Restoring Mauna Kea's Crown Jewel

Robert Robichaux

The Mauna Kea silversword (Argyroxiphium sandwicense ssp. sandwicense) is a crown jewel of Hawaii's native flora. The plant is named for its mountain habitat and its striking rosette of dagger-shaped leaves covered with dense layers of silvery hairs. The rosettes appear jewel-like in the cinder and lava fields on the upper slopes of Mauna Kea volcano, especially when water condenses on the leaves as clouds pass by. Large rosettes, which can be 2 feet (0.6 meter) in diameter at maturity, produce a massive, 6-foot (2-m) tall flowering stalk with up to 600 showy heads, each containing up to 500 individual flowers.

The Mauna Kea silversword is a member of the silversword alliance, an endemic plant lineage in the sunflower family (Asteraceae), that is one of Hawaii's premier examples of adaptive radiation. Though species in the silversword alliance grow in a dazzling array of habitats and exhibit great variation in form, they evolved from a single ancestor that arrived in Hawaii several million years ago from North America, probably as a seed caught in the feathers of a wandering bird.

The endangered Mauna Kea silversword and its relatives not only epitomize the special nature of the Hawaiian flora, but also illustrate the severity of the threats that confront the flora, especially those resulting from the introduction of alien (i.e., non-native) organisms. Early naturalists' records suggest that the original range of the Mauna Kea silversword encircled the 13,796-foot (4,205-m) volcano on the Island of Hawaii, with the plants growing commonly in exposed subalpine and alpine habitats between 8,500 and 12,500 feet (2,600 and 3,800 m).

In the 1790's, Captain Vancouver and other European voyagers introduced sheep and other alien ungulates to the island. (Hawaii has no native ungulates.) These non-native animals spread rapidly across the island. By the 1820's, sheep were reported from Mauna Kea's summit area, and by the 1930's, the sheep population on Mauna Kea had reached 40,000. As ungulate populations increased, silverswords declined severely in range and number, presumably due to heavy browsing. By the 1970's, only a small remnant silversword population persisted on Mauna Kea, confined to cliffs and rock faces that were inaccessible to ungulates.

The Hawaii Department of Land and Natural Resources' Division of Forestry and Wildlife initiated a program in the 1970's to promote the recovery of the Mauna Kea silversword. In 1973, three plants flowered in the remnant natural population. Seeds from two of the plants were collected by Kaoru Sunada and used by the Division of Forestry and Wildlife to produce container grown seedlings for outplanting. Intermittent outplanting since 1973, first into fenced and later unfenced sites, has created an outplanted population of over 800 plants. The outplanting program has thus significantly increased the size of the silversword population on Mauna Kea.

Population Bottleneck

The outplanting program, however, has unintentionally resulted in a major population bottleneck. All outplanted individuals derive from the seeds collected in 1973 or from seeds collected more recently from the outplanted population. Because no additional seeds were collected from the natural population, the outplanted population appears to include only first- or subsequent-generation offspring of the original two maternal parents (population founders).

Molecular analyses show that this population bottleneck has been accompanied by a major reduction in the level of detectable genetic variation in the outplanted population, which may limit its long-term survival and potential for adaptive evolution.[1] Of special concern is the possible loss of variation at specific genes, such

as the one that controls self-incompatibility in silverswords. This gene limits successful mating between plants of similar genotypes (i.e., of similar genetic constitutions). Loss of variation at this gene in the outplanted population may thus reduce viable seed production, which may affect the species' long-term chances for recovery.

To overcome the legacy of the population bottleneck, we are implementing a genetic management strategy for the Mauna Kea silversword in close cooperation with Steven Bergfeld and Lyman Perry of the Division of Forestry and Wildlife and Patrice Moriyasu of the University of Hawaii's Volcano Rare Plant Facility. The strategy is designed to bring more founders from the natural population into the outplanting program, thus increasing genetic variation in the outplanted population. One management option is to transfer pollen by hand among flowering plants in the natural population or between flowering plants in the natural and outplanted populations, then use the seeds from the crosses to produce container-grown seedlings for outplanting. Because the plants in the natural population are widely scattered, manual pollen transfer is much more reliable than pollination by native insects.

Though simple in principle, this management option is challenging in practice, mainly because flowering is so rare in the natural population. Only 45 adult plants remain in the natural population, and most are unbranched and strictly monocarpic, which means that they flower only once before dying. Because these plants may live 40 years or more before flowering, few if any plants flower in a given year. For example, no plants flowered from 1994 through 1996.

Fortunately, 1997 turned out to be a boom year for Mauna Kea silverswords, with two plants flowering in the natural population. By transferring pollen to and from the plants by hand, we were able to help generate large numbers of seeds, enabling a doubling of the number of known maternal founders for the outplanting program. (Because plants in the natural population only grow in places out of the reach of browsing ungulates, collecting and transferring pollen often involves perching precariously on steep cliffs and rock

faces!) We expect to add more founders in future years, and are now considering additional management options, such as equalizing founder representation (i.e., balancing the genetic contribution of different parents) to ensure that most of the genetic variation in the remnant natural population is retained during reintroduction.

