

Notes on Status and Ecology of the Endangered Hawaiian Annual 'Āwiwi, *Centaurium sebaeoides* (Gentianaceae)¹

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ABSTRACT: The annual, endemic, coastal herb *Centaurium sebaeoides* is the only native Hawaiian species in the gentian family. The U.S. Fish and Wildlife Service listed it as Endangered under the Endangered Species Act on 29 October 1991. Before surveys reported here, the total population of this species statewide was estimated at 80–110 individuals in eight populations. During counts made in April and May 1997, following ample winter rains, 12 populations of *C. sebaeoides* with a total of 6300–6600 plants were noted on five islands (Kaua'i, O'ahu, Lāna'i, Moloka'i, and Maui). Five populations were mapped with a global positioning system and counted; in the remaining seven populations, the numbers of individuals were estimated. More recent surveys in 1998–1999 estimated a total of only 60–80 individuals at all sites. Such dramatic population fluctuations are believed to be related to the sporadic occurrence of winter rains. Threats that further contribute to the rarity of the species include (1) displacement and overtopping by salt-tolerant nonnative woody species, especially *Casuarina* spp., (2) trampling and erosion of habitat by ungulates, and (3) damage caused by off-road vehicles.

Centaurium sebaeoides (Griseb.) Druce is the only native Hawaiian gentian (Gentianaceae). The genus *Centaurium* consists of about 20 species distributed in North America, Eurasia, mountains of South America, northern Africa, Australia, and some Pacific islands (Wagner et al. 1990). Though Hillebrand (1888) noted that the Hawaiian species was similar to a Mediterranean species, *Erythraea spicata*, Fosberg (1948) listed the progenitor species as likely having originated in the New World. Another species of the genus, bitter herb (*Centaurium erythraea* Raf.), native to Eurasia, is naturalized and relatively common on all of the main Hawaiian Islands except Ni'ihau at 10–2140 m elevation (Wagner et al. 1990). The native Hawaiian name of *C. sebaeoides* is 'āwiwi (Pukui and Elbert 1986).

Of 956 native species of Hawaiian plants, only 29 (3%) have annual life cycles; the majority are in the genera *Sicyos* (12 species) and *Panicum* (6 species) (Wagner et al. 1990). *Centaurium sebaeoides* appears to be a determinate annual; triggered by declining photoperiod, the plant produces seeds and dies, a pattern also typical of annual grasses in Mediterranean climates (Harper 1977).

Knowledge of historic populations is based on herbarium specimens in Herbarium Pacificum, B. P. Bishop Museum, and references in Hillebrand (1888) and Degener (1934). Historically, the species is known from Kaua'i, O'ahu (Ka'ena, Hale'iwa, 'Ewa Plain, Pearl Harbor, Honolulu, Pu'uloa, Lā'ie Point, Mokolē'ia, and Kahuku), Lāna'i, Moloka'i (Mo'omomi, west of Ka'a near 'Īlio Point, north of Ho'olehua near Manaepapa, and Waikolu), and Maui (Mōkōlea, Pōhakupule, Nāpili, the isthmus between East and West Maui, Makamaka'ole, and north of Waihe'e).

Before the 1997 surveys reported here, the

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TABLE 1

LIST OF 12 KNOWN POPULATIONS OF *Centaurium sebaeoides* IN THE HAWAIIAN ISLANDS IN 1997

ISLAND/DISTRICT	HABITAT	POPULATION SIZE
1. Kaua'i/Pōhakuau	Dry coastal cliffs	25 plants, winter 1997 (K. Wood)
2. Kaua'i/Kalalau	Dry coastal cliffs	70 plants, winter 1997 (K. Wood)
3. Kaua'i/Awa'awapuhi Valley	Dry coastal cliffs	<100 plants, 1997 (K. Wood)
4. O'ahu/Hālonā	Coastal	100–300 plants, winter 1997 (B. Gagné)
5. Moloka'i/Kalaupapa	Coastal	4,020 plants, April 1997 (R. Potts, A.C.M., C.G.C., S.M.J., P.D.K.)
6. Moloka'i/Mokio Point	Coastal	1 plant, April 1994 (M. Bruegmann, R. Hobdy, J. Yoshioka)
7. Lāna'i/Maunalei Gulch	Lowland	27 plants, May 1997 (R. Hobdy)
8. Maui/Pōhakupule	Coastal	104 plants, May 1997 (H. Oppenheimer, S. Meidell, J.-Y. Meyer, A.C.M., C.G.C., S.M.J., P.D.K.)
9. Maui/Mōkōlea Point	Coastal	192 plants, May 1997 (R. Hobdy, A.C.M., C.G.C., L.L.L.)
10. Maui/Kahakuloa Head	Coastal	1,636 plants, May 1997 (H. Oppenheimer, S. Meidell, J.-Y. Meyer, A.C.M., C.G.C., S.M.J., P.D.K.)
11. Maui/Makamaka'ole	Coastal	18 plants, June 1997 (A.C.M.)
12. Maui/N of Waihe'e	Coastal	123 plants, May 1997 (R. Hobdy, A.C.M., C.G.C., L.L.L.)

