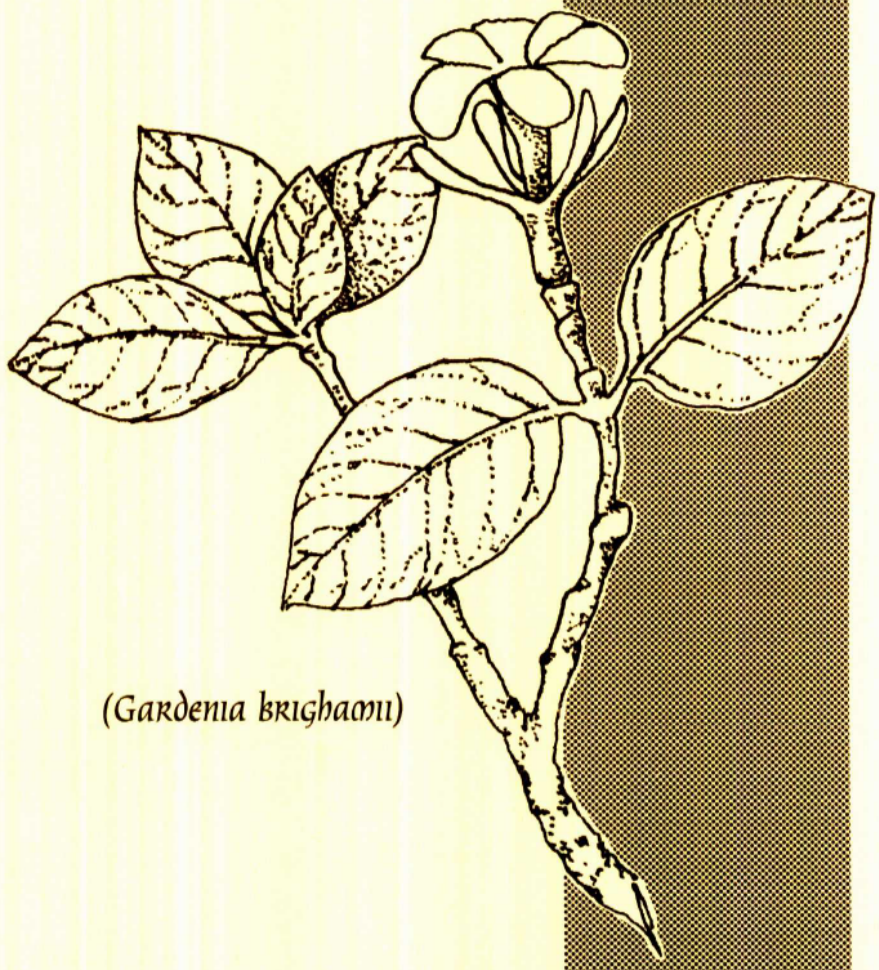
Recovery Plan for the Hawaiian Gardenia



(*Gardenia brighamii*)

RECOVERY PLAN

FOR THE

HAWAIIAN GARDENIA

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for
Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

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Acting
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Date: SEP 30 1993

EXECUTIVE SUMMARY OF THE RECOVERY PLAN FOR THE HAWAIIAN GARDENIA

Current Species Status: The Hawaiian gardenia (*Gardenia brighamii*) is federally listed as endangered. Currently, there are only six known wild populations, two on Oahu, three on Lanai and one on Molokai. Two of the populations are made up of only a single tree. There are less than 20 individuals remaining in the wild.

Habitat Requirements and Limiting Factors: *Gardenia brighamii* is found in dry scrub and forests on the leeward sides of the main Hawaiian islands. Sites are generally located at low to mid-elevation (1,000 to 1,800 feet; 304.8 to 548.6 meters) with well-drained, lateritic soils of low fertility. All populations are threatened by alien plant competitors, introduced herbivores, fire, and pathogens.

Recovery Objective: Downlist to threatened status.

Recovery Criteria: The species may be downlisted when it is represented by three naturally reproducing, healthy, fenced populations, each with 50 mature plants, on each of Lanai, Molokai, Oahu, Hawaii and Maui.

Actions Needed:

1. Secure habitat of current populations and manage threats.
2. Conduct research on limiting factors.
3. Increase numbers and monitor.
4. Reestablish in former range.
5. Validate recovery objectives.

Total Estimated Cost of Recovery ($1,000):

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Total
1992	8	0	0	0	0	8
1993	14.25	0	0	0	0	14.25
1994	258.75	141	204	88	0	691.75
1995	91.50	141	161	32	0	425.50
1996	91.50	141	469	293	36	1030.50
1997	91.50	141	456	253	36	977.50
1998	91.50	141	295.75	85	56	669.25
1999	91.50	125	295.75	85	56	653.25
2000	91.50	125	282	76	56	630.50
2001	91.50	125	282	76	36	610.50
2002	91.50	125	282	76	36	610.50
2003	91.50	125	282	76	36	610.50
2004	91.50	0	147	76	36	350.50
2005	91.50	0	147	76	36	350.50
2006	91.50	0	147	76	36	350.50
2007	91.50	0	147	76	36	350.50
2008	91.50	0	147	76	36	350.50
2009	91.50	0	147	76	36	350.50
2010	91.50	0	147	76	36	350.50
Total	1745.00	1330.00	4038.50	1672.00	600.00	9385.50

Date of Recovery: Downlisting to Threatened should initiate in 2010, if recovery criteria are met.

THIS IS THE COMPLETED RECOVERY PLAN FOR THE HAWAIIAN GARDENIA (GARDENIA BRIGHAMII). IT DELINEATES REASONABLE ACTIONS THAT ARE BELIEVED TO BE REQUIRED TO RECOVER AND/OR PROTECT THE SPECIES. OBJECTIVES WILL BE ATTAINED AND ANY NECESSARY FUNDS MADE AVAILABLE SUBJECT TO BUDGETARY AND OTHER CONSTRAINTS AFFECTING THE PARTIES INVOLVED, AS WELL AS THE NEED TO ADDRESS OTHER PRIORITIES. THIS RECOVERY PLAN DOES NOT NECESSARILY REPRESENT OFFICIAL POSITIONS OR APPROVALS OF THE COOPERATING AGENCIES, AND IT DOES NOT NECESSARILY REPRESENT THE VIEWS OF ALL INDIVIDUALS WHO PLAYED A ROLE IN PREPARING THE PLAN. IT IS SUBJECT TO MODIFICATION AS DICTATED BY NEW FINDINGS, CHANGES IN SPECIES STATUS, AND COMPLETION OF TASKS DESCRIBED IN THE PLAN.

ACKNOWLEDGEMENTS

The recovery plan for the Hawaiian gardenia (Gardenia brighamii) was prepared by Dr. Loyal Mehrhoff, Assistant Botanist, Bishop Museum, P.O. Box 19000A, Honolulu, Hawaii 96817-0916.

LITERATURE CITATIONS

Literature Citations should read as follows:

U.S. Fish and Wildlife Service. 1993. Recovery Plan for the Hawaiian Gardenia (Gardenia brighamii). U.S. Fish and Wildlife Service, Portland, OR. 69 pp.

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I. INTRODUCTION

Brief Overview

The State of Hawaii harbors the most unique and imperiled flora in the United States of America. Of the 1,000 native species known from Hawaii, almost 900 are found only on these islands (Wagner et al. 1990). At least 80 endemic Hawaiian species have been completely extirpated by human activities and approximately another 200 species are in immediate danger of extinction (Loyal Mehrhoff, unpublished data).

Many of the extinct and at-risk species are former components of Hawaii's dry forest ecosystems, expecially the low elevation dry forests. Early naturalists, such as Rock (1913), were particularly impressed with these forests and considered them to be among the most diverse and unique communities in Hawaii. Today, the dry land forest communities are most notable by their absence.

Soon after their arrival 1,500 years ago, the prehistoric Hawaiians began to extensively alter the dry forests by converting lowland areas to agriculture, intentionally burning forested areas, and introducing alien species (Cuddihy and Stone 1990). A little over 200 years ago, Europeans arrived and greatly accelerated activities detrimental to lowland ecosystems. These actions have combined to almost eliminate this formerly widespread vegetation type. Today, less than 10% of the original dry forest remains and much of this remnant forest is highly fragmented and infested with alien weeds (Hawaii Department of Land and Natural Resources et al. 1991).

One member of Hawaii's dry land forests is the Hawaiian gardenia (Gardenia brighamii; Fig. 1). This species is known only from the Hawaiian Islands. It is thought to have originally been

