5-YEAR REVIEW

Short Form Summary

Species Reviewed: *Solanum incompletum* (popolo ku mai)

Current Classification: Endangered

Federal Register Notice announcing initiation of this review:

[USFWS] U.S. Fish and Wildlife Service. 2013. Endangered and threatened wildlife and plants; Initiation of 5-year status reviews of 44 species in Oregon, Hawaii, Guam, and the Northern Mariana Islands. Federal Register 78(24):8185-8187.

Lead Region/Field Office:

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

Name of Reviewer(s):

Chelsie Javar-Salas, Plant Biologist, PIFWO
Marie Bruegmann, Plant Recovery Coordinator, PIFWO
Kristi Young, Programmatic Deputy Field Supervisor, PIFWO

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 4, 2013. The review was based on a review of current, available information since the last 5-year review for *Solanum incompletum* (USFWS 2008). The evaluation by Chelsie Javar-Salas, Plant Biologist, was reviewed by the Plant Recovery Coordinator. It was subsequently reviewed and approved by the Programmatic Deputy Field Supervisor.

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 at: *http://ecos.fws.gov/tess_public*.

Review Analysis:

Please refer to the previous 5-year review for *Solanum incompletum* published on January 18, 2008 (available at: *https://ecos.fws.gov/docs/five_year_review/doc1809.pdf*) for a complete review of the species' status, threats, and management efforts. No significant new information regarding the species' biological status has come to light since listing to warrant a change in the Federal listing status of *S. incompletum*.

This short-lived perennial shrub in the nightshade family (Solanaceae) is endangered and reported from Kauai, Molokai, Lanai, Maui, and the island of Hawaii (Symon 1999). Currently, there are no known populations of this species on Lanai, Molokai, or Maui (Hawaii Biodiversity and Mapping Program 2008; Plant Extinction Prevention Program [PEPP] 2009). The status and trends for *Solanum incompletum* are provided in the tables below.

New status information:

- In 2009, there were 14 individuals at Puu Anahulu on Hawaii Island (PEPP 2009). In 2010, there were 15 plants at Puu Anahulu and Puu Waawaa (PEPP 2010). In 2011, an estimated 75 individuals of *Solanum incompletum* was known from Pohakuloa Training Area (PTA), Puu Anahulu, and Puu Waawaa (PEPP 2011). However, approximately 10 individuals were lost in the Puu Waawaa region apparently due to drought conditions (PEPP 2011). In 2014, two populations containing approximately 30 to 75 mature wild individuals of *S. incompletum* were known (PEPP 2014). In 2014, there were five individuals at Puu Anahulu (PEPP 2014).
- In 2010, there were 158 wild individuals (72 mature and 86 immature) of *Solanum incompletum* at PTA (U.S. Army Garrison [U.S. Army 2010]). Quantifying abundance for this species has proven difficult at PTA given its tendency for below ground clonal reproduction and the formation of above ground root sprouts (U.S. Army 2010). When uncertainty exists as to whether an above ground structure is an individual or a clone from another individual, it is tagged and marked as a possible clone and tallied accordingly. Nevertheless, there is likely some error in counts representing the actual number of individual plants present in a given area. In August 2013, there were an estimated 81 individuals, including an estimate of all potential clones (U.S. Army 2014).
- Overall, the numbers of individuals have increased from the approximately 83 wild mature individuals reported in the previous 5-year review to approximately 86 wild individuals in 2015. The number of reintroduced individuals decreased from the estimated 950 individuals reported in the previous 5-year review to more than 554 individuals in 9 populations. Natural recruitment was observed at two reintroduced sites at PTA with a total of 46 mature and 68 immature individuals. Natural recruitment of approximately 68 mature and 121 immature individuals of *S. incompletum* was also observed at outplanting sites located on State-owned lands outside of PTA.

New threats:

- Climate change adaptation strategy – Fortini *et al*. (2013) conducted a landscape-based assessment of climate change vulnerability for native plants of Hawaii using high resolution climate change projections. Climate change vulnerability is defined as the relative inability of a species to display the possible responses necessary for persistence under climate change. The assessment by Fortini *et al*. (2013) concluded that *S. incompletum* has a low vulnerability to the impacts of climate change.
- Stochastic events – Drought mortality or reduced viability – Drought may exacerbate the effects of ungulates and has direct adverse impacts on *S. incompletum* (PEPP 2010, 2014; U.S. Army 2010).
- Collecting impacts – Illegal collection for scientific, horticultural or other purposes threatens the populations of *S. incompletum*, as well as possible excessive visitation. For instance, on two incidents in 2013, seven reintroduced individuals of *S. incompletum* were uprooted in the Mauna Kea area and those plants were stolen along with other common and federally listed plants (P. Peshut and S. Evans, pers. comm. 2013).