known extant number of individuals was most recently estimated at 80–110 plants in eight populations (Anonymous 1997). Because of its scarcity, *C. sebaeoides* was proposed as Endangered in 1990 under the Endangered Species Act by the U.S. Fish and Wildlife Service and listed on 29 October 1991 (Anonymous 1991).

were made by several observers who methodically moved through the area, using clicker counters to tally all individuals. In the seven populations not GPS-mapped, map locations were manually recorded and numbers of individuals were based on observer estimates.

MATERIALS AND METHODS

We discovered populations of *Centaurium sebaeoides* through firsthand searches of suitable habitat, through information received from others, or by reexamining sites of historic collections. For example, the Mōkōlea site on Maui was rediscovered in 1997 based on the herbarium specimen collected there in 1913. Five of the twelve populations were visited in winter–spring 1997, and the population extents were mapped with a global positioning system (GPS) (Trimble Pro XL) capable of submeter accuracy (Anonymous 1995a). GPS mapping can be especially valuable in habitat mapping of ephemeral annual species such as *C. sebaeoides* by allowing site relocation and management even when no plants are present. In the five GPS-mapped populations, actual counts of plants

RESULTS AND DISCUSSION

In April and May 1997, we noted 12 extant populations of *Centaurium sebaeoides* on five islands (Kaua'i, O'ahu, Lāna'i, Moloka'i, and Maui) with a total statewide population of approximately 6300–6600 individuals (Table 1 and Figure 1). Two large populations, Kalaupapa on Moloka'i (4020 plants) and Kahakuloa Head on West Maui (1636 plants), accounted for over 85% of all known individuals. It is interesting that estimates of population numbers made before physical counts fell consistently and markedly below the actual recorded totals.

We believe the relatively heavy winter rains of 1996–1997 were responsible for the large number of individuals observed in 1997 versus totals recorded in previous years. Such dramatic population fluctuations are characteristic of annual species that can develop

