5-YEAR REVIEW
Short Form Summary
Species Reviewed: *Argyroxiphium sandwicense* subsp. *macrocephalum* (ahinahina)
Current Classification: Endangered

Federal Register Notice announcing initiation of this review:
[USFWS] U.S. Fish and Wildlife Service. 2009. Endangered and threatened wildlife and plants; initiation of 5-year reviews of 103 species in Hawaii. Federal Register 74(49):11130-11133.

Lead Region/Field Office:
Region 1/Pacific Islands Fish and Wildlife Office (PIFWO), Honolulu, Hawaii

Name of Reviewer(s):
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Methodology used to complete this 5-year review:
This review was conducted by staff of the Pacific Islands Fish and Wildlife Office of the U.S. Fish and Wildlife Service (USFWS), beginning on March 16, 2009. The review was based on final critical habitat designations for *Argyroxiphium sandwicense* subsp. *macrocephalum* and other species from the island of Maui (USFWS 2003) as well as a review of current, available information. The National Tropical Botanical Garden provided an initial draft of portions of the review and recommendations for conservation actions needed prior to the next five-year review. The evaluation of Samuel Aruch, a biological consultant, was reviewed by the Plant Recovery Coordinator. The document was then reviewed by Recovery Program Lead and the Assistant Field Supervisor for Endangered Species before submission to the Field Supervisor for approval.

Background:
For information regarding the species listing history and other facts, please refer to the Fish and Wildlife Service's Environmental Conservation On-line System (ECOS) database for threatened and endangered species (http://ecos.fws.gov/tess_public).

Application of the 1996 Distinct Population Segment (DPS) Policy:
This Policy does not apply to plants.

Review Analysis:
Please refer to the final critical habitat designations for *Argyroxiphium sandwicense* subsp. *macrocephalum* published in the Federal Register on May 14, 2003 (USFWS 2003) for a complete review of the species' status (including biology and habitat), threats, and management efforts. No new threats and no significant new information regarding the species biological status have come to light since listing to warrant a change in the Federal listing status of *A. sandwicense* subsp. *macrocephalum*.

The monocarpic (flowers only once, at the end of its lifetime) *Argyroxiphium sandwicense* subsp. *macrocephalum* (Haleakala silversword) reaches full maturity in 15 to 50 years. It blooms in the summer, from June to October (Starr and Loop 2009). The plant remains a compact rosette of leaves until it sends up an erect, central flowering stalk, sets seed, and dies (Starr et al. 2007a). A census of the flowering of *A. sandwicense* subsp. *macrocephalum* on Haleakala Volcano was sporadically done from 1934 to 1962, but since 1969, has been done almost every year. In 2007, the number of flowering plants was 1,133 individuals, the 11th largest year out of 40 years on record. With 1,148 blooming individuals, 2008 was a relatively large flowering year, and also the 10th largest year out of 41 years on record (Starr et al. 2008). The largest year ever recorded was 1991, with 6,632 blooms. The smallest year ever was 1970 with 0 blooming individuals. It is still not known what triggers the plants to bloom, with massive bloom events in some years and hardly any flowering at all in other years (Starr et al. 2007a). In monitoring plots on Haleakala, 32 percent (48 of 152) of the plants have been in the plots since 1982, *i.e*., are at least 24 years old. The smallest of these plants is three centimeters in diameter; the largest is 39 centimeters in diameter. One of the plants, which flowered in 2007, was first reported in 1986, making it 21 years old at the time of flowering In 2008, two individuals which bloomed were first recorded from the plots in 1982 (26 years old). The flowering age of other individuals from these plots were recorded at 24, 22, 19, and 12 years (Starr et al. 2007a, 2008, 2009).

A study of the mycorrhizal fungi associated with roots and root-zone soil from *Argyroxiphium sandwicense* subsp. *macrocephalum* and *Dubautia menziesii* (kaupaoa), both members of the Asteraceae, were collected in a tropical alpine area in Haleakala National Park, Maui. All root samples and all soil collections contained spores of mycorrhizal fungi. Spores of *Acaulospora*, *Entrophospora*, *Glomus*, and *Scutellospora* spp. were found. These fungi are known to play a vital role in scavenging phosphorus and other nutrients from soils and providing them to plants. This association is especially critical to plants growing in soils with low availability of phosphorus, like many of the volcanic soils in Hawaii. Mycorrhizal fungi have also been found to improve drought tolerance. The level of mycorrhizal fungus populations in the soil (the potential for inoculation) may influence recruitment and mortality (Koske and Gemma 2002).

