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Population Size and Frequency of Branching in the Eke Silversword, *Argyroxiphium caliginis* (Asteraceae), on Eke Crater, West Maui, Hawaii[1]

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ABSTRACT: The Eke silversword, *Argyroxiphium caliginis*, is a rosette plant endemic to the summit bogs of Eke Crater and Puu Kukui, West Maui, Hawaii. On 2 November 1985, a belt transect across Eke Crater was used to estimate the population of silverswords on the summit bog. Total population of the Eke silversword on Eke Crater was estimated to be about 76,000 plants. Although the plant has been described as a branching shrub that reproduces vegetatively, the majority of the individuals in the sampled population of the Eke silversword on Eke Crater were unbranched, monocarpic plants that appeared to reproduce by seed.

THE EKE SILVERSWORD (*Argyroxiphium caliginis* Forbes) is a rosette plant endemic to the summit bogs and ridges of Eke Crater (1360 m elevation) and Puu Kukui (1600 m) of West Maui, Hawaii (Figure 1). The Eke silversword is one of five extant species in the Hawaiian genus *Argyroxiphium* (family Asteraceae, subtribe Madiinae). All members of the genus are endemic to Hawaii.

The Eke silversword has been frequently described as a branching, dwarf shrub (Keck 1936, Degener 1937, Neal 1965, Carlquist 1974, Carr 1985, 1990). Degener (1930) described the growth habit of the Eke silversword as "creeping profusely over the ground and progressively dying back at the base, thus isolating the branches into independent plants." Carlquist (1974, 1980) suggested that the Eke silversword on Puu Kukui rarely flowered and depended on branching for reproduction. However, Forbes (1920), in his description of the species, did not describe the Eke silversword as a branching plant, but stated simply, "The plant proves to be a different species from that found on either the uplands of the island of Hawaii or of East Maui. It differs from the other described species in its much smaller size."

Monocarpic silverswords live for many years as a vegetative single-stemmed rosette and die after a single episode of flowering and subsequent seed set. Branching is extremely rare in the Haleakala silversword (*A. macrocephalum* Gray) (pers. obs.), occurs in less than 8% of the plants in a population of the Ka'u silversword (*A. kauense* (Rock and Neal) Degener and Degener) in the Upper Waiakea Forest Reserve on the island of Hawaii (unpublished data), and is present in about 26% of the remnant naturally occurring population of the Mauna Kea silversword (*A. sandwicense* De Candolle) (Powell 1992). Therefore, the habit described by Degener (1930) for the Eke silversword is unusual for silverswords. No other silversword species has been reported as capable of vegetative reproduction. However, the greensword (*A. grayanum* (Hillebrand) Degener) may be capable of vegetative reproduction in nature (G. Carr, pers. comm.).

The purpose of this paper is to present an estimate of the population size, frequency of branching, and mode of reproduction of the Eke silversword on the summit bog of Eke Crater.