The Search

A key part of the genetic management strategy is searching for more silverswords on Mauna Kea, a challenging task given the rugged volcanic terrain and high elevations. Until recently, the remnant natural population was thought to be confined to a single gulch. However, in late 1996, we discovered five plants in the upper reaches of a second gulch. Though small in number, these plants may be important sources of additional genetic variation with special value to the recovery effort.

Our extensive searching has also turned up remains of long-dead silverswords in almost every major gulch on Mauna Kea. The gulches were likely the last refuges for silverswords on the volcano, as ungulates eliminated plants from the more accessible slopes. The remains conclusively document the historical range of silverswords on Mauna Kea, which is crucial for planning the scope of the reintroduction.

Along with our focus on genetic factors influencing recovery, we are evaluating major ecological factors affecting survival and growth of the silversword population. One factor of overriding importance is the size of the ungulate populations on Mauna Kea. In the 1980's, a court-ordered removal program substantially reduced, but did not eliminate, ungulate populations on the upper slopes. The presence of ungulates continues to pose a serious threat to silversword recovery. Should ungulate populations increase significantly, even the most sophisticated genetic management strategy will be of limited value.

The interaction between silverswords and their native pollinators, such as endemic yellow-faced bees

(Hylaeus spp.), is another important ecological factor. Accidentally introduced alien insect predators, such as Argentine ants (Iridomyrmex humilis), have the potential to decimate native pollinator populations. By disrupting plant pollinator interactions, alien insects could have a major effect on the survival of the silversword.

In a larger context, we view recovery of the silversword as a key step in the restoration of Mauna Kea's alpine and subalpine ecosystems. Silverswords were a major ecosystem component before alien ungulates arrived, particularly at high elevations where few native plants can grow. In reestablishing this key plant species, we also hope to promote the recovery of other important ecosystem elements, especially native insects (pollinators, seed predators, and planthoppers) that depend on silverswords for food or shelter.

Though great challenges remain, the prospects for recovery of the jewel-like Mauna Kea silversword now look bright, especially compared to its status 25 years ago before the first outplanting efforts and passage of the Endangered Species Act. Our hope is that this plant serves as a harbinger for the future of Hawaii's many endangered plant species, whose collective recovery would restore a true national treasure.

The recovery of the Mauna Kea silversword and related species on the Island of Hawaii involves a close partnership among individuals representing various State and Federal agencies, academic institutions, and private organizations. Through its cooperative spirit, the partnership serves as a model for other plant recovery efforts in Hawaii. Among other individuals, the partnership includes:

S. Bergfeld, L. Perry (Hawaii Division of Forestry & Wildlife)

F. Warshauer (U.S. Geological Survey, Biological Resources Division)

T. Tunison (National Park Service)

M. Bruegmann, J. Canfield, D. Hopper (FWS)

P. Moriyasu (University of Hawaii)

E. Friar (Rancho Santa Ana Botanic Garden & Claremont Graduate University)

R. Robichaux (Hawaiian Silversword Foundation & University of Arizona)

The Mauna Kea silversword is featured in the 1997 "BOOK IT!" National Reading Incentive Program sponsored by Pizza Hut, Inc., and Sea World/Busch Gardens. The centerpiece of the program is BioReader II, a booklet developed in conjunction with the FWS that discusses world biodiversity "hotspots" under the umbrella of five imperiled species. As one of the featured species, the Mauna Kea silversword illustrates the challenges confronting island habitats and species, especially the problem of invasion by alien organisms. By providing BioReaders to 895,000 classrooms in 57,000 schools nationwide, the BOOK IT! Program serves a vital role in educating children about their future role as stewards of the planet's biodiversity--tigers, rhinos, parrots, frogs, and silverswords alike. To learn more about Mauna Kea silverswords and island habitats, visit the Kid's Corner on the FWS website (http://www.fws.gov/~r9endspp/endspp.html) or the BioReader bibliographic website (http://www.bookitprogram.com).

The Mauna Kea silversword exemplifies the plight of many Hawaiian plants. A total of 137 Hawaiian plant species have fewer than 50 individuals left in the wild. Further, of the 668 threatened and endangered plant species in the U.S., 282 (42 percent) are Hawaiian. Hawaii's unenviable reputation as the "endangered species capital of the world" results in part from the spectacular diversity and high level of endemism exhibited by its native species. Human activities, from agricultural and urban development to the introduction of alien organisms, have pushed many species to the brink of extinction. It will take cooperative efforts, with both public and private support, to achieve recovery of Hawaii's endangered plants and the

ecosystems on which they depend.

[1] Robichaux RH, Friar EA, Mount DW (1997). Conservation Biology 11:1140-1146.

Robert Robichaux is a professor at the University of Arizona and director of the Hawaiian Silversword Foundation, a non-profit scientific organization devoted to conserving and restoring native Hawaiian plants and ecosystems. Joan Canfield is a Biologist with the FWS Division of Endangered Species in Washington, D.C. Frederick Warshauer is a Biologist with the U.S. Geological Survey, Biological Resources Division, Pacific Island Ecosystems Research Center, near Volcano, Hawaii. Marie Bruegmann is a Biologist with the FWS Pacific Islands Ecoregion Office, Honolulu, Hawaii. Elizabeth Friar is a professor at Claremont Graduate University and research scientist at Rancho Santa Ana Botanic Garden, California.