Argyroxiphium sandwicense subsp. *macrocephalum* experiences reduced reproductive success in low flowering years. This is probably an "Allee effect," in which individual fitness is reduced as population size decreases, with extinction becoming more likely as a population declines. Allee effects may be due to a variety of genetic, demographic, and/or ecological factors, including increased levels of inbreeding depression. A five year study of *A. sandwicense* subsp. *macrocephalum* suggests that the Allee effect with this species is pollinator-mediated. The study demonstrated that plants flowering out of synchrony with most of the population (*i.e.*, in low flowering years) exhibited lower percent seed set than synchronously-flowering plants (*i.e*., those flowering in high flowering years). Two pollination experiments conducted over multiple years measured pollen limitation and self-incompatibility in this species. In the three-year pollen limitation study, plants flowering asynchronously were pollen-limited, whereas plants

flowering synchronously were not. This species is strongly self-incompatible (Forsyth 2003), or what is called an "obligate out-crosser" (Loope 2007).

A spontaneous intergeneric hybrid population of *Argyroxiphium sandwicense* subsp. *macrocephalum* and *Dubautia menziesii* is primarily found within Haleakala Crater, especially on Puu o Pele and Puu o Maui cinder cones. Individuals of the hybrid are uncommon, often flowering for several successive years before dying (Medeiros et al. 1998).

Argyroxiphium sandwicense subsp. *macrocephalum* is endemic to the summit of Haleakala Volcano on the island of Maui. It is known from disturbed sites within a 1,000-hectare (2,500 acre) area at 2,100 to 3,000 meters (6,900 to 9,800 feet) elevation in the crater and outer slopes of Haleakala Volcano (USFWS 1997). On the summit, hundreds of flowering individuals were observed in 1999 at the rim of the volcano (Perlman 2009). In 2001, the entire population on Haleakala was estimated to be 50,000 individuals (Starr et al. 2009). Lloyd Loope of the U.S. Geological Survey Haleakala Field Station reported in 2007 that the population declined from 75,000 in 1990 to 50,000 in 2006; he also reported that of these, 4,300 flowered in 2004. The Maui office of the National Guard reported that they had 20 individuals bloom in 2003 (USFWS 2008).

Yearly measurements and counts of the taxon in 11 monitoring plots displayed a population decline. Each year's census includes mapping individual plants, measuring live crown diameter of each plant, and noting life history changes (seedlings, flowered, death). The plots were established in 1982 and have been monitored almost every year. In 2007 and 2008, a 22 percent population decline occurred. In 2009, the population numbers declined another 12 percent, down to 111 individuals in the 11 plots. The total number of plants in the plots dropped by 73 percent since 1982, from 414 to 111 plants. No new seedlings were recorded in the plots in 2007, 2008, or 2009. Survival of the 3 seedlings from 2006 is now 0 percent (none still alive). For the 25 seedlings from 2005 survival has been 15 percent (3 still alive). For the 127 seedlings from 2004 survival has been about 9 percent (11 still alive). For the 5 seedlings from 2001 survival has been about 20 percent (1 still alive). And for the 2 seedlings from 2000 survival has been 50 percent (1 still alive). Thirty-two percent (43 of 133) of the plants have been in the plots since 1982. In summary, 32 percent (43) of the plants in plots are at least 27 years old. The smallest of these older plants are four centimeters in diameter; the largest is 32 centimeters in diameter. The largest plant in the plot has been recorded since1986 and measures 40 centimeters in diameter (Starr et al. 2007a, 2008, 2009).

Inside Haleakala Crater, 4 kilometers (2.5 miles) down Sliding Sands Trail, a few hundred scattered individuals of *Argyroxiphium sandwicense* subsp. *macrocephalum* were seen flowering and fruiting in 1999 at 2,359 meters (7,740 feet) elevation (Perlman, 2009). This group of individuals was reported to be doing well in 2009 (Starr et al. 2009). In 1998, populations in the Crater at Kalapawili and upper Kaupo Gap were believed to be extirpated. In upper Kipahulu Valley, west slope, *A. sandwicense* subsp. *macrocephalum* grew on rocky, steep back walls at 2,225 to 3,048 meters (7,300 to 10,000 feet) elevation. Isolated remnant west slope plants included a single individual

near Koolau Peak at 2,281 meters (7,485 feet); two individuals on the roadside at 2,286 meters (7,500 feet); and a small population (10 to 15 individuals) below the water catchment system, at about 2,225 meters (7,300 feet) elevation (Medeiros 1998). One individual, in fruit, was also observed in the Hanawi Natural Area Reserve, at Puu Alaea, on Maui, at 2,295 meters (7,530 feet) elevation in 2008 (Perlman 2009).