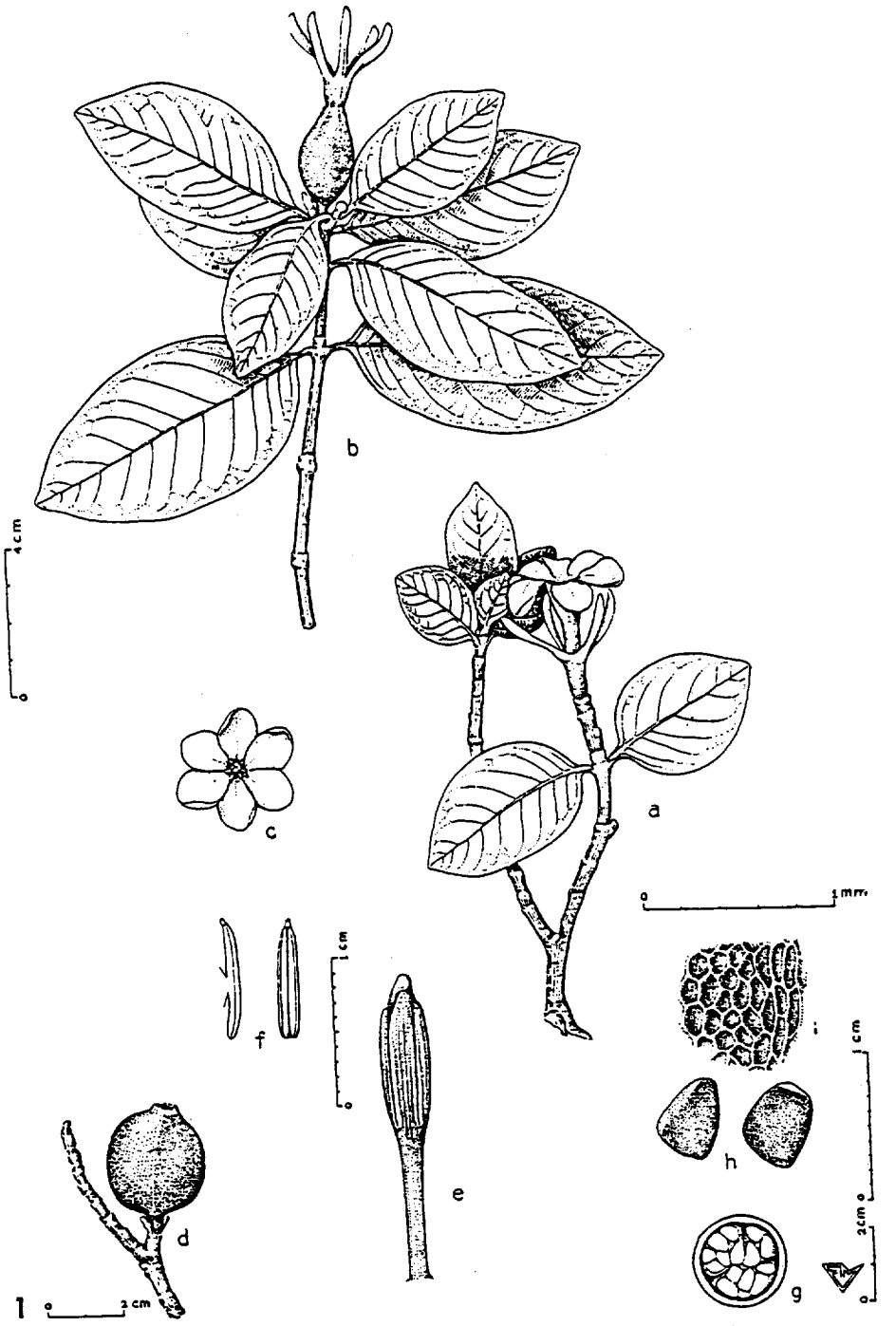
a widespread species inhabiting all eight of the main Hawaiian Islands. Due to extensive destruction of the dry land forests, this species has been greatly reduced in both distribution and population density. At present, there are only six known wild populations with a total of less than 20 individuals. Gardenia brighamii is in immediate danger of extinction. All populations are threatened by alien plant competitors, introduced herbivores, fire, and pathogens. The preservation of G. brighamii is severely complicated by a lack of secure, functional habitat and by the small sizes of the few remaining populations.

Gardenia brighamii was federally listed as endangered on August 21, 1985 (Herbst 1985). At the time of listing it was determined that the designation of critical habitat would be neither appropriate nor prudent.

Taxonomy

The genus Gardenia consists of approximately 250 species which are found throughout the Pacific Islands and old-world tropics (Wagner et al. 1990). There are three gardenia species native to Hawaii: G. brighamii, G. manni, and G. remyi. All three are also endemic to Hawaii.

Gardenia brighamii appears to be clearly distinct from the other two Hawaiian species and was first collected by Mann and Brigham sometime in 1864 or 1865. Mann (1868) later described the species, naming it in honor of Brigham. Fosberg (1948) suggested that these species were derived from at least two colonization events; presumably, one for G. brighamii and one for the other two species (Wagner et al. 1990). Smith (1974) felt that there were probably three separate colonizations - one for each of the Hawaiian species. He also suggested that G. brighamii was most



Gardenia Brighamii Mann. *a*, habit, from *Mann & Brigham 348*, west end of Lanai, × ½, isotype (BISH); *b*, habit and immature fruit, from *Munro 28*, Kalulu, Lanai, × ½; *c*, flower, from *C. S. Judd 270*, Puu Kuua, Oahu, × ½; *d*, fruit, from *Forbes 160.L*, Lanai, west end, × ½; *e*, style and stigmas, from *C. S. Judd 270*, Puu Kuua, Oahu, × ½; *f*. anther, lateral and dorsal views, from *C. S. Judd 270*, Puu Kuua, Oahu, × 2; *g*, fruit cross section with seeds, from *Forbes 160. L*, Lanai, west end, × ½ *h*, seeds, from *Forbes 160.L*, Lanai, west end, × 2; *i*, surface of seed, from *Forbes 160.L.*, Lanai, west end, × 25.

Figure 1. Illustration of Gardenia brighamii from St. John and Kuykendall (1948).

closely allied with G. hillii, a species native to the dry thickets and woodlands of Fiji.

Species Description

The Hawaiian gardenia (Gardenia brighamii) superficially resembles a commonly cultivated species, the Tahitian gardenia (Gardenia taitensis). Gardenia brighamii is a small tree up to 20 feet (6.096 meters) in height. Trunks are up to 12 inches (30.48 centimeters) in diameter and somewhat smooth. The shiny, dark green leaves are oval-shaped and measure from 1 to 4 inches (2.2 to 10.5 centimeters) long and 1/2 to 2 inches (1.5 to 5.5 centimeters) wide. The solitary flowers are white and very fragrant. The flowers range in size from 1 to 1 1/2 inches (2.54 to 3.81 centimeters) in diameter. Fruits are hard, round, greenish, and moderate in size - about 1 1/2 inches (3.81 centimeters) in diameter. The inside of the fruit is fleshy and contains many small seeds. Gardenia brighamii is not known to reproduce vegetatively in the wild, but can be air-layered using horticultural techniques.

Habitat Description

Gardenia brighamii is found in dry scrub and forests on the leeward sides of the main Hawaiian islands. The populations receive 15 to 35 inches (38.1 to 88.9 centimeters) of rain per year and experience a summer drought (Gagne 1982, Spence and Montgomery 1976). Sites are generally located at low to mid-elevation (1,000 to 1,800 feet; 304.8 to 548.6 meters) with well-drained, lateritic soils of low fertility (Gagne 1982). Slope ranges from gradual to steep and the aspect is variable.

The surrounding vegetation is usually low and windswept, rarely exceedng 20 feet (6.096 meters) in height (Gagne 1982). Gardenia brighamii is a component of the Diospyros sandwicensis, and Erythrina sandwicensis dry forest communities (Gagne and

Cuddihy 1990). Associated native species include: Diospyros sandwicensis, Nestegis sandwicensis, Erythrina sandwicensis, Nototrichium sandwicensis, Nesoluma polynesicum, Bobea sandwicensis, Santalum freycinetianum, Nothocestrum latifolium, Pouteria sandwicensis, Rauvolfia sandwicensis, Dodonaea viscosa, Waltheria indica. Most sites also have a large component of alien vegetation. The most important alien species are: Lantana camara, Leucaena leucocephala, Panicum maximum, Tecoma stans, Grevillea robusta, and Schinus terebinthifolius.

Historic Range and Population Status

Gardenia brighamii is endemic to the Hawaiian Islands and is thought to have at one time occurred on all of the main islands: Hawaii, Maui, Molokai, Lanai, Oahu, Kauai, Kahoolawe, and Niihau. However, it has never been collected from the latter three islands (Wagner et al. 1990). The known distribution of G. brighamii is shown in Figure 2. Appendix A cross-references sites described in this plan with element codes used by the Hawaii Heritage Program.

None of the naturalists in the 1800's commented on the population status of Gardenia brighamii; thus, it is not clear how abundant this species was prior to European contact. Judging from its use by the Hawaiians as a cloth dye, its habitat, associated species, and distribution in the early 1900's, it was probably a relatively common member of the lowland dry forests. At the beginning of the 20th century, it was considered common on west Molokai and Maui, but was already either extirpated or very rare on the other islands.

Current Range and Population Status

As of January 1992, the total known population of wild Gardenia brighamii was less than 20 individuals. These plants are distributed among six populations on three islands (Table 1). All sites are on privately owned land.

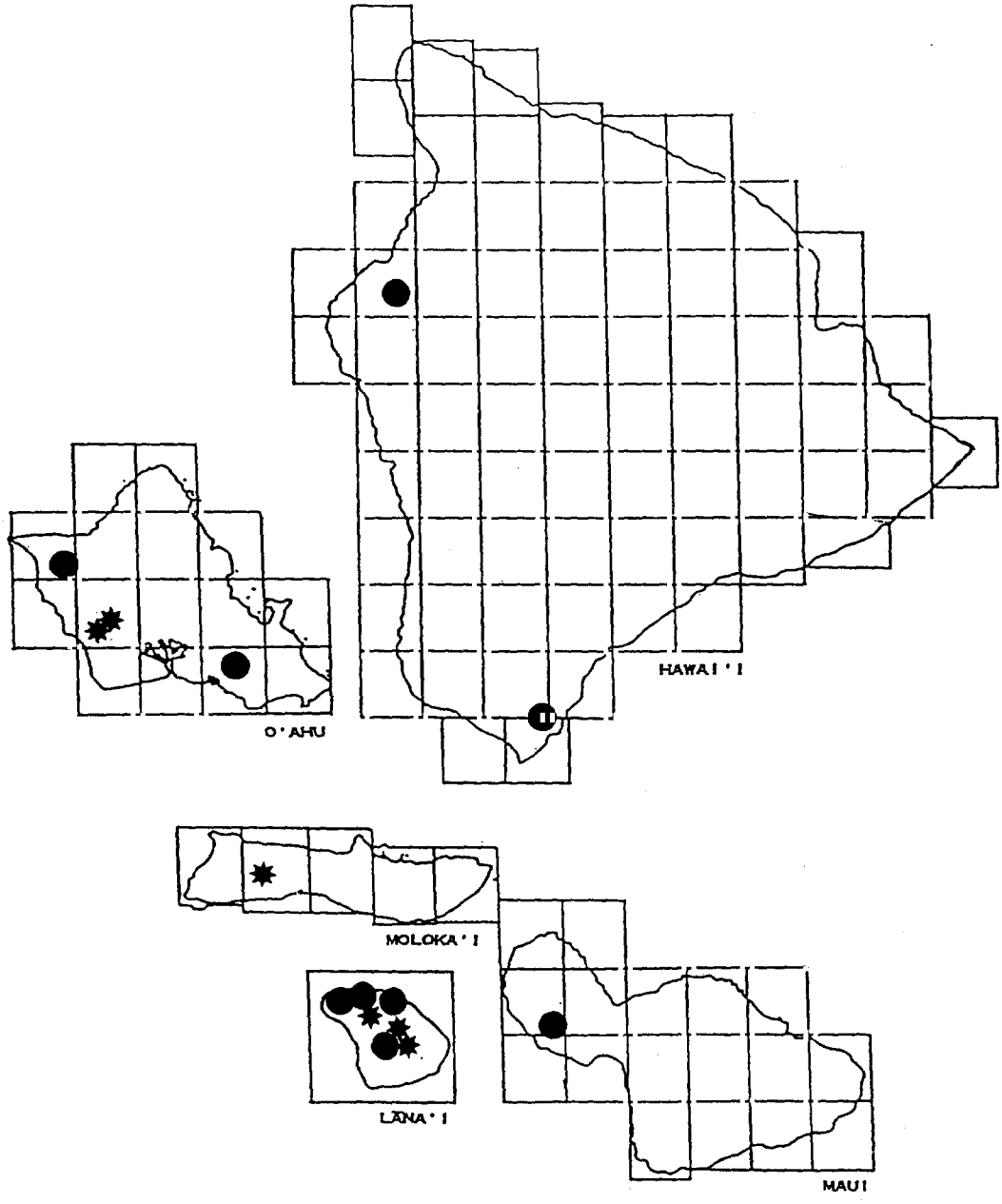


Figure 2. The distribution of Gardenia brighamii in Hawaii. Solid dots indicate the location of extinct populations. Stars indicate the location of extant populations.

