2007). New plant records, rediscoveries, range extensions, and possible extinctions within the Hawaiian islands. *Bishop Museum Occasional Papers*, *96*, 18–22.

Wood, K. R., Oppenheimer, H., & Keir, M. (2019). A checklist of endemic Hawaiian vascular plant taxa that are considered possibly extinct in the wild. National Tropical Botanical Garden, Technical Report #314, Retrieved from https://www.researchgate.net/publication/332916448_A_checklist_of_endemic_Hawaiian_vascular_plant_taxa_that_are_considered_possibly_extinct_in_the_wild

How to cite this article: Rønsted N, Wood KR. *Cyanea kuhihewa*: Rediscovering one of Hawai'i's rarest trees. *Plants, People, Planet*. 2020;00:1–4. https://doi.org/10.1002/ppp3.10099