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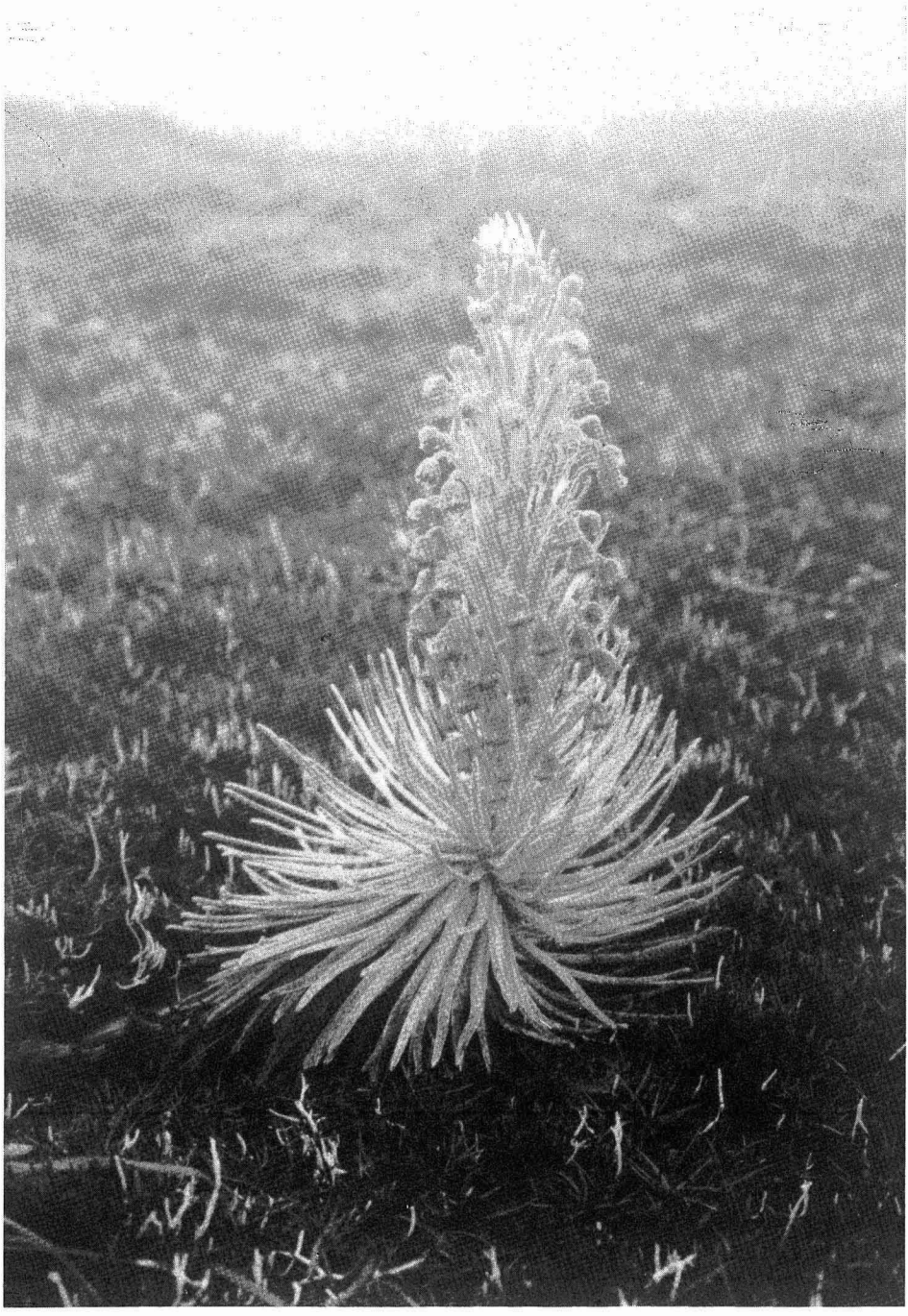

Figure 1. A flowering Eke silversword on the summit bog of Eke Crater, West Maui, Hawaii.

Study Site

Eke Crater is an extinct volcanic dome with eroded sides and gently concave summit. The summit bog is underlain by a clay hardpan over a compressed lava core and is characterized by numerous pits and open water ponds. The vegetation of the summit bog, which consists primarily of grasses, sedges, and low-growing shrubs, was in a pristine state at the time of this study: Alien plants were absent and the vegetation appeared not to have been disturbed by humans or feral animals. The summit of Eke Crater has been designated a Natural Area Reserve by the State of Hawaii Department of Land and Natural Resources.

METHODS

On 2 November 1985, a 2 m × 360 m belt transect was extended in 10-m intervals from the north rim of Eke Crater across the center of the summit to the edge of the south rim. The number of silversword plants, the rosette diameter of each plant, and the number of rosette branches for each plant in the transect were recorded. The transect covered only flat and gently sloping surfaces and did not include pits. Less than 25 m^2 of the transect was open water ponds.

The number of flowering silverswords on the summit of Eke Crater was estimated by counting the number of flowering plants encountered and in view during a 5-hr walk around the perimeter of the summit bog. The rosette diameter and inflorescence height were measured on 81 flowering individuals, and the number of flowering stalks from previous flowering seasons that were encountered in the walk was recorded. The height of the inflorescence from the ground surface was measured for 39 flowering silverswords that had fully elongated inflorescences.

The area of Eke Crater was determined by planimeter from a 1 : 24,000, 7.5-min. series topographic map published by the U.S. Geological Survey. However, because the surface of the summit is not flat, but concave with numerous pits, the planimeter reading for the summit is an underestimate of the total surface area of the summit of Eke Crater.

RESULTS

The belt transect covered 720 m^2 and represented 0.005% (1/189) of the area of the summit of Eke (13.6 ha), as determined by planimeter. A total of 404 individual plants, of which three were in flower, occurred within the belt transect. If one assumes that the density of silverswords within the transect (0.56 plants per m^2) is the same as the density of silverswords on the summit of Eke Crater, then the total population is estimated as the number of silverswords found in the transect (404) times the number of possible transect areas on the summit of Eke (189), or about 76,000 silverswords.