New management actions:

- Surveys / inventories
  - A single new location of *S. incompletum* was recorded within the installation wide survey area in the Kipuka Kalawamauna West Fence Unit (U.S. Army 2014). This new discovery significantly benefits this species because there are only four known locations of this species at PTA (U.S. Army 2014).
- Ungulate monitoring and control
  - In 2009, seven fenced enclosures approximately 3 meters by 3 meters (10 feet by 10 feet) were constructed to protect wild individuals of *S. incompletum* at Puu Anahulu (PEPP 2009).
  - In 2010, extreme drought conditions throughout PTA led to an increase in ungulate pressure to rare plants and their habitat. Consequently, emergency fences constructed of lightweight materials (plastic orange fencing) were breached and significant browse damage was observed on individuals of *S. incompletum* within Areas of Species Recovery (ASRs) 24 and 40 (U.S. Army 2010). The emergency fences were replaced with small-scale fences constructed from metal t-posts and hog wire fencing to ensure the plants were protected from ungulates.
  - The *Solanum incompletum* Fence Unit and the external perimeter of the Mixed Tree Fence Unit were completed in 2010 (U.S. Army 2010). All known individuals of *S. incompletum* at PTA are protected by large-scale fence units and ungulate control commenced in 2011. As of 2013, the *Solanum incompletum* Fence Unit was ungulate-free (U.S. Army 2014).
  - In May 2014, a damaged 10-acre enclosure in Upper Puu Anahulu/Puuwaawaa was repaired (State of Hawaii Department of Land and Natural Resources [DLNR] 2014). The enclosure will provide protected habitat for outplanting the following endangered species *Zanthoxylum hawaiiense*, *Neraudia ovata*, *Solanum incompletum*, *Haplostachys haplostachya*, *Stenogyne angustifolia*, *Portulaca sclerocarpa*, and other dry to mesic species (DLNR 2014).
- Invasive plant monitoring and control – Manual hand clearing and maintenance spraying of weeds is ongoing around individuals of *S. incompletum* at PTA (U.S. Army 2010, 2014).
- Rodent predation or herbivory control – Snap traps and rodenticides are used to control rodents at PTA (U.S. Army 2010). As of 2013, rodent control was suspended pending a review of control methods and efficacy (U.S. Army 2014). In 2014, primarily work will identify which rodent species is responsible for damaging plants, and species-specific control methods will be developed and implemented (U.S. Army 2014).
- Captive propagation for genetic storage and reintroduction
  - The Volcano Rare Plant Facility (2013) had 10 individuals growing in their nursery from the Puu Anahulu population and propagated 11 plants for reintroductions next year. The Volcano Rare Plant Facility (2014) had 10 individuals growing in their nursery from the Puu Anahulu population.
  - The Lyon Arboretum's Seed Conservation Laboratory (2014) has 550 seeds in storage.
  - The National Tropical Botanical Garden (2014) propagated 37 seeds in 2012 from PTA. There are three plants outplanted at the Visitor's Center in Lawai and one