TABLE 1. The current status of wild Gardenia brighamii in Hawaii. Data from the Hawaii Heritage Program (1991). Joel Lau (Hawaii Heritage Program, personal communication 1991), and Steve Perlman (Hawaii Plant Conservation Center, personal communication 1991).

ISLAND	POPULATION	NUMBER OF PLANTS
Lanai	Kanepuu area	7 - 8
	Wahane Gulch	2 - 3
	Puhielelu Ridge	4
Oahu	Puu Kuua	1
	Nanakuli	2
Molokai	Mahana	1
Total		17 - 19

Distribution and Status on Individual Islands

Molokai. Earlier in this century, J.F. Rock (1913) described Gardenia brighamii as being expecially common in the dry forests of western Molokai. All of the herbarium collections of this species are from the areas of Mahana and Maunaloa. Subsequent development of pineapple fields on Molokai eliminated much of the dry forest in this area (St. John and Kuykendall 1949). In 1963, there were 7 G. brighamii trees remaining on Molokai (*N. Pekelo s.n.*, **BISH**). The population dropped to four trees by 1972 (*N. Pekelo s.n.*, **BISH**) and two trees by 1982 (Gagne 1982). At present, only a single tree remains on Molokai. The site is privately owned by Molokai Ranch.

Hawaii. Gardenia brighamii is known from two areas on Hawaii: (a) the North Kona area near Huehue and Puuwaawaa, and (b) in the general area of Puu Koihala in the southern part of the island. The North Kona population consisted of 11-12 individuals when it was first collected by Rock in 1909 (*J. Rock 3550*, **BISH**). All but one tree were destroyed by a road repair crew in 1930 (*G. Russ s.n.*, **BISH**). The remaining tree survived at least until

1955, when it was last collected, again by Rock (*J. Rock s.n.*, **BISH**). The exact site location was revisited by the former Puuwaawaa Ranch manager and Dr. Carolyn Corn, State Botanist for Hawaii, in an effort to relocate the plant; however, no plants were found (Carolyn Corn, Division of Forestry and Wildlife, personal communication 1991). The Puu Koihala site is based upon a 1929 specimen in the Smithsonian Institution (Derral Herbst, U.S. Fish and Wildlife Service, personal communication 1991; collection information not available). The current status of this population is not known. Gardenia brighamii is presumed extinct on Hawaii.

Maui. The only collections of Gardenia brighamii from Maui were made in 1920 by Forbes (*C. Forbes 2387.M.*, **BISH**) from a single tree at the head of Olowalu Valley. The species is presumed extinct on Maui.

Lanai. Rock (1913, p. 433) stated that Gardenia brighamii was very common on Lanai in valleys of Mahana and Kaiholena and the slopes of Kaa Desert. Seven historical populations are known from this island: (a) Kanepuu, (b) Wahane Gulch, (c) Puhielelu Ridge, (d), Kaiholena Valley, (e) Mahana, (f) Paomai, and (g) Kaena. The first three populations are probably still extant while the latter four are extinct. The Kanepuu population is thought to have 7 or 8 individuals. The Wahane Gulch population may have up to 3 plants. The Puhielelu Ridge population probably has from 3 to 4 trees. A total of 13 to 15 plants remain on Lanai. These sites are privately owned by Castle and Cooke, Inc., with the Kanepuu population contained in the Kanepuu Preserve managed by The Nature Conservancy of Hawaii.

Oahu. Gardenia brighamii has been recorded at four sites: (a) Makaleha, Waianae Mountains, listed by Hillebrand (1888); (b) Nuuanu Valley, Koolau Mountains, mentioned by both Mann (1868) in his original description and by Hillebrand (1888); (c) Puu Kuua, Waianae Mountains; and, (d) Nanakuli, Waianae Mountains. The first two sites are from areas which have been heavily disturbed

and the populations are probably extinct. The population at Puu Kuua has been known since 1925 and consists of only a single tree. This tree is still alive, but it has not produced any natural seedlings. This site is privately owned by Campbell Estate. The Nanakuli population was discovered in 1987 (Wagner et al. 1990) and consists of two trees. This site is in the Nanakuli Forest Reserve and is privately owned by Hawaiian Home Lands. A total of three trees remain in the wild on Oahu.

Life History

Very little is known about the life history and biology of Gardenia brighamii. Growth rates and longevity are not known, though the single tree at Kuua, Oahu, has been under observation since at least 1925, a period of over 65 years. Collections were made from this plant in 1925, 1929, 1931, 1945, and 1987. No seedlings have been observed at this site. In 1925, the height of this tree was given as 13 feet (3.96 meters) (*C. Judd 40*, **BISH**), in 1931, it was listed as 20 feet (6.096 meters) (*H. St. John 11165*, **BISH**), and the most recent account also states 20 feet (6.096 meters) (*S. Perlman 5148*, **BISH**). This plant does not appear to be increasing in height.

Reports of wild seedlings are rare. Gagne (1982) observed one seedling (2.5 inches (6.35 centimeters)) tall, but the subsequent growth and fate of this individual are not known. She also reported that others had seen seedlings before and that there was some mortality attributed to trampling by humans and feral ungulates. Steve Perlman (Hawaii Plant Conservation Center, personal communication 1991) reported several seedlings in the Lapaiki fenced exclosure on Lanai, but these did not survive (they were possibly destroyed by introduced game birds).

Flowering and fruiting times vary among the populations. On Oahu and Hawaii, flowering is primarily from October through December. On Maui, Molokai, and Lanai, flowering is primarily in

the spring (March, April, and May) with sporadic flowering in December and July. Cultivated plants seem to bloom more continuously. It has been suggested that flowering is positively correlated with rainfall (John Obata, Hawaii Plant Conservation Center, personal communication to Gagne 1982). Flowers open in late afternoon and last approximately one day.

Pollination and fruit set occur in at least some of the wild populations. The seed is easily grown and seedlings survive well under nursery conditions, though they seem to be somewhat susceptible to soil pathogens (William Garnett, Waimea Arboretum, personal communication 1991) or have problems with leaf fungal infections (Heidi Bornhorst, The Nature Conservancy of Hawaii, personal communication 1992). Wild-collected seed is viable and the resulting plants have lived in cultivation for at least 15 years (John Obata, Hawaii Plant Conservation Center, personal communication 1991). Some of these cultivated plants have, in turn, produced seed and seedlings. The original pollen vector is not known, but the flowers would suggest an insect. A serphid fly was collected on open flowers in 1991 by Heidi Bornhorst of The Nature Conservancy and identified as Allograpta exotica, a common species, by Neil Evenhuis of Bishop Museum. Gardenia brighamii is apparently self-compatible and seedlings resulting from self-pollination have shown high survivability. The original dispersal agent is not known, but was most likely a bird.

Reasons for Decline and Current Threats

The arrival of humans some 1,500 years ago set in motion activities which have been devastating to Gardenia brighamii. The lowland forests have been extensively cleared for agricultural and urban uses, subjected to intentional and unintentional fires, heavily grazed (by cattle, goats, pigs, Axis deer and Mouflon sheep), and become infested with alien weeds and pathogens. These activities have reduced the dry leeward forests to a scattering of

individual native plants surrounded by a sea of alien weeds or, at best, small fragmented pockets of remnant vegetation.

1. **Herbivores.** Numerous species of mammalian herbivores have been introduced into Hawaii, notably cattle, goats, pigs and deer. Their introduction (and continued existence) has been the single most destructive aspect of European contact. These animals destroy Gardenia brighamii and other native species not only by grazing, browsing, and trampling, but also indirectly by increasing erosion and soil compaction, dispersing the seed of alien plants, and creating disturbances which allow alien plant competitors to become established. Seven plants are known to exist within fenced herbivore exclosures. While these exclosures provide much needed short-term protection of individual plants, none of these protected areas is large enough to support a viable population of G. brighamii. Without constant maintenance and repair, the fences would eventually no longer protect even these few individual plants.

(a) **Oahu**. The areas where Gardenia brighamii were known to occur have been heavily disturbed by cattle, goats, and pigs. At present, both remaining populations are within fenced exclosures. However, both sites are still grazed and the exclosures are not sufficiently large to support viable populations of G. brighamii.

(b) **Molokai**. The area harboring the last remaining tree has been grazed for decades. This plant is currently within a fenced exclosure, but there is insufficient area to support a viable population of Gardenia brighamii.

(c) **Lanai**. Populations of Axis deer and Mouflon sheep are the major threats to the Lanai populations. Goats, pigs, and cattle have been controlled by the landowner for almost half a century; however, high densities of both Axis deer and Mouflon sheep have not been eliminated. Three fenced, deer-proof exclosures have been erected in the Kanepuu population, each of which protects a single plant. The

other 10 to 15 plants on the island are unprotected from intense herbivore pressure.