The distribution of rosette diameters of the sampled silversword population showed a reverse J curve typical of expanding populations (Figure 2). Forty-eight percent of the plants within the transect were <10 cm in diam. There were, however, few seedlings <3 cm in diam. It is possible that the silverswords in this bog grow more rapidly than 1 or 2 cm per year. If so, seedlings that resulted from the seed crop of 1984 would have been larger than 2 cm by the time of this census in 1985. It is also possible that seedling recruitment occurs irregularly and that few seedlings were recruited in 1984.

Sixty-nine of the 404 silverswords (17%) within the transect had multiple rosettes and were considered branched; the remaining 335 had only one rosette and were unbranched (monocarpic). Of the branched individuals, 33% ($n = 23$) had two rosettes, 17% ($n = 12$) had three rosettes, and 14% ($n = 10$) had >10 rosettes. The maximum number of rosettes on any silversword plant in the transect was 36.

Branched silverswords had several shoots that terminated in rosettes radiating from a central point on the aboveground shoot of the plant (Figure 3). The radiating shoots did not extend farther than about 20 cm from the central shoot. In only one case was a radiating shoot found to be rooted in the soil and the connection between it and the parent shoot broken. Although no silverswords were excavated to make these determinations, no connections between plants were obvious in the surface layers of vegetation, nor were connec-

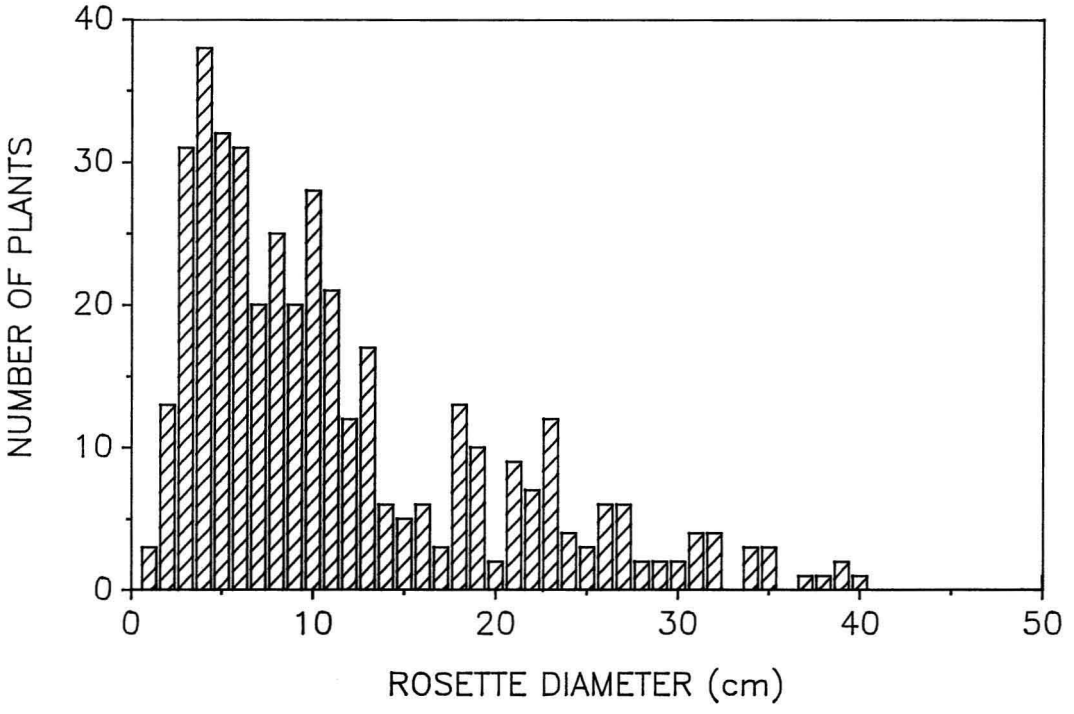

FIGURE 2. Distribution of rosette diameters of the sampled silversword population on Eke Crater. Graph does not include two plants: one had a rosette diameter of 61 cm and the other had a rosette diameter of 84 cm.

tions between silverswords found by gently probing the vegetation to the soil surface in areas between plants. It is, however, possible that more connections existed than were encountered by these methods.