Staff at Haleakala National Park believe that while some populations have increased or remained healthy, that the decline in the 11 monitoring plots may indicate an overall decline in the species which needs to be monitored more closely (Loope 2007). Currently, *Argyroxiphium sandwicense* subsp. *macrocephalum* is found in 7 populations of approximately 50,000 total individuals.

Invasive introduced plant species have altered the habitat for *Argyroxiphium sandwicense* subsp. *macrocephalum* and compete for resources (Listing Factor A and E). These species include *Hypochoeris radicata* (hairy cat's-ear), *Arenaria serpyllifolia* (thyme-leaved sandwort), *Erodium cicutarium* (storksbill), *Lobularia maritima* (sweet alyssum), *Malva neglecta* (common mallow), *Medicago lupulina* (black medick), *Oenothera stricta* subsp. *stricta* (evening primrose), *Plantago lanceolata* (common plantain), *Polycarpon tetraphyllum* (polycarpon), *Rumex acetosella* (sheep sorrel), *Senecio sylvaticus* (wood groundsel), *Sonchus* sp. (sow thistle), and *Taraxacum officinale* (common dandelion). Introduced grasses include *Anthoxanthum odoratum* (sweet vernalgrass), *Bromus willdenowii* (rescue grass), *Cynodon dactylon* (Bermuda grass), *Holcus lanatus* (Yorkshire fog), *Poa annua* (annual bluegrass), *Poa pratensis* (Kentucky bluegrass), and *Vulpia bromoides* (brome fescue) (Perlman 2009; Starr and Starr 2002).

Loss of native pollinators may be affecting the survivorship of *Argyroxiphium sandwicense* subsp. *macrocephalum* (Listing Factor E) (Forsyth 2003). Drought is a possible contributing factor to the decline of the species (Listing Factor E). Many years during the past two decades have been dry years, including a string of the driest years on record. However, local scale measurements of weather have not been kept, and the installation of a weather station is proposed. There also have been some population declines in wet years. Other factors contributing to decline may be higher temperatures and a more stable inversion layer (Starr et al. 2009). Climate change may also pose a threat to this species (Listing Factors A and E). However, current climate change analyses in the Pacific Islands lack sufficient spatial resolution to make predictions on impacts to this species. The Pacific Islands Climate Change Cooperative (PICCC) has currently funded climate modeling that will help resolve these spatial limitations. We anticipate high spatial resolution climate outputs by 2013.

Rats (*Rattus* spp.), slugs (various species) and ants are pests of this species (Listing Factor C) (Perlman 2009). In Hawaii, the Argentine ant (*Linepethima humile*) poses a direct threat to native arthropods at higher elevations, and an indirect threat to *Argyroxiphium sandwicense* subsp. *macrocephalum*, which is dependent on native invertebrates for pollination (Listing Factor E) (Starr et al. 2007b). The Argentine ant has been invading Haleakala National Park since at least 1967, and in areas where it occurs some insect pollinators are greatly reduced in abundance. While the Argentine ant

currently overlaps with only a small portion of the total *A. sandwicense* subsp. *macrocephalum* population in the Kalahaku area, past patterns of its spread strongly suggest that, if unchecked, this ant will invade the majority of the subalpine shrubland and alpine zones in the park which includes all *A. sandwicense* subsp. *macrocephalum* habitat. A reduction in important native pollinators throughout the species' range could lead to significant decline in seed set. Even a relatively modest reduction in average seed set from 30 to 20 percent could mean the difference between an increasing and decreasing population over the long term. In 1997, a group of plants located in ant-invaded habitat at Kalahaku had an average seed set of only 2.3 percent, as compared to an average seed set rate of 40.8 percent in non-invaded areas within Haleakala's crater (Loope 2007).

The results of a recent study indicate that the Argentine ant is contributing to significant changes in the Haleakala arthropod fauna and may pose a threat to endemic plants such as *Argyroxiphium sandwicense* subsp. *macrocephalum* and *Dubautia menziesii* (Listing Factor E) (Danoff-Burg 2003).