2. **Land Conversion**. The clearing of dry forest for agricultural and urban uses was without question an important contributor to the endangerment of Gardenia brighamii. However, this activity is not known to be a threat to the existing sites.

3. **Fire**. The early Hawaiians apparently used fire to clear forests and to maintain desired habitats (Cuddihy and Stone 1990). European colonization also resulted in an increased frequency of fire, though most fires were, and are, unintentional. Fire poses a serious threat to Gardenia brighamii by killing trees outright and by creating disturbances which generally favor alien plant invaders over the slower-growing native species. Because the remaining individuals of G. brighamii are in small, localized populations, fire should be viewed as a catastrophic event from which the populations would probably not recover. None of the populations or fenced exclosures are protected by firebreaks.

4. **Disease and predation**. Damage to Gardenia brighamii from various insects, rats, and diseases has not been adequately studied. At the present time, the following factors appear to be threats:

(a) **Black twig borer** (Xylosandrus compactus). This insect attacks terminal shoots. The single tree at Puu Kuua, Oahu, was heavily damaged by twig borers in the 1970's, but the State Division of Forestry and Wildlife (DOFAW) apparently controlled the twig borers (and probably saved the tree) by spraying with malathion (Gagne 1982 and Carolyn Corn, DOFAW, personal communication 1991).

(b) **Rats**. Reportedly, rats climb into G. brighamii trees and eat or damage the fruits (Gagne 1982). Ziegler (1989)

considered rat predation to be the main reason that G. brighamii is not reproducing within the fenced exclosures.

(c) **Rust**. Gagne (1982) reported that the G. brighamii trees on Lanai were affected by some sort of fungal infection or rust. The effect of this rust on growth, reproduction, or survival is not known.

(d) **Scale insects**. Gagne (1982) also reported that various scale insects are attracted to G. brighamii. The impact of this factor on G. brighamii is not known.

(e) **Future naturalizations**. The introduction of alien organisms into Hawaii continues to this day. It is entirely possible that future introductions could be harmful to G. brighamii. For example, the black vine weevil (Otiorhynchus sulcatus) and citrus whitefly (Dialeurodes citri) are known to be serious nursery pests in North America of gardenia roots (Stimmann et al. 1985) and leaves (Hicks and Oliver 1987). If these, or other pathogens, become naturalized in Hawaii, they could prove to be a major threat to wild populations of G. brighamii.

5. **Alien plants**. Alien plants pose a serious threat to the existence of Gardenia brighamii. These species probably compete with G. brighamii for light, water, space, and/or nutrients. In addition, some alien weeds may release allelopathic substances or alter the soil chemistry. Many alien species also increase the threat of fire at G. brighamii sites, because they greatly increase the fuel load of these areas. The most important alien weeds at the existing G. brighamii sites are: Lantana camara, Leucaena leucocephala, Panicum maximum, Tecoma stans, Grevillea robusta, and Schinus terebinthifolius.

6. **Soil erosion**. The toppling of plants due to erosion is a problem at the Molokai site, where several plants were lost due to erosion of the gully walls (Herbst 1985).

7. Overcollection. Overcollection for horticultural or scientific purposes does not appear to be much of a threat to the existence of Gardenia brighamii. Most of the plants are large, mature individuals which do not appear to be excessively harmed by occasional collection. Indeed, the plant at Puu Kuua, Oahu, has been collected many times over a 65-year period. All of the other threats to G. brighamii are more important.

Conservation Efforts

1. Federal actions. The United States listed Gardenia brighamii as an endangered species in 1985 (Herbst 1985). The decision was based upon a status report completed by Gagne (1982) and comments from the public. A designation of critical habitat was initially proposed, but finally rejected at the time of listing.

2. State of Hawaii actions.

(a) **Legal protection**. Because Gardenia brighamii is a federally listed species, the State of Hawaii also officially lists Gardenia brighamii as an endangered species under Chapter 195D of the Hawaii Revised Statutes. All of the existing G. brighamii populations are on private lands and all are afforded protection under Hawaiian law.

(b) **Protection from feral herbivores**. Four plants are currently protected by State-constructed herbivore exclosures. Fencing areas from herbivores (goats, pigs and deer) does provide much needed short-term protection of individual plants; however, these efforts are inadequate to protect the species from extinction, because all of the fenced areas are too small to maintain a viable population of G. brighamii. In addition, regeneration is not occurring in the exclosures, and the mature plants within the exclosures are still threatened by alien plants, rats, disease, and/or fire.

(1) Oahu. Concerned foresters have a long history of protecting the single plant at Puu Kuua, Oahu. By 1931, Hawaiian foresters had already put up a wooden exclosure to keep cattle away from the Puu Kuua tree (*H. St. John 11165*, **BISH**). This fence lasted until the 1980's when it was replaced by DOFAW. The new fence is a 4-foot (1.22 meters) high hog wire fence that encloses an area measuring 20 feet (6.096 meters) by 50 feet (15.24 meters). DOFAW personnel attached a rat barrier to this tree in the hopes of reducing predation on Gardenia brighamii seeds. Alien trees within the exclosure have been removed. Both plants at the Nanakuli, Oahu, site have been fenced by DOFAW. Eight G. brighamii seedlings from the Puu Kuua and Nanakuli trees were planted into the Puu Kuua exclosure in October 1991 and there are plans to plant another 12 into the Nanakuli exclosures in the near future (Earl Pawn, DOFAW, personal communication 1991).

(2) Molokai. In 1990, the single plant at Kahana was enclosed by DOFAW within a 4 1/2-foot (1.37 meters) high hog wire fence with a top strand of barbed wire. The fence encloses an area of 1/10 acre.

(c) **Collection and propagation of wild-collected plants and seed.** The State of Hawaii has funded the Hawaii Plant Conservation Center's efforts to collect and propagate seed from Gardenia brighamii and other rare plants. These efforts have resulted in the successful cultivation of seeds from both Oahu sites (Kuua and Nanakuli) and one of the Lanai populations (Kanepuu). In addition, the Maui District staff of DOFAW have successfully air-layered three plants from the Molokai plant (Richard Nakagawa, DOFAW, personal communication 1992). The State has also pursued cooperative

agreements with local botanical gardens to promote the conservation of Hawaiian plants, including G. brighamii. At present, the State has agreements or contracts with the National Tropical Botanical Garden (Hawaii Plant Conservation Center), Lyon Arboretum, Waimea Arboretum and Botanical Garden, Amy Greenwell Ethnobotanical Garden, and Honolulu Botanical Gardens.

(d) **Control of disease and predation**. The Puu Kuua plant on Oahu was sprayed by DOFAW in the 1970's to control twig borers (Carolyn Corn, DOFAW, personal communication 1991). The treatment was apparently successful and the plant has recovered well (Gagne 1982).

(e) **Control of alien plant competitors**. To date, the only control has been the selective removal of alien shrubs within the herbivore exclosure at Puu Kuua, Oahu.

3. Nongovernmental actions.

(a) **Lanai Ranch**. Starting in 1918, the ranch manager of Lanai Ranch, George C. Munro, fenced the dry land forests in the area of Kanepuu (Ziegler 1989) and removed virtually all feral herbivores from the island (Fosberg 1936). Wild cattle were removed from the mountains and domesticated, the mountains were fenced from the ranch cattle, and the other feral herbivores were killed. Fosberg (1936) stated that "there is probably not a pig or cow or goat left wild on the island, and the deer and sheep, if any remain, are so few as to be negligible." These efforts were evidently successful, for in 1935 Fosberg (1936) visited Lanai and found that "contrary to reports that there are only a few acres of forest remaining on the island, we found that there are thousands of acres of forest in good condition." He went on to describe Kaiholena Valley as a "botanist's paradise" and stated that the fenced dry forest at Kanepuu (with Gardenia brighamii) was "perhaps the finest dry land forest in the

Hawaiian Islands" and that it was "apparently the sole remaining good example of the type of dry land forest which before the advent of Europeans must have covered great areas in the lowlands of the older islands of the Hawaiian group." Fosberg (1936) also implied that Munro's actions had "almost eliminated" guava and lantana from the forests. Unfortunately, the fences were removed in 1935 and cattle grazing of the forest continued until 1950 (Ziegler 1989). Populations of Axis deer and Mouflon sheep have increased to the point where they are now a serious threat.

(b) **Castle and Cooke, Inc.** In 1976, the current landowners of Lanai, Castle and Cooke, provided major funding to fence three Gardenia brighamii at Kanepuu. The exclosures range in size from 1/2 to 1 acre in size (Ziegler 1989). Each exclosure harbors a single G. brighamii. As of 1989, these fences were damaged and not providing adequate protection (Ziegler 1989). The fences have now been repaired, but do require continual maintenance (Heidi Bornhorst, The Nature Conservancy of Hawaii, personal communication 1992). In 1989, Castle and Cooke gave The Nature Conservancy of Hawaii a perpetual conservation easement on approximately 590 acres of thee Kanepuu dry forest. This land is now managed by The Nature Conservancy of Hawaii as the Kanepuu Preserve. The Nature Conservancy intends to fence and restore the area (Ziegler 1989). All of the G. brighamii in this population will eventually be fenced from herbivores (7-8 plants).

(c) **Collection and propagation.** Waimea Arboretum and Botanical Garden, Honolulu Botanical Gardens, the Maui District Office of DOFAW, and the National Tropical Botanical Garden have living, wild-collected plants of Gardenia brighamii. Table 2 provides a detailed account of the genetic diversity present in botanical garden holdings. It should be noted that while many G. brighamii are currently being grown, certain genotypes are overrepresented

and others underrepresented. Two of the remaining 17-19 wild genotypes are also represented in botanical garden collections; one as a plant derived from a cutting and the other as air-layered branches. In addition, over 260 plants have been grown from wild-collected seed. However, these collections only represent 4 to 6 family lineages and 4 or 5 populations.

(d) **Center for Plant Conservation**. The World Wildlife Fund has provided funds to the Center for Plant Conservation to endow conservation efforts aimed at preserving Gardenia brighamii (William Garnett, Waimea Arboretum, personal communication 1991). This endowment contributes $400 per year to maintain the collection of G. brighamii at Waimea Arboretum and Botanical Garden.

(e) **Volunteer efforts**. Starting in the 1970's, a number of volunteers and organizations, including the Hui Malama Pono o Lanai, erected and maintained protective fences around the Kanepuu, Lanai, plants.