About 200 silverswords were in flower or beginning to come into flower on the summit bog on 2 November 1985. Of the 81 flowering plants measured for inflorescence height, 39 plants (48%) had fully elongated inflorescences; the remainder (42 plants) had portions of the inflorescence in bud. The rosette diameter of the 81 flowering silverswords ranged from 15 to 44 cm. The mean diameter was 27.0 cm ($n = 81$, SD = 5.5) (Figure 4). The height of inflorescences ranged from 29 to 81 cm. The mean inflorescence height was 51.8 cm. Only 22 flowering stalks from previous flowering seasons were found. These stalks were fragile and partially decomposed.

DISCUSSION

The estimated population of about 76,000 Eke silversword plants on Eke Crater was larger than the total estimated population of any other species of silversword. The estimated population of the Haleakala silversword was about 50,000 plants in 1986 (Loope and Crivellone 1986). The Haleakala silversword has suffered disturbance from humans and feral goats. The Mauna Kea silversword, a federally listed endangered species, has been reduced to a naturally occurring population size of less than 40 individuals from a population that probably ranged over the alpine and subalpine slopes of Mauna Kea before the introduction of goats and sheep to Hawaii Island (Powell 1992). The largest Ka'u silversword population, which is located on Kahuku Ranch, Hawaii Island, has declined rapidly from a "magnificent colony" of "several thou-

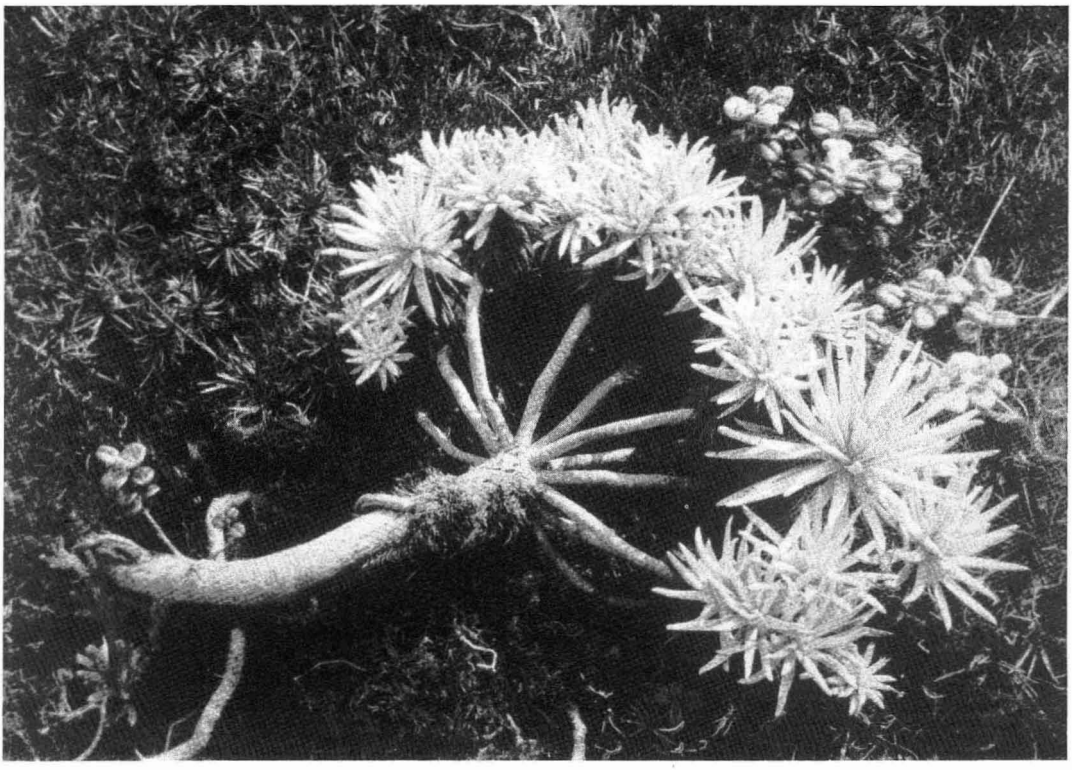

FIGURE 3. A branched Eke silversword on Eke Crater.

sand plants" in 1974 (Degener et al. 1976) to an estimated population size of less than 2000 individuals in 1984 (unpublished data). This species has suffered greatly from browsing by mouflon sheep and has been proposed for listing as an endangered species (U.S. Fish and Wildlife Service 1990).