plant at McBryde Lower Valley Conservation and Horticulture Center (National Tropical Botanical Garden 2015) for genetic storage and education.
    - In 2010, four more founders of *S. incompletum* were added to the three founders already in cultivation at the Rare Plant Propagation Facility at PTA (U.S. Army 2010). Two of the seven founders at the Rare Plant Propagation Facility are no longer extant at PTA.
    - In 2013, there were more than 13,000 seeds from 117 accessions representing three groups and 57 founders of *S. incompletum* in long-term storage at PTA (U.S. Army 2014). In 2015, nine fruits from four founders were collected and placed into long-term storage at PTA (U.S. Army 2015).
    - In 2014, fruit from *S. incompletum* was collected from Upper Puu Anahulu and Puu Waawaa Forest Reserve (DLNR 2014).
- Captive propagation protocol development – Propagation trials were conducted to determine appropriate storage and propagation techniques for *S. incompletum*. The trials indicated that seeds from *S. incompletum* had a low germination rate over an extended period of years (the number of years was not specified) and the seeds remained viable for more than 15 years (U.S. Army 2015).
- Population viability monitoring and analysis
    - In 2009, 13 of the 14 known wild individuals at Puu Anahulu were monitored for reproductive development (PEPP 2009). Fruit was collected from one founder and delivered to Volcano Rare Plant Facility.
    - In 2010, the populations at Puu Anahulu and Puu Waawaa were monitored for reproductive development and overall health of the plants (PEPP 2010). Fifteen plants were observed and cuttings were collected from five individuals. Most of the plants were noted as wilting from the effects of severe drought.
    - In 2010, no mature plants were reproductively active at the time of monitoring (U.S. Army 2010). This differs from 2009 when more than half (58%) of mature individuals were reproductive. Based on field observations, this may be driven primarily by drought conditions experienced in 2010.
    - In 2011, there was a substantial decline of 10 plants in the Puu Waawaa region, apparently due to the recent droughts (PEPP 2011). It is likely this species suffered similar declines across its entire range, including on adjacent federal lands at PTA (PEPP 2011).
    - Careful and closer analysis is needed to determine whether wild individuals are indeed separate individuals or are they actually attached underground and the root shoots represent a single individual (PEPP 2014). If this is true, staff at PTA estimated that they may have 25 distinct individuals with an additional 5 plants located outside PTA (PEPP 2014).
    - In 2013, five of the 12 known individuals at Puu Anahulu were monitored (PEPP 2014). Fruit was collected from a single individual and four cuttings were collected (PEPP 2014). In 2014, the five individuals were monitored again (PEPP 2014).
    - At site 209 in the Kipuka Kalawamauna east fence unit, 27 reintroduced individuals (84 percent) survived of the 32 planted in 2003 (U.S. Army 2015). Although a few seedlings have been observed over the last 4 years, none have persisted (U.S. Army 2015). This may be due to insufficient rain or insect

predation. In 2014, eight naturally recruited seedlings were observed at the site (U.S. Army 2015).
    - At site 214 within the Kipuka Alala South fence unit, monitoring of the site in 2014 tallied 123 reintroduced individuals and 46 naturally recruited mature and approximately 60 immature individuals at the site (U.S. Army 2015).
    - Near Saddle Road on State-owned lands, natural recruitment of 30 seedlings and/or suckers was observed in 2014 (U.S. Army 2015).
    - In North Kona on State-owned lands, natural recruitment of three adults and two immature individuals were observed in 2014 (U.S. Army 2015).
    - At Puu Waawaa Cone Unit on State-owned lands monitoring conducted in 2014 revealed natural recruitment of 19 mature and 21 immature individuals (U.S. Army 2015).
- Reintroduction / translocation
    - In 2010, 10 individuals of *S. incompletum* were reintroduced at three sites at PTA (U.S. Army 2010).
    - In 2014, 8 individuals were added to site 209 of the Kipuka Kalawamauna east fence unit (U.S. Army 2015).
    - In 2014, 16 individuals of *S. incompletum* were reintroduced at Mixed Tree fence unit (U.S. Army 2015).
    - During 2002 to 2012 at site 214 within the Kipuka Alala south fence unit, 152 individuals were reintroduced to the site (U.S. Army 2015). In 2014, an additional 18 individuals were reintroduced to the site.
    - At site 219 within the Kipuka Alala South fence unit, four individuals were reintroduced in 2014 (U.S. Army 2015).
    - In 2014, at site 220 within the Kipuka Kalawamauna north fence unit three individuals were reintroduced (U.S. Army 2015).
    - Near Saddle Road on State-owned lands, 445 individuals were reintroduced during 2002 to 2012, 10 individuals were added in 2014, and 209 plants remained in 2014 (U.S. Army 2015).
    - In North Kona on State-owned lands, 225 individuals were outplanted during 2004 to 2009 and only 4 individuals remained in 2014 (U.S. Army 2015).
    - At Puu Waawaa Cone Unit on State-owned lands, 391 individuals were reintroduced during 2005 to 2012 and additional 15 individuals were reintroduced in 2014 (U.S. Army 2015). In 2014, 138 reintroduced individuals remained.
    - On County-owned lands in North Kona, nine individuals were reintroduced during 2008 to 2012 with an additional two individuals reintroduced in 2014. Only four plants survived in 2014 (U.S. Army 2015).
- Stochastic events – Build resilience and redundancy – In 2010, all individuals of *S. incompletum* within ASRs 24 and 40 at PTA were watered (U.S. Army 2010). Plants located in ASR 24 were visited monthly, due to its remote location, and provided approximately 0.5 gallons of water. Plants located in ASR 40 were visited once a week and each plant was given approximately 0.5 gallons of water. The frequency of watering in ASR 40 was reduced to once every two weeks, then once every four weeks. Supplemental monitoring was conducted following the watering and plants were photo documented. After supplemental watering was initiated in ASR 40, invasive ants and scale were observed on and around individuals of *S. incompletum*.