(f) **Private individuals' gardens**. Private individuals are known to have some plants in their gardens. It is very possible that these private gardens contain wild-collected genotypes not represented in the botanical gardens. If this is so, then these collections may be of great value.

TABLE 2. Diversity of G. brighamii holdings in Hawaiian botanical gardens. Data from National Tropical Botanical Garden, Honolulu Botanical Gardens, the State of Hawaii, and Waimea Arboretum and Botanical Garden. Over 260 plants of G. brighamii are in cultivation, but these represent only 4 to 6 wild lineages and 4 or 5 populations.

* Indicates that one plant at Manuka State Park may be derived from a cutting from a wild-collected plant from the now extinct North Kona population.

ISLAND	POPULATION	WILD PLANTS	ON GROUNDS	IN NURSERY	STORED SEED
Maui	Olowalu	extinct			
Hawaii	North Kona	extinct	*		
	Puu Koihala	extinct			
Molokai	Mahana	# 1		3	
Oahu	Puu Kuua	# 1		26	10
	Nanakuli	# 1	8	160	15
		# 2			
Lanai	Kanepuu	# 1	56	3	18
		# 2			
		# 3			
		# 4			
		# 5			
		# 6			
		# 7			
		# 8 ?	?	15	
	Wahane	# 1			
		# 2			
		# 3 ?			
	Puhielehu	# 1			
		# 2			
		# 3			
		# 4			
TOTALS		17 - 19	64-66	207	43

II. RECOVERY

Objectives

This recovery plan establishes the framework within which efforts are undertaken to ensure the long-term survival of Gardenia brighamii under natural conditions. Target objectives are provided first for stabilizing current populations, then downlisting to threatened status, and finally delisting, with the complete removal of all federal protective status.

Stabilization of Populations

In order to stabilize the decline of Gardenia brighamii, it will be necessary to increase the remaining six populations to the point where they are each composed of at least 20 reproductive plants. These plants must be either from the original wild population or first-generation outcrossed progeny of the original wild population. They must be genetically representative of the original wild population, with all of the original wild individuals included. A population size of at least 20 individuals is needed to capture the majority of the genetic variability within the population. For downlisting to threatened status, a population size of 50 mature plants provides additional long-term viability. To ensure perpetual viability, a population of 100 mature plants is suggested. The rationale in establishing the number and distribution of populations for downlisting and delisting is to maintain the species for the long term, given the threats of natural catastrophic events, such as hurricanes, fire, and volcanic activity.

To be considered stable, these populations must be fenced from herbivores and protected from seed predators, alien plant competitors, and disease/pathogens. Plants must be able to complete their entire life cycle within the fenced exclosures. This would be measured by comparing the number of reproductive individuals, the number of seedlings, the amount of seed produced per plant, and the number of plants progressing through size classes to reproductive maturity. Each of the 17 to 19 currently known wild plants must be "backed up" by at least 5 plants growing in "safe" localities such as botanical gardens. These back-up plants must be either vegetatively propagated from the original wild plant or be first-generation outcrossed progeny from these wild plants. A survey of the origin of all cultivated plants must be undertaken to determine if there are cultivated progeny derived from other populations, particularly the North Kona population.

Downlisting to Threatened Status

Consideration for downlisting to threatened status can occur once:

(1) The "stabilization" targets are realized.

(2) Gardenia brighamii is represented by 750 plants in:

   (a) Three healthy, naturally reproducing, fenced populations, each with 50 mature plants on each of Lanai, Molokai, and Oahu. This would be a total of 450 wild plants. As with the "stabilization" targets, the plants must be derived from the original wild populations. New populations will need to be created on Oahu and Molokai. The new Oahu population should be composed of plants derived from both the Puu Kuua and Nanakuli populations. The two new Molokai populations should be established from a mix of stock from Molokai and Lanai.

   (b) Three healthy, naturally reproducing, fenced populations, each with 50 mature plants on each of Maui and Hawaii. This would be a total of 300 wild plants. Since the original populations of G. brighamii on these islands are apparently extinct, the reestablished populations should be a composite of all 17 to 19 of the current wild plants. This will ensure that at least 6 populations are genetically diverse and not inbred.

Delisting

Consideration for delisting can occur once:

(1) Gardenia brighamii is represented by at least 3 populations, each with at least 100 mature, healthy, reproductive plants, on secure lands on each of Oahu, Hawaii, Maui, Molokai, and Lanai.

(2) These 15 populations must be unfenced, unmanipulated, self-reproducing, and stable over a period of 10 years.

NARRATIVE

1. Secure and stabilize the 6 known populations of Gardenia brighamii.

The intent of this task is to preserve the last few remaining wild plants and restore the surrounding habitat so that the population can either expand naturally or be artificially augmented. In order to accomplish this task, it will be necessary to secure landowner cooperation at each site. Agreements with the landowner should be long-term and spell out precisely what actions are anticipated.

11. Secure and stabilize the 3 populations on Lanai.

It is important to secure the three extant populations on Lanai, through negotiations with the landowner (Castle and Cooke, Inc.) and development of conservation easements, cooperative agreements, leases, or fee purchases.

111. Enter into long-term agreement with Castle and Cooke, Inc., to secure and manage the Kanepuu, Wahane Gulch and Puhielelu Ridge populations.

The Kanepuu population is currently managed by The Nature Conservancy of Hawaii (TNCH) for the landowner. It is, therefore, already in the process of being secured. Steps should be taken to make sure that all three populations are secured via a long-term easement, cooperative agreement, lease or fee purchase, between the landowner, TNCH, the Fish and Wildlife Service (Service), and the Hawaii Department of Land and Natural Resources, Division of Forestry and Wildlife (DLNR-DOFAW).

112. Control threats to the Kanepuu population.

All known threats to the existence of the Kanepuu population must be controlled or removed.

1121. Control grazing of alien herbivores by constructing and maintaining fence.

The most important action is to immediately ensure that all plants are adquately fenced from herbivores. While it is desirable to fence as large an area as possible, it is more important that the fencing be completed as soon as possible. These exclosures will provide much needed short-term protection of individual plants, but will not adequately ensure the survival of the species.

The exclosure sites will need to be visited on a regular basis and the fences examined and repaired several times per year to ensure sufficient protection from herbivores.

The 4 to 5 unfenced trees in the Kanepuu area need to be fenced. The fences must be sufficient to deny access to Axis deer and Mouflon sheep.

1122. Control alien weeds.

Plants in the exclosures must be protected from alien plant competitors by physically removing all alien weeds on a continual basis.

1123. Control predation and disease.

Disease and predation by insects and rats must be controlled within the exclosures. This may prove to be difficult, in the cases of insect predation and disease, but previous success in combating twig borers indicates that it is possible. Monitoring programs should be initiated to detect these problemns at the earliest possible time. Rat control should be possible with the use of rat traps on a continual basis within and around the exclosures.

1124. Reduce the risk of catastrophic fire.

Sites should be surveyed to determine the magnitude of the fire hazard and, if required, reduce the fuel load at each site. Reduction of the fuel load may be accomplished by removing all alien weeds (Task #1122). Fire emergency plans should be developed for each site and fire breaks constructed where appropriate.

1125. Back-up all wild individuals with at least 5 vegetatively produced plants located in botanical gardens or other secure locations.

Because Gardenia brighamii populations are continuing to decline, it will be necessary to create a back-up genetic reserve. The number of plants is so low that cuttings from each of the 17 to 19 wild plants must be safeguarded in botanical gardens. Wild-collected cuttings are preferable to wild-collected seed, because cuttings preserve the original genetic diversity. This is particularly true for situations where there is

only a single tree in a population (e.g., Puu Kuua and Mahana). Seed from these single trees will most likely be inbred seed and, while it may be viable, it may also be less fit than outcrossed seed. A minimum of five cuttings should be established from each of the remaining 17 to 19 plants.

A minimum of five cuttings need to be taken from each of the 7-8 trees in the Kanepuu area and safeguarded in botanical gardens.

113. Control threats to the Wahane Gulch population.

All known threats to the existence of the Wahane Gulch population must be controlled or removed.

1131. Control grazing of alien herbivores by constructing and maintaining fence.

The 2 to 3 trees in Wahane Gulch need to be fenced in a manner sufficient to deny access to Axis deer and Mouflon sheep.

1132. Control alien weeds.

See narrative for Task #1122.

1133. Control predation and disease.

See narrative for Task #1123.

1134. Reduce the risk of catastrophic fire.

See narrative for Task #1124.

1135. Back-up all wild individuals with at least 5 vegetatively produced plants located in botanical gardens or other secure locations.

See narrative for Task #1125.

114. Control threats to the Puhielelu Ridge population.

All known threats to the existence of the Puhielelu Ridge population must be controlled or removed.

1141. Control grazing of alien herbivores by constructing and maintaining fence.

The 4 trees at Puhielelu Ridge need to be fenced in a manner sufficient to deny access to Axis deer and Mouflon sheep.

1142. Control alien weeds.

See narrative for Task #1122.

1143. Control predation and disease.

See narrative for Task #1123.

1144. Reduce the risk of catastrophic fire.

See narrative for Task #1124.

1145. Back-up all wild individuals with at least 5 vegetatively produced plants located in botanical gardens or other secure locations.

See narrative for Task #1125.

12. Secure and stabilize the single population on Molokai.

It is important to secure the habitat of the lone, extant tree on Molokai through negotiations with the landowner (Molokai Ranch) and development of a conservation easement, cooperative agreement, lease, or fee purchase.

121. Enter into long-term agreement with Molokai Ranch to secure and manage the Mahana population.

Steps should be taken to secure this population via a long-term easement, cooperative agreement, lease or fee purchase between the landowner, the Service, and DLNR-DOFAW.

122. Control threats to the Mahana population.

All known threats to the existence of the Mahana population must be controlled or removed.

1221. Control grazing of alien herbivores by maintaining fence.

The single tree that constitutes the Wahane population has been fenced to exclude herbivores.

All other threats must be controlled within the exclosure.

1222. Control alien weeds.

See narrative for Task #1122.

1223. Control predation and disease.

See narrative for Task #1123.

1224. Reduce the risk of catastrophic fire.

See narrative for Task #1124.