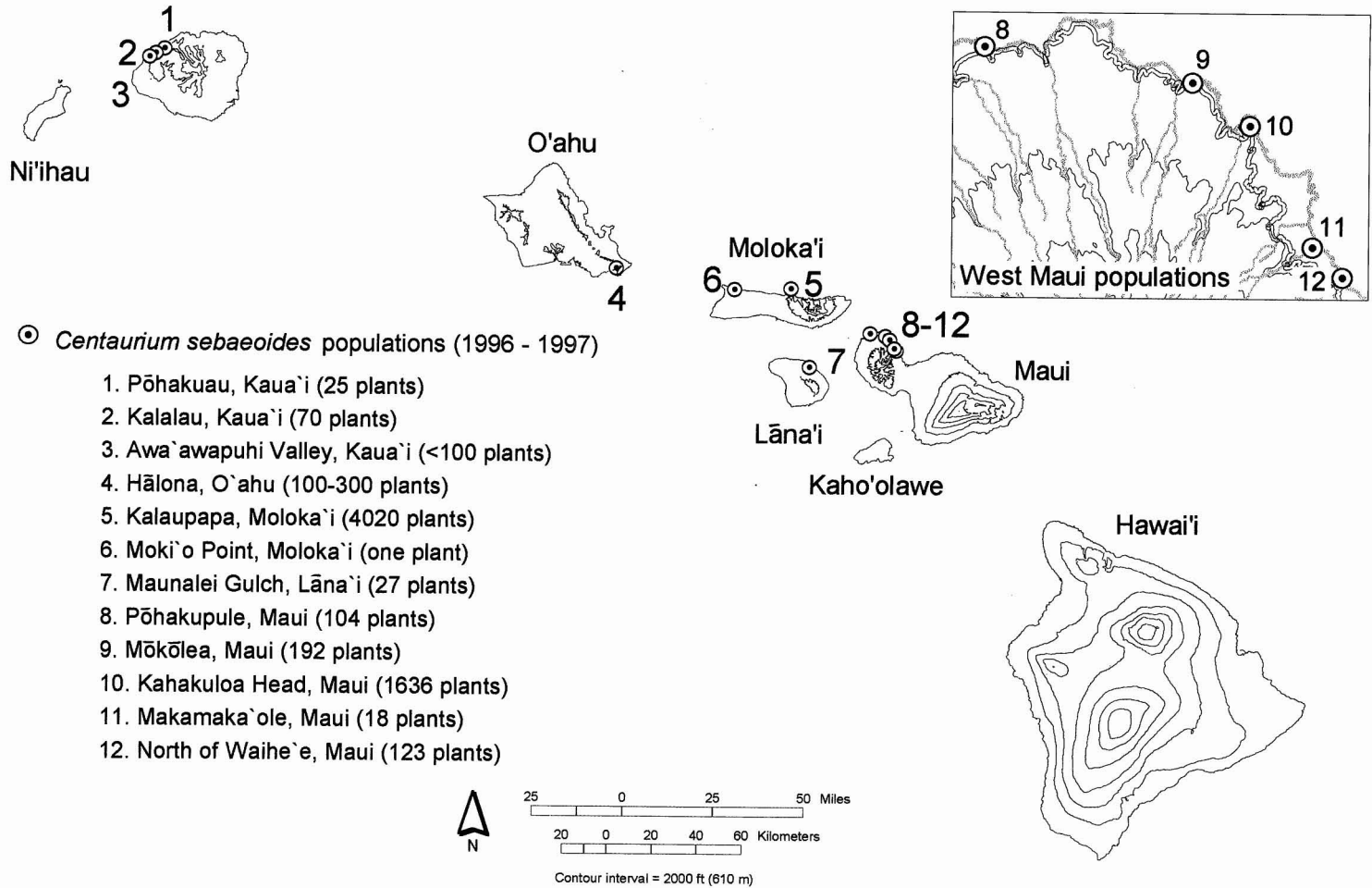


FIGURE 1. Distribution of 12 *Centaurium sebaeoides* populations on five Hawaiian islands.

extensive, long-lived seed banks to survive poor years and successfully exploit favorable years. In fact, just such a population fluctuation occurred in the subsequent seasons of 1998–1999, during which an El Niño-induced drought resulted in little or no rainfall in the coastal habitats, and only 60–80 *C. sebaeoides* plants, less than 1.3% of 1997 totals, were documented. Whether the virtual “disappearance” of the species is solely due to the almost complete lack of winter rainfall or is the result of a combination of several factors is unknown, but such a precipitous drop in numbers emphasizes the fact that *C. sebaeoides* is by no means at “safe” levels and should not lose its Endangered status. To the contrary, the long-term survival of the species is tenuous at best because its present habitat is currently subject to a variety of detrimental factors including displacement and modification by aggressive nonnative plants, trampling by feral and domestic ungulates, and heavy recreational use by humans.

The phenology of this short-lived annual is apparently keyed to the brief and variable occurrence of winter rains. Based on observations made in study populations in the 1996–1997 wet season, the phenology of *C. sebaeoides* can be summarized as follows. Seedlings were first noted in March and April, suggesting germination a few weeks earlier. Star-shaped, white to lilac flowers approximately 5 mm across were first observed in April and May. Immature capsules were first observed beginning in April but continuing through late May. Mature capsules were observed beginning in May and continuing through June. By the first week of July, most plants were dried brown or dead and were becoming detached from the substrate.

Mean annual precipitation in *C. sebaeoides* habitat ranges from approximately 500 mm (20 in.) on Moloka‘i and Lāna‘i to 1500–2000 mm (60–80 in.) on Kaua‘i (Giambelluca et al. 1986), with the majority falling between November and April (Anonymous 1995b). The total amount and timing of winter–spring precipitation in the habitat of *C. sebaeoides* varies substantially from year

to year. Precipitation in the 1996–1997 winter was clearly heavier than normal. A flooding winter storm at Kalaupapa on 12–13 November 1996 dropped 161 mm of rain, a 2-day amount greater than the average precipitation (124 mm) for the entire month of November. This unusual flood event deposited debris and left water erosion marks that were still evident in April 1997.