As a result, ant control was implemented at six of the seven plant locations (one location was excluded because the plant had died).

- Listing and critical habitat designation – Seven units of critical habitat for *S. incompletum* was proposed in the lowland dry, lowland mesic, and subalpine ecosystems on Maui (USFWS 2012). On Lanai, critical habitat for *S. incompletum* was proposed in six units in the coastal, lowland dry, lowland mesic, and dry cliff ecosystems. The final rule for critical habitat designations has not been published at the time of this review.

Synthesis:
Stabilizing, downlisting, and delisting objectives are provided in the recovery plan for the multi-island plants (USFWS 1999), based on whether the species is an annual, a short-lived perennial (fewer than 10 years), or a long-lived perennial. *Solanum incompletum* is a short-lived perennial, and to be considered stable, the taxon must be managed to control threats (e.g., fenced) and be represented in an *ex situ* (at other than the plant's natural location, such as a nursery or arboretum) collection. In addition, a minimum of three populations should be documented on the islands where they now occur or occurred historically. Each of these populations must be naturally reproducing and increasing in number, with a minimum of 50 mature individuals per population.

The interim stabilization goals for this species have not been met. Although, there are approximately 86 individuals known in the wild, none of the two populations contain more than 50 mature individuals, and survivorship of plants and resultant seedlings in reintroduced populations are extremely low (Table 1). In addition, all threats are not being sufficiently managed throughout all of the populations (Table 2). Therefore, *Solanum incompletum* meets the definition of endangered as it remains in danger of extinction throughout its range.

Recommendations for Future Actions:

- Surveys / inventories – Survey geographical and historical range for a current assessment of the species' status.
- Captive propagation for genetic storage and reintroduction – Continue collection of genetic resources for storage, propagation, and reintroduction into protected suitable habitat within historical range.
- Ungulate monitoring and control – Maintain existing exclosures and monitor for potential incursions.
- Invasive plant monitoring and control – Eradicate invasive introduced plants within ungulate exclosures and maintain exclosures free of invasive plants.
- Population viability monitoring and analysis – Continue monitoring wild and reintroduced individuals.
- Fire monitoring and control – Develop and implement a fire management plan at the existing exclosures.
- Alliance and partnership development – Initiate planning and contribute to implementation of ecosystem-level restoration and management to benefit this taxon.

Table 1. Status and trends of *Solanum incompletum* from listing through current 5-year review.

Date	No. wild indivs	No. outplanted	Stability Criteria identified in Recovery Plan	Stability Criteria Completed?
1994 (listing)	2	0	All threats managed in all 3 populations	No
			Complete genetic storage	No
			3 populations with 50 mature individuals each	No
1999 (recovery plan)	40	0	All threats managed in all 3 populations	Partially
			Complete genetic storage	Partially
			3 populations with 50 mature individuals each	No
2003 (critical habitat)	12	527	All threats managed in all 3 populations	Partially
			Complete genetic storage	Partially
			3 populations with 50 mature individuals each	No
2008 (5-yr review)	83	950 (ca 10% mature)	All threats managed in all 3 populations	Partially
			Complete genetic storage	Partially
			3 populations with 50 mature individuals each	No
2012 (proposed critical habitat)	0 (Maui, Lanai, & Molokai only)	n/a	All threats managed in all 3 populations	No
			Complete genetic storage	No
			3 populations with 50 mature individuals each	No
2015 (5-yr review)	~86	554 (189 natural recruits)	All threats managed in all 3 populations	Partially
			Complete genetic storage	Partially
			3 populations with 50 mature individuals each	No

Table 2. Threats to *Solanum incompletum* and ongoing conservation efforts.