1225. Back-up all wild individuals with at least 5 vegetatively produced plants located in botanical gardens or other secure locations.

See narrative for Task #1125.

13. Secure and stabilize the 2 populations on Oahu.

It is important to secure the habitat of the two extant populations on Oahu through negotiations with the landowners (Campbell Estate and Hawaiian Home Lands) and development of conservation easements, cooperative agreements, leases, or fee purchases.

131. Enter into long-term agreement with Campbell Estate to secure and manage the Puu Kuua population.

See narrative for Task #121.

132. Enter into long-term agreement with Hawaiian Home Lands to secure and manage the Nanakuli Forest Reserve population.

See narrative for Task #121.

133. Control threats to the Puu Kuua population.

All known threats to the existence of the Puu Kuua population must be controlled or removed.

1331. Control grazing of alien herbivores by maintaining fence.

The single tree that constitutes the Puu Kuua population has been fenced to exclude herbivores.

All other threats must be controlled within the exclosure.

1332. Control alien weeds.

See narrative for Task #1122.

1333. Control predation and disease.

See narrative for Task #1123.

1334. Reduce the risk of catastrophic fire.

See narrative for Task #1124.

1335. Back-up all wild individuals with at least 5 vegetatively produced plants located in botanical gardens or other secure locations.

See narrative for Task #1125.

134. Control threats to Nanakuli Forest Reserve population.

All known threats to the existence of the Nanakuli population must be controlled or removed.

1341. Control grazing of alien herbivores by maintaining fence.

Both trees that make up the Nanakuli population have been fenced to exclude herbivores. All other threats must be controlled within the exclosure.

1342. Control alien weeds.

See narrative for Task #1122.

1343. Control predation and disease.

See narrative for Task #1123.

1344. Reduce the risk of catastrophic fire.

See narrative for Task #1124.

21. Determine appropriate augmentation/reintroduction techniques.

Horticultural staff at the Hawaii Plant Conservation Center, Honolulu Botanical Gardens, and Waimea Arboretum have already developed extremely successful techniques for seed germination. Thus, horticultural research can be focused on the next step: the development of appropriate augmentation/reintroduction techniques. Information from these studies could also suggest the best locations for reestablishing populations within G. brighamii's former range.

22. Develop augmentation plan for each of the six extant sites.

In order to accomplish stabilization, it will be necessary to develop detailed population augmentation plans which address the specific genetic stock to be used in the augmentation and the precise anticipated location of all transplants (with a resolution of a few feet).

221. Kanepuu population.

A specific population augmentation plan must be developed for the Kanepuu population.

2211. Select genetic stock to use in augmenting population.

The most controversial aspect of this program will probably be the selection of genetic stock for augmentation. At one extreme is the philosophy that it is always best to maintain the genetic integrity or purity of each population. This would mean that all transplants must be derived from the population to be augmented. For existing populations which are already genetically diverse, this would be the preferred course of action. At the other extreme is the idea that it is best to create populations that are as genetically diverse as possible. The theory behind this view is that Gardenia brighamii has been severely reduced in numbers and has probably experienced a genetic "bottleneck" with the remaining populations being too small to prevent damaging inbreeding effects. Certainly for the populations with only a single wild individual, it may be unwise to plant 20 clones into the site and consider the site "stable". On the other hand, transplanting all 20 lineages into each site may eliminate any unique population features or genotypes. Until

research can clarify which of these two courses of action is most appropriate, it is best to ensure that the augmentation does not irreversibly lock recovery efforts into either option. It is therefore an absolute must that the parentage of all transplants be known and that all wild plants are mapped and marked. For the immediate future, the augmentation plan should be conservative and only reintroduce plants or lineages originally obtained from each site. This may pose a problem with inbreeding at the Molokai or Oahu sites and future augmentation with different genotypes may be required. The Kanepuu population on Lanai with its 7 to 8 wild plants may be diverse enough so that the use of only Kanepuu lineages would be preferable under all circumstances. Populations which will be established on islands with extinct populations (Task 4) could be composed of all genetic stocks with little risk.

2212. Identify areas to augment population.

Once the appropriate genetic stock has been determined for the collection of cuttings, specific areas within the exclosures must be identified as the precise anticipated location of all transplants (with a resolution of a few feet).

2213. Propagate genetically suitable plants.

Once the genetic stock has been selected, plants must be propagated by grafts and air-layering under controlled conditions.

2214. Fence areas to contain expanded population.

The existing exclosures may be too small to hold additional plants, so some exclosures may need to be enlarged. This should take place well in advance of actual transplantation.

2215. Control alien weeds within expanded exclosures.

All alien weeds within the expanded exclosures must be removed prior to transplantation and on a continual basis thereafter.

2216. Control predation and disease within expanded exclosures.

Care must be taken to ensure that the nursery-grown G. brighamii plants will not introduce disease or pathogens into the existing wild population.

2217. Ensure fire protection plan extends to expanded exclosures.

See narrative for Task #1124.

2218. Transplant nursery-grown plants into expanded exclosures.

Once the transplant areas have been identified, the threats to G. brighamii are controlled, and the proper genetic stock propagated, transplantation into a site can commence. It may be necessary to temporarily provide water to transplanted G. brighamii. All plants which fail to survive transplantation will need to be replaced with genetically similar nursery-grown plants.

222. Wahane Gulch population.

A specific population augmentation plan must be developed for the Wahane Gulch population.

2221. Select genetic stock to use in augmenting population.

See narrative for Task #2211.

2222. Identify areas to augment population.

See narrative for Task #2212.

2223. Propagate genetically suitable plants.

See narrative for Task #2213.

2224. Fence areas to contain expanded population.

See narrative for Task #2214.

2225. Control alien weeds within expanded exclosure.

See narrative for Task #2215.

2226. Control predation and disease within expanded exclosure.

See narrative for Task #2216.

2227. Ensure fire protection plan extends to expanded population.

See narrative for Task #2217.

2228. Transplant nursery-grown plants into expanded exclosure.

See narrative for Task #2218.

223. Puhielelu Ridge population.

A specific population augmentation plan must be developed for the Puhielelu Ridge population.

2231. Select genetic stock to use in augmenting population.

See narrative for Task #2211.

2232. Identify areas to augment population.

See narrative for Task #2212.

2233. Propagate genetically suitable plants.

See narrative for Task #2213.

2234. Fence areas to contain expanded population.

See narrative for Task #2214.

2235. Control alien weeds within expanded exclosure.

See narrative for Task #2215.

2236. Control predation and disease within expanded exclosure.

See narrative for Task #2216.

2237. Ensure fire protection plan extends to expanded population.

See narrative for Task #2217.

2238. Transplant nursery-grown plants into expanded exclosure.

See narrative for Task #2218.

224. Mahana population.

A specific population augmentation plan must be developed for the Mahana population.

2241. Select genetic stock to use in augmenting population.

See narrative for Task #2211.

2242. Identify areas to augment population.

See narrative for Task #2212.

2243. Propagate genetically suitable plants.

See narrative for Task #2213.

2244. Fence areas to contain expanded population.

See narrative for Task #2214.

2245. Control alien weeds within expanded exclosure.

See narrative for Task #2215.

2246. Control predation and disease within expanded exclosure.

See narrative for Task #2216.

2247. Ensure fire protection plan extends to expanded population.

See narrative for Task #2217.

2248. Transplant nursery-grown plants into expanded exclosure.

See narrative for Task #2218.

225. Puu Kuua population.

A specific population augmentation plan must be developed for the Puu Kuua population.

2251. Select genetic stock to use in augmenting population.

See narrative for Task #2211.

2252. Identify areas to augment population.

See narrative for Task #2212.

2253. Propagate genetically suitable plants.

See narrative for Task #2213.

2254. Fence areas to contain expanded population.

See narrative for Task #2214.

2255. Control alien weeds within expanded exclosure.

See narrative for Task #2215.

2256. Control predation and disease within expanded exclosure.

See narrative for Task #2216.

2257. Ensure fire protection plan extends to expanded population.

See narrative for Task #2217.

2258. Transplant nursery-grown plants into expanded exclosure.

See narrative for Task #2218.

226. Nanakuli population.

A specific population augmentation plan must be developed for the Nanakuli population.

2261. Select genetic stock to use in augmenting population.

See narrative for Task #2211.

2262. Identify areas to augment population.

See narrative for Task #2212.

2263. Propagate genetically suitable plants.

See narrative for Task #2213.

2264. Fence areas to contain expanded population.

See narrative for Task #2214.

2265. Control alien weeds within expanded exclosure.

See narrative for Task #2215.

2266. Control predation and disease within expanded exclosure.

See narrative for Task #2216.

2267. Ensure fire protection plan extends to expanded population.

See narrative for Task #2217.

2268. Transplant nursery-grown plants into expanded exclosure.

See narrative for Task #2218.

3. **Develop and maintain detailed monitoring of all individuals.**

Careful records must be maintained on the fate and location of each cutting in botanical gardens and each plant in the wild. These cuttings will form the backbone of any reintroduction, restoration, or augmentation plan. There are almost 300 individuals of G. brighamii in cultivation, almost all of which are from wild-collected seed. While this represents a much better genetic representation than is available for many species, it is still inadequate because it consists of only single cuttings from 1 or 2 wild plants and a few more air-layered offspring from another plant. In addition, the remaining plants represent only 4 to 6 lineages (i.e., all were derived from only 4 to 6 trees). As a result, only the Mahana plant (and population) with its three recently obtained air-layered plants is adequately preserved in cultivation. It will be necessary to permanently map, tag, and monitor all wild G. brighamii.

31. Kanepuu population and cultivars derived from it.

All of the plants that make up the Kanepuu population, and all cultivars derived from them, must be mapped, tagged and monitored.

311. Map, tag and monitor all wild plants.

Each of the 7 - 8 plants that make up the Kanepuu population must be mapped and tagged and monitored on a regular basis. Each cutting that is taken from this population should be identified as to its plant of origin, by plant of origin tag number and date of collection. Accurate records must then be maintained on the fate and location of each cutting in botanical gardens and on each wild plant and cultivar in the exclosure sites.