Haleakala National Park (NP) has made extensive effort to collect, propagate, and outplant *Argyroxiphium sandwicense* subsp. *macrocephalum*. Haleakala NP Service Research and Resource Management programs have developed and implemented state-of-the-art techniques for fencing and feral animal control and have removed all ungulates and implemented invasive introduced plant control, rodent control, introduced insect management, and ecosystem monitoring. In 2004, almost 600 grams (21.2 ounces) of seeds were collected from 79 founder individuals (Haleakala NP Resource Management, Vegetation Management 2004). In 2005, 5,500 seeds were collected from 21 founders, and the Haleakala NP nursery has 693 individuals in cultivation from the summit area representing 50 wild founder individuals. In 2004, 7 individuals were outplanted. In 2005, 45 individual plants and thousands of seeds were reintroduced on the west slope of the summit and in the Crater. In 2006, 615 seeds were outplanted. In 2007, 57500 seeds were planted from 15 founders. In 2008, 20 individuals were outplanted at the summit, 2000 seeds were collected, and 642 propagules were being grown from 50 founders at the Haleakala NP nursery (Haleakala National Park 2008; USFWS 2008). The National Tropical Botanical Garden has two accessions of seeds collected in 1991, totaling 10,850 seeds (M. Clark, National Tropical Botanical Garden, pers. comm. 2009; National Tropical Botanical Garden 2009).

Stabilizing, downlisting, and delisting objectives are provided in the recovery plan for the Maui plant cluster (USFWS 1997), based on whether the species is an annual, a short-lived perennial (fewer than ten years), or a long-lived perennial. *Argyroxiphium sandwicense* subsp. *macrocephalum* does not fit into any of these categories because of its unique life history. To be delisted, the threat to its pollinators from the alien Argentine ant must be controlled through management action, no other threat of comparable magnitude must arise during the time it is not controlled, and the single population must continue to exceed 50,000 individuals.

The delisting goals for this species have not been met as the species does not exceed 50,000 individuals (Table 1) and the threat to its pollinators from the alien Argentine ant has not been controlled through management (Table 2). Therefore, *Argyroxiphium sandwicense* subsp. *macrocephalum* meets the definition of threatened as it remains in danger of extinction in the foreseeable future throughout its range.

Recommendations for Future Actions:

- Study population dynamics over the entire population with accurate mapping so that factors such as blooming and seed set can be correlated with abiotic factors such as climate change.

- Study pollinators and other insects visiting these flowers, and their relationship to the invasive Argentine ant.

- Determine which pollinators are most critical to seed set, and thus to the long-term survival of the species.

- Work with the National Park Service, the Hawaii Division of Forestry and Wildlife and other land managers to continue implementation of ecosystem-level restoration and management to benefit this species.

- Assess the modeled effects of climate change on this species, and use to determine future landscape needed for the recovery of the species.

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Table 1. Status of *Argyroxiphium sandwicense* subsp. *macrocephalum* from listing through 5-year review.

Date	No. wild indivs	No. outplanted	Stability Criteria identified in Recovery Plan	Stability Criteria Completed?
1992 (listing)	50,000	0	Threat to its pollinators from the alien Argentine ant is controlled through management action	No
			No other threat of comparable magnitude arises during that time	Yes
			The single population continues to exceed 50,000	No
1997 (recovery plan)	>64,000	0	Threat to its pollinators from the alien Argentine ant is controlled through management action	No
			No other threat of comparable magnitude arises during that time	Yes
			The single population continues to exceed 50,000	Yes
2003 (critical habitat)	39,025 - 44,025	Unknown	Threat to its pollinators from the alien Argentine ant is controlled through management action	No
			No other threat of comparable magnitude arises during that time	Yes
			The single population continues to exceed 50,000	No
2010 (5-year review)	~ 50,000	27	Threat to its pollinators from the alien Argentine ant is controlled through	No (Table 2)

Date	No. wild indivs	No. outplanted	Stability Criteria identified in Recovery Plan	Stability Criteria Completed?
			management action	
			No other threat of comparable magnitude arises during that time	Yes
			The single population continues to exceed 50,000	No, the population has declined to 50,000

Table 2. Threats to *Arygyroxiphium sandwicense* subsp. *macrocephalum*.

Threat	Listing factor	Current Status	Conservation/ Management Efforts
Ungulates – habitat modification and herbivory	A, D	Ongoing	Yes, all of Haleakala Crater is fenced
Ants – predation on pollinators	C	Ongoing	Yes, testing efficient and effective methods
Rats – herbivory	C	Ongoing	Yes, but inefficient until aerial rodenticide is available
Slugs – herbivory	C	Ongoing	No
Invasive introduced plants	A, E	Ongoing	Yes
Climate change	A, E	Increasing	No, but research on impacts ongoing

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SIGNATURE PAGE for 5-YEAR REVIEW of *Argyroxiphium sandwicense* subsp. *macrocephalum* (ahinahina)

Pre-1996 DPS listing still considered a listable entity? N/A

Recommendation resulting from the 5-year review:

_____ Delisting
_____ Reclassify from Endangered to Threatened status
_____ Reclassify from Threatened to Endangered status
_X_ No Change in listing status

Field Supervisor, Pacific Islands Fish and Wildlife Office

Date 8/2/15