Threat	Listing factor	Current Status	Conservation/ Management Efforts
Ungulates – degradation of habitat and herbivory	A, C, D, E	Ongoing	Partially, PTA is fenced and small-scale fences at Puu Anahulu
Invasive introduced plants	A, E	Ongoing	Partially, ongoing at PTA
Rodent predation or herbivory – rats and mice	C	Ongoing	Partially, control suspended at PTA in 2013, studies ongoing in 2014
Drought	E	Ongoing	Partially, supplement watered at PTA in 2010
Fire	E	Ongoing	None
Military activities	E	Ongoing	Partially, ESA consultations at PTA
Low numbers	E	Ongoing	Partially, captive propagation for genetic storage and reintroduction
Climate change	A, E	Increasing	None

References:

See previous 5-year review for a full list of references (USFWS 2008). Only references for new information are provided below.

Fortini, L., J. Price, J. Jacobi, A. Vorsino, J. Burgett, K. Brinck, F. Amidon, S. Miller, S. Gon II, G. Koob, and E. Paxton. 2013. A landscape-based assessment of climate change vulnerability for all native Hawaiian plants. Technical report HCSU-044. Hawaii Cooperative Studies Unit, University of Hawaii at Hilo, Hawaii. 141 pages.

Harold L. Lyon Arboretum Seed Conservation Laboratory. 2014. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. Seed storage Microsoft Access database. University of Hawaii at Manoa, Honolulu, Hawaii. Unpublished.

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[PEPP] Plant Extinction Prevention Program. 2009. Plant Extinction Prevention Program annual report, fiscal year 2009 (July 1, 2008-June 30, 2009).

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[PEPP] Plant Extinction Prevention Program. 2010. Plant Extinction Prevention Program annual report, fiscal year 2010 (July 1, 2009-June 30, 2010). Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii.

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[DLNR] State of Hawaii Department of Land and Natural Resources. 2014. Department of Land and Natural Resources, Division of Forestry and Wildlife, Section 6 annual performance report for plant restoration and enhancement, threatened, endangered, candidate, and species of concern outplanting, Hawaii; interim report. July 1, 2013 – June 30, 2014. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii.

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[U.S. Army] U.S. Army Garrison Pohakuloa. 2014. Natural Resources Office, biennial report, Pohakuloa Training Area, Island of Hawaii. 01 October 2011 to 30 September 2013. Prepared in cooperation with the Center for Environmental Management of Military Lands, Colorado State University. 166 pages.

[U.S. Army] U.S Army Garrison. 2015. FY 2014 annual report for the natural resources office, Pohakuloa Training Area, Island of Hawaii. 84 pages. Unpublished report submitted to the U.S. Fish and Wildlife Service, Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii.

[USFWS] U.S. Fish and Wildlife Service. 1999. Recovery plan for multi-island plants. U.S. Fish and Wildlife Service, Portland, Oregon. 206 pages + appendices.

[USFWS] U.S. Fish and Wildlife Service. 2008. *Vigna o-wahuensis* 5-year review short form summary. Pacific Islands Fish and Wildlife Office, Honolulu, Hawaii. 5 pages.

[USFWS] U.S. Fish and Wildlife Service. 2012. Endangered and threatened wildlife and plants; listing 38 species on Molokai, Lanai, and Maui as endangered and designating critical habitat on Molokai, Lanai, Maui, and Kahoolawe for 135 species; proposed rule. Federal Register 77(112):34464-34775.

Volcano Rare Plant Facility. 2013. Report on controlled propagation of listed and candidate species, as designated under the U.S. Endangered Species Act. 12 pages. Unpublished.

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Personal communications

Peshut, Peter J. and Steven A. Evans. 2013. Manager, Natural Resources Office, US Army Garrison-Pohakuloa and Botanical Program Manager, Center for Environmental Management Military Lands. Letter to Tim Langer, Pacific Islands Fish and Wildlife Office, dated December 23, 2013. Subject: theft of listed plants.

U.S. FISH AND WILDLIFE SERVICE
SIGNATURE PAGE for 5-YEAR REVIEW of *Solanum incompletum* (popolo ku mai)

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

Appropriate Listing/Reclassification Priority Number, if applicable:_____

for **Programmatic Deputy Field Supervisor, Pacific Islands Fish and Wildlife Office**

Maria M Bluegmann Date 2015-08-06