312. Map, tag and monitor all transplanted plants.

All transplanted G. brighamii individuals must be mapped, tagged, and monitored in order to determine the success of the program. It is important to know the lineages of all transplants, so that in the event that some seedlings die, they can be replaced with genetically similar plants to ensure that the populations do not become dominated by a single lineage or genotype. Knowledge of the lineages of individual plants also allows for the selective culling of specific genetic stocks should research dictate a change in management philosophy.

32. Wahane Gulch population and cultivars derived from it.

All of the plants that make up the Wahane Gulch population, and all cultivars derived from them, must be mapped, tagged and monitored.

321. Map, tag and monitor all wild plants.

Each of the 2 - 3 plants that make up the Wahane Gulch population must be mapped and tagged and monitored on a regular basis. (See narrative for Task #311)

322. Map, tag and monitor all transplanted plants.

See narrative for Task #312.

33. Puhielelu Ridge population and cultivars derived from it.

All of the plants that make up the Puhielelu Ridge population, and all cultivars derived from them, must be mapped, tagged and monitored.

331. Map, tag and monitor all wild plants.

Each of the 4 plants that make up the Puhielelu Ridge population must be mapped and tagged and monitored on a regular basis. (See narrative for Task #311)

332. Map, tag and monitor all transplanted plants.

See narrative for Task #312.

34. Puu Kuua popluation and cultivars derived from it.

The single plant that makes up the Puu Kuua population, and all cultivars derived from it, must be mapped, tagged and monitored.

341. Map, tag and monitor all wild plants.

The plant that makes up the Puu Kuua population must be mapped and tagged and monitored on a regular basis. (See narrative for Task #311)

342. Map, tag and monitor all transplanted plants.

See narrative for Task #312.

35. Nanakuli population and cultivars derived from it.

All of the plants that make up the Nanakuli population, and all cultivars derived from them, must be mapped, tagged and monitored.

351. Map, tag and monitor all wild plants.

Each of the 2 plants that make up the Nanakuli population must be mapped and tagged and monitored on a regular basis. (See narrative for Task #311)

352. Map, tag and monitor all transplanted plants.

See narrative for Task #312.

36. Mahana population and cultivars derived from it.

The single plant that makes up the Mahana population, and all cultivars derived from it, must be mapped, tagged and monitored.

361. Map, tag and monitor all wild plants.

The plant that makes up the Mahana population must be mapped and tagged and monitored on a regular basis. (See narrative for Task #311)

362. Map, tag and monitor all transplanted plants.

See narrative for Task #312.

4. **Reestablish Gardenia brighamii in former range.**

The intent of this task is to restore Gardenia brighamii to a point where the species is no longer in immediate danger of extinction due to catastrophic events or genetic inbreeding. All islands within the historic range should have sites which are able to naturally maintain large, genetically diverse populations within protected exclosures. It is expected that these populations will still require active land management to eliminate threats posed by herbivores, alien weeds, and disease/pathogens. The target objectives for this task are the establishment of three naturally maintaining populations of 50 trees each on all five islands: Hawaii, Lanai, Maui, Molokai and Oahu. This would result in 15 populations with a total of 750 reproductive trees. If this goal is reached, then G. brighamii can be considered for downlisting to threatened. These conditions would not allow for complete delisting because the populations would still be threatened by herbivores, alien weeds, and possibly predators or pathogens if active management (e.g., fencing) was discontinued.

The task of identifying specific areas for reintroductions and augmentations will be more difficult than the previous tasks because larger protected areas will be required and at least 9 sites must be chosen for reintroduction. As a result, the reintroduction plan will be complex. Each exclosure should, as a minimum, provide enough area to maintain 50 to 100 Gardenia brighamii trees. For planning purposes, this is estimated to be approximately 5 acres. Future research may indicate a larger or smaller area requirement.

41. Reestablish gardenia on Oahu.

Steps should be taken to reestablish the Hawaiian gardenia in an additional area on Oahu.

411. Identify one specific area for reintroduction on Oahu.

One reintroduction site should be established in either the northern Waianae Mountains or the Koolau Mountains. It would be preferable to establish the site in the Koolau Mountains, since the two extant sites are both in the Waianae Mountains.

412. Secure site identified in Task #411.

Once the reintroduction site has been selected, it will be necessary to secure the site through negotiations with the landowner(s) and development of conservation easements, cooperative agreements, leases, or fee purchases.

413. Select genetic stock to use in reintroduction efforts.

Populations should continue to be augmented only with transplants which originated from that population, unless future research dictates otherwise. However, populations which are to be reestablished in areas where G. brighamii has been extirpated should be comprised of genetically diverse stock. This program would still maintain the genetic "purity" of the original 6 populations, but would allow for the establishment of 9 genetically diverse populations to buffer against future inbreeding depression in the original populations.

The two extant sites on Oahu should be augmented to a total of 50 plants each using genetic stock from their respective original wild populations. The reintroduced population should consist of genetic stock from all three wild plants currently found on Oahu.

414. Fence area to contain reintroduced population.

Areas to contain the reintroduced population must be fenced to exclude herbivores. (See narrative for Task #1121.)

415. Control alien weeds within reintroduced plant exclosure.

See narrative for Task #1122.

416. Control predation and disease within reintroduced plant exclosure.

See narrative for Task #1123.

417. Ensure fire protection plan extends to reintroduced population.

See narrative for Task #1124.

418. Reintroduce plants into reintroduction site.

Once the reintroduction site has been identified, the threats to G. brighamii are controlled, and the proper genetic stock propagated, transplantation into a site can commence. It may be necessary to temporarily provide water to transplanted G. brighamii. All plants which fail to survive transplantation must be replaced with genetically similar nursery-grown plants.

419. Monitor reintroduction.

All reintroduced plants in the reintroduction site must be mapped and tagged and records maintained of their lineages and fates.

42. Reestablish gardenia on Molokai.

Steps should be taken to reestablish the Hawaiian gardenia in two additional areas on Molokai.

421. Identify two specific areas for reintroduction on Molokai.

Two reintroduction sites should be located on the western half of the island of Molokai.

422. Secure sites identified in Task #421.

See narrative for Task #412.

423. Select genetic stock to use in reintroduction efforts.

The single extant site should be augmented with stock derived from the only remaining Molokai tree. The two reintroduction sites should be planted with diverse genetic stock from Molokai and Lanai. (See narrative for Task #413.)

424. Fence areas to contain reintroduced populations.

See narrative for Task #414.

425. Control alien weeds within reintroduced plant exclosure.

See narrative for Task #415.

426. Control predation and disease within reintroduced plant exclosure.

See narrative for Task #416.

427. Ensure fire protection plan extends to reintroduced population.

See narrative for Task #417.

428. Reintroduce plants into reintroduction sites.

See narrative for Task #418.

429. Monitor reintroduction.

See narrative for Task #419.

43. Reestablish gardenia on Hawaii.

Steps should be taken to reestablish the Hawaiian gardenia in three sites on Hawaii.

431. Identify three specific areas for reintroduction on Hawaii.

Three reintroduction sites should be established in the North Kona area on the island of Hawaii.

432. Secure sites identified in Task #431.

See narrative for Task #412.

433. Select genetic stock to use in reintroduction efforts.

Since G. brighamii is extinct on Hawaii, the reintroduction sites should be composed of diverse stock derived from all 17 to 19 of the currently remaining wild plants, unless it turns out that Manuka State Park does indeed have a plant derived from a wild-collected plant from the island of Hawaii. If

plant(s) of island of Hawaii ancestry can be located, they should be used for the reestablishment of at least one population. (See narrative for Task #413.)

434. Fence areas to contain reintroduced populations.

See narrative for Task #414.

435. Control alien weeds within reintroduced plant exclosures.

See narrative for Task #415.

436. Control predation and disease within reintroduced plant exclosure.

See narrative for Task #416.

437. Ensure fire protection plan extends to reintroduced population.

See narrative for Task #417.

438. Reintroduce plants into reintroduction sites.

See narrative for Task #418.

439. Monitor reintroduction.

See narrative for Task #419.

44. Reestablish gardenia on Maui.

Steps should be taken to reestablish the Hawaiian gardenia in three sites on Maui.

441. Identify three specific areas for reintroduction on Maui.

Three reintroduction sites should be established on west Maui.

442. Secure sites identified in Task #441.

See narrative for Task #412.

443. Select genetic stock to use in reintroduction efforts.

Since G. brighamii is extinct on Maui, the populations should be established using diverse stock from all 17 to 19 wild individuals. (See narrative for Task #413.)

444. Fence areas to contain reintroduced populations.

See narrative for Task #414.

445. Control alien weeds within reintroduced plant exclosures.

See narrative for Task #415.

446. Control predation and disease within reintroduced plant exclosure.

See narrative for Task #416.

447. Ensure fire protection plan extends to reintroduced population.

See narrative for Task #417.

448. Reintroduce plants into reintroduction sites.

See narrative for Task #418.

449. Monitor reintroduction.

See narrative for Task #419.

5. **Verify or determine the scientific validity of the recovery objectives.**

An important role for research is to verify the scientific validity of the stated recovery objectives in this plan.

51. Determine the number of populations needed to ensure survival over the next 200 years.

It will be necessary to know whether the projected 15 populations are adequate to safeguard against catastrophic events over the next 200 years.

52. Determine the number of individuals needed to ensure the long-term survival of each population.

It is of utmost importance that we determine the number of individuals needed to ensure the long-term survival of each population.

53. Determine germination requirements and the identity, distribution and status of pollen vectors.

In order to determine whether populations will ever be naturally maintaining, it will be necessary to determine germination requirements in the wild and to identify the effective pollen vectors and their distribution and density.

54. Determine breeding system and susceptibility to inbreeding depression.

It is necessary to determine whether it is more appropriate to maintain the genetic "purity" of the wild populations or if it is better to inject diversity into these populations. An answer to this question will probably not be available until after research has determined Gardenia brighamii's breeding system and susceptibility to inbreeding depression.

55. Determine if hypothesized human-induced changes in climate will affect populations.

Hypothesized human-induced changes in global climate may also impact on local climates and thus plant distributions. It would be prudent to hypothesize how these global climate changes might affect the long-term survivability of existing Gardenia brighamii populations.

LITERATURE CITED

Cuddihy, L.W. and C.P. Stone. 1990. Alteration of Native Hawaiian Vegetation. University of Hawaii Cooperative National Park Resources Studies Unit, Honolulu.