Regarding the habitat of this species, Hillebrand (1888:287) stated, “On grassy plains near the coast.” We observed *C. sebaeoides* along windward coastlines and lowlands from near sea level to 30 m (100 ft) elevation and rarely on sea cliffs, such as at Maunalei Gulch, Lāna‘i, up to 250 m (800 ft) elevation. *Centaurium sebaeoides* grows in sand or soil pockets along sea cliffs, along the upper fringes of the strand zone, in adjacent coastal pastures, in arid shrublands just inland of the strand zone, beneath sparse native shrubs, and through thin mats of alien grasses, especially *mānienie*, *Cynodon dactylon* (L.) Pers., and Henry’s crabgrass, *Digitaria ciliaris* (Retz.) Koeler. Associated native species include *Chamaesyce celastroides*, *Dodonaea viscosa*, *Fimbristylis cymosa*, *Heteropogon contortus*, *Lipochaeta heterophylla*, *L. integrifolia*, *Lycium sandwicense*, *Lysimachia mauritiana*, *Mariscus phleoides*, *Panicum fauriei*, *P. torridum*, *Scaevola sericea*, *Schiedea globosa*, *Sida fallax*, and *Wikstroemia uva-ursi*.

Typically, *C. sebaeoides* occurs in small groups of individuals, usually representing a wide range of size classes from small, recently emerged seedlings to flowering and fruiting plants. Full-sized flowering plants ranged from 4 to 25 cm tall, bearing from a single to over 100 flowers. Smaller plants are slender and erect or rarely repent. Larger plants bear somewhat succulent leaves, with a triangular habit, invariably with a single basal stem. Despite conspicuous flowers and local abundance of potential pollinating insects, no diurnal flower visitation was observed for *C. sebaeoides*. Nevertheless, some form of cross-pollination is likely to occur because the perfect flowers of the genus are protandrous, with twisted stigmatic surfaces that are receptive only after dehiscence of the anthers (Zomlefer 1994).

Unlike many Hawaiian species, *C. sebaeoides* apparently possesses chemicals that discourage browsing by ungulates. Despite abundant ungulate browsing at several of the field sites, no sign of browsing on *C. sebaeoides* was noted in this survey. Other species in the genus *Centaurium* are reported to contain "bitter principles" (Heywood 1993) and bitter glucosides in the roots and rhizomes (Zomlefer 1994). The foliage is noted to be extremely bitter, with medicinal qualities, and is recognized as a drug in the National Formulary, a reference book for pharmacists (Dobelis 1986).

Threats to *C. sebaeoides* at the 12 study populations include (1) displacement by nonnative woody species, (2) trampling and erosion of habitat by ungulates, and (3) damage caused by off-road vehicles. Non-native woody species capable of invading and highly modifying *C. sebaeoides* habitat include *Casuarina equisetifolia*, *C. glauca*, *Leucaena leucocephala*, *Prosopis pallida*, *Schinus terebinthifolius*, *Syzygium cumini*, and *Tournefortia argentea*. Site invasion by *Casuarina* appears to be particularly damaging because of the smothering leaf litter layers that exclude most plant species. Indirect effects of overgrazing, such as trampling and erosion, also likely contribute to the decline or disappearance of the species depending on the severity, timing, longevity, and nature of the disturbance. Destruction of plants growing in coastal sites by off-road vehicles may also be an important source of mortality.

Undiscovered populations of *C. sebaeoides* undoubtedly occur. One such population of 25 plants was documented at Honolua Bay, West Maui, in May 1999 (H. Oppenheimer, pers. comm.). The ephemeral appearance, small size, and superficial similarity of the species to the common naturalized herb scarlet pimpernel (*Anagallis arvensis* L.), which often occupies the same sites, are all potential reasons why the species is easily overlooked. *Centaurium* is readily distinguished from *Anagallis* by its lighter-colored, almost glaucous foliage that lacks dark, reddish spots on leaf undersides, and when flowering, by its white to lilac flowers (versus orange in *Anagallis*).

Ultimately, although more obvious threats can be identified and mitigated, it is difficult to give sound management recommendations for long-term protection of an annual plant species about which so little is known. Information that could be important in effective management of this species includes reproductive biology, germination and establishment requirements, mycorrhizal associations, and the size and persistence of the seed bank. Whether large annual fluctuations of numbers of individuals is simply related to winter rainfall or whether other factors are involved is unknown.

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