Although the Eke silversword has repeatedly been described as a branching or creeping shrub (Degener 1937, Neal 1965, Carr 1985), only 17% of the sampled population on Eke Crater was found to be branched. The majority of the sampled population consisted of monocarpic, unbranched plants. This result does not support the description of the Eke silversword as a creeping shrub that reproduces vegetatively. The frequency of branching observed for the Eke silversword on Eke Crater is less than the frequency of branching observed for the naturally occurring population of the Mauna Kea silversword, which is considered primarily monocarpic.

Carlquist (1974, 1980) suggested that the Eke silversword on Puu Kukui rarely flowered and, therefore, depended on branching for reproduction. This did not appear to be the case on Eke Crater. Because few branching silverswords were encountered, numerous unattached seedlings were found, and numerous plants were in flower, I conclude that the Eke silversword reproduces primarily by seed on Eke Crater.

It is unknown whether the level of flowering observed in 1985 (about 200 plants) was high or low compared to that of other flowering seasons. No other flowering censuses have been reported for the Eke silversword during peak flowering periods. Because old flowering stalks decompose rapidly, it was impossible to assess the level of flowering in previous years.

The vegetation of Eke Crater was in a pristine condition in 1985. The high density of silverswords on Eke Crater (about 5600 silverswords per ha) suggests that other silversword

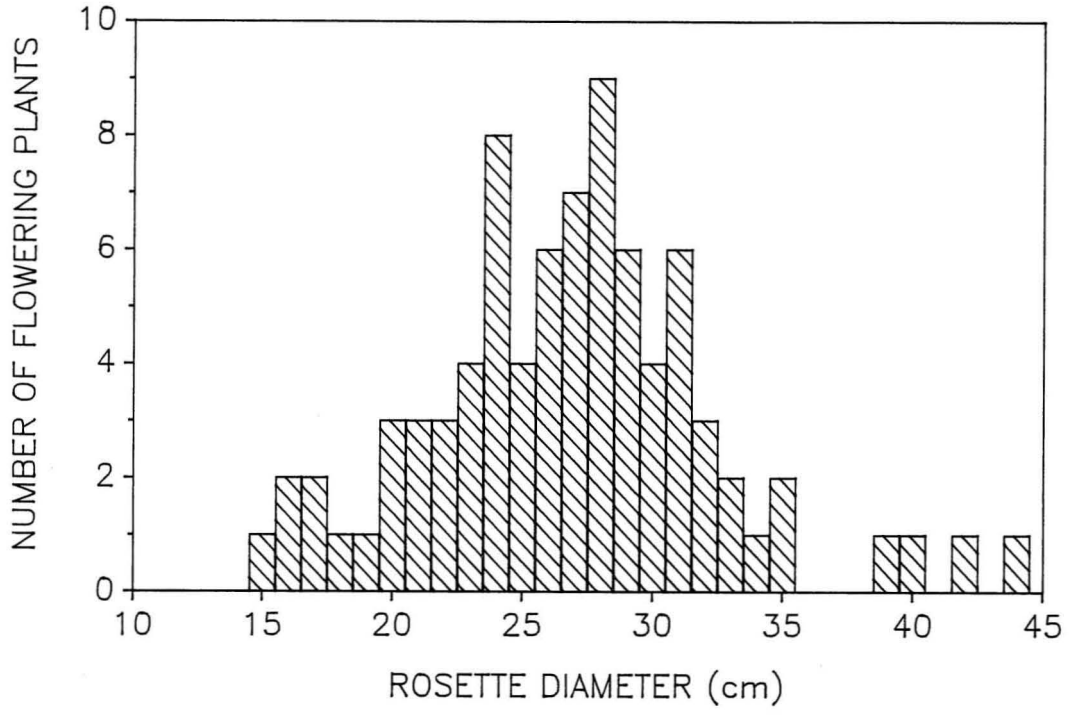

Figure 4. Distribution of rosette diameters of 81 flowering plants on Eke Crater on 2 November 1985.

species may have been very numerous, and had high population densities, before disturbance by humans and feral animals.

Although the Eke silversword population appeared to be large and to be reproducing in 1985, the silversword is threatened by feral pigs (Gagné 1987). Where feral pigs have gained access to pristine bog habitats in Hawaii, the native vegetation has declined rapidly and alien weeds have replaced the native vegetation (Medeiros et al., in press). Unless Eke Crater is completely protected from feral pigs, the Eke silversword will probably suffer a rapid and drastic reduction of population size.

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