Fosberg, F.R. 1936. Plant collecting on Lanai, 1935. Mid-Pacific Magazine 49:119-123.

Fosberg, F.R. 1948. Derivation of the flora of the Hawaiian Islands. In Insects of Hawaii, Volume I, pp. 107-119, E.C. Zimmerman (editor). University of Hawaii Press, Honolulu.

Gagne, B.H. 1982. Gardenia brighamii. Unpublished status report to the U.S. Fish and Wildlife Service. 38 pp.

Hawaii State Department of Land and Natural Resources, U.S. Fish and Wildlife Service, and The Nature Conservancy. 1991. Hawaii's Extinction Crisis: a call to action. DLNR, Honolulu.

Herbst, D. 1985. Endangered and threatened wildlife and plants; determination of endangered status for Gardenia brighamii (Na'u or Hawaiian Gardenia) and withdrawal of proposed designation of critical habitat. Federal Register 50(162):33728-33731.

Hicks, C.B. and A.D. Oliver. 1987. Citrus whitefly preference among four ornamental host plants. Hortscience 22:59-60.

Hillebrand, W.F. 1888. Flora of the Hawaiian Islands. B. Westerman, New York.

Mann, H. 1866-1868. Enumeration of Hawaiian plants. Proceedings of the American Academy of Arts and Science 7:143-234.

Rock, J.F. 1913. The Indigenous Trees of the Hawaiian Islands. Reprinted in 1974 by Charles E. Tuttle, Rutland, Vermont.

Smith, A.C. 1974. Studies of Pacific Island plants. XXVII. The genus Gardenia (Rubiaceae) in the Fijiian region. American Journal of Botany 61:109-128.

Spence, G. and S.L. Montgomery. 1976. Ecology of the dry land forest at Kanepuu, island of Lanai. Newsletter of the Hawaiian Botanical Society 15(4/5):62-80.

St. John, H. and J.R. Kuykendall. 1949. Revision of the native Hawaiian species of Gardenia (Rubiaceae). Hawaiian plant studies: 15. Brittonia 6(4):431-449.

Stimman, M.W., H.K. Kaya, T.M. Burlando, and J.P. Studdert. 1985. Black weevil management in nursery plants. California Agriculture 39:25-26.

Wagner, W.L., D.R. Herbst, and S.H. Sohmer. 1990. Manual of the Flowering Plants of Hawaii. University of Hawaii Press and Bishop Museum Press, Honolulu.

Ziegler, M.F.Y. 1989. Kanepuu: a remnant dry forest on Lanai, Hawaii. Elepaio 49:19-24.

III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the Hawaiian gardenia recovery program, as set forth in this recovery plan. It is a guide for meeting the objectives discussed in Part II of this Plan. This schedule indicates task priority, task numbers, task descriptions, duration of tasks, the agencies responsible for committing funds, and lastly, estimated costs. The agencies responsible for committing funds are not, necessarily, the entities that will actually carry out the tasks. When more than one agency is listed as the responsible party, an asterisk is used to identify the lead entity.

The actions identified in the implementation schedule, when accomplished, should protect habitat for the species, stabilize the existing populations and increase the population sizes and numbers on Oahu, Lanai, Molokai, Hawaii and Maui. Monetary needs for all parties involved are identified to reach this point.

Priorities in Column 1 of the following implementation schedule are assigned as follows:

Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly.

Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery of the species.

Key to Acronyms Used in Implementation Schedule

FWE	-	Fish and Wildlife Service, Ecological Services, Honolulu, Hawaii
DLNR	-	Hawaii Department of Land & Natural Resources
TNCH	-	The Nature Conservancy of Hawaii
CC	-	Castle & Cooke, Inc.
MR	-	Molokai Ranch
HHL	-	Hawaiian Home Lands
CE	-	Campbell Estate
FWS-RES	-	Fish and Wildlife Service, Research Division

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
		LANAI:									
1	111	Enter into long-term agreement with Castle & Cooke, Inc., to secure the Kanepuu, Wahane Gulch and Puhielelu Ridge populations.	2	FWE*	2		1	1			
				TNCH	0.5		0.25	0.25			
				CC	0.5		0.25	0.25			
				DLNR	0.5		0.25	0.25			
		Kanepuu population:									
1	1121	Control grazing by constructing and maintaining fence.	C	FWE*	17			15	1	1	
				DLNR	19			15	2	2	
				TNCH	14	1	1	10	1	1	
1	1122	Control alien weeds.	C	DLNR*	15			5	5	5	
				FWE	3			1	1	1	
				TNCH	10	2	2	2	2	2	
1	1123	Control predation & disease.	C	DLNR*	21			7	7	7	
				FWE	6			2	2	2	
				TNCH	25	5	5	5	5	5	
1	1124	Reduce the risk of catastrophic fire.	1	DLNR*	5			5			
				FWE	2			2			
				TNCH	3			3			
1	1125	Back-up all wild plants with 5 vegetatively produced plants.	1	FWE	3			3			
				DLNR*	5			5			
				TNCH	1			1			
		Wahane Gulch population:									
1	1131	Control grazing by constructing and maintaining fence.	C	FWE*	17			15	1	1	
				DLNR	19			15	2	2	
1	1132	Control alien weeds.	C	DLNR*	9			3	3	3	
				FWE	1.5			0.5	0.5	0.5	
1	1133	Control predation and disease.	C	DLNR*	15			5	5	5	
				FWE	3			1	1	1	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
1	1134	Reduce the risk of catastrophic fire.	1	DLNR* FWE	5 2			5 2			
1	1135	Back-up all wild plants with 5 vegetatively produced plants.	1	FWE DLNR*	2 4			2 4			
		Puhielelu Ridge population:									
1	1141	Control grazing by constructing and maintaining fence.	C	FWE* DLNR	17 19			15 15	1 2	1 2	
1	1142	Control alien weeds.	C	DLNR* FWE	9 1.5			3 0.5	3 0.5	3 0.5	
1	1143	Control predation and disease.	C	DLNR* FWE	15 3			5 1	5 1	5 1	
1	1144	Reduce the risk of catastrophic fire.	1	DLNR* FWE	5 2			5 2			
1	1145	Back-up all wild plants with 5 vegetatively produced plants.	1	FWE DLNR*	2 4			2 4			
		MOLOKAI (Mahana Population):									
1	121	Enter into long-term agreement with Molokai Ranch to secure & manage the Mahana population.	2	FWE* MR DLNR	2 0.5 0.5		1 0.25 0.25	1 0.25 0.25			
1	1221	Control grazing by maintaining fence.	C	FWE DLNR*	3 9			1 3	1 3	1 3	
1	1222	Control alien weeds.	C	DLNR* FWE	9 1.5			3 0.5	3 0.5	3 0.5	
1	1223	Control predation and disease.	C	DLNR* FWE	15 3			5 1	5 1	5 1	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
1	1342	Control alien weeds.	C	DLNR*	9			3	3	3	
				FWE	1.5			0.5	0.5	0.5	
1	1343	Control predation and disease.	C	DLNR*	15			5	5	5	
				FWE	3			1	1	1	
1	1344	Reduce the risk of catastrophic fire.	1	DLNR*	5			5			
				FWE	2			2			
1	1345	Back-up all wild plants with 5 vegetatively produced plants.	1	FWE	0.5			0.5			
				DLNR*	1.5			1.5			
	NEED 1 (SECURE HABITAT & MANAGE THREATS)				464	8	14.25	258.75	91.5	91.5	
2	141	Determine the effects of currently known introduced insects.	10	DLNR*	30			10	10	10	
				FWE	15			5	5	5	
				FWS-RES	30			10	10	10	
2	142	Determine the effects of rusts & fungus.	10	DLNR*	15			5	5	5	
				FWE	6			2	2	2	
				FWS-RES	6			2	2	2	
2	143	Determine the effects of rats on reproduction.	5	DLNR*	15			5	5	5	
				FWE	15			5	5	5	
				FWS-RES	6			2	2	2	
2	144	Determine the effects of currently known introduced birds on reproduction.	10	FWS-RES*	30			10	10	10	
				FWE	15			5	5	5	
				DLNR	15			5	5	5	
2	145	Determine the mechanisms by which currently known alien weeds impact the species.	10	DLNR*	15			5	5	5	
				FWE	15			5	5	5	
				FWS-RES	6			2	2	2	
2	151	Develop methods to control feral herbivores.	10	DLNR*	21			7	7	7	
				FWE	15			5	5	5	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
1	1224	Reduce the risk of catastrophic fire.	1	DLNR* FWE	5 2			5 2			
1	1225	Back-up all wild plants with 5 vegetatively produced plants.	1	FWE DLNR*	0.5 1			0.5 1			
	OAHU:										
1	131	Enter into long-term agreement with Campbell Estate to secure & manage the Puu Kuua population.	2	FWE* CE DLNR	2 0.5 0.5		1 0.25 0.25	1 0.25 0.25			
1	132	Enter into long-term agreement with Hawaiian Home Lands to secure & manage the Nanakuli pop.	2	FWE* HHL DLNR	2 0.5 0.5		1 0.25 0.25	1 0.25 0.25			
	Puu Kuua population:										
1	1331	Control grazing by maintaining fence.	C	FWE DLNR*	3 9			1 3	1 3	1 3	
1	1332	Control alien weeds.	C	DLNR* FWE	9 1.5			3 0.5	3 0.5	3 0.5	
1	1333	Control predation and disease.	C	DLNR* FWE	15 3			5 1	5 1	5 1	
1	1334	Reduce the risk of catastrophic fire.	1	DLNR* FWE	5 2			5 2			
1	1335	Back-up all wild plants with 5 vegetatively produced plants.	1	FWE DLNR*	0.5 1			0.5 1			
	Nanakuli population:										
1	1341	Control grazing by maintaining fence.	C	FWE DLNR*	3 9			1 3	1 3	1 3	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	2216	Control predation & disease.	C	DLNR*	1					1	
				FWE	1					1	
				TNCH	1					1	
2	2217	Ensure fire protection plan extends to expanded exclosure.	1	DLNR*	1					1	
				FWE	1					1	
				TNCH	1					1	
2	2218	Transplant into expanded exclosures.	4	DLNR*	5					5	
				FWE	1					1	
				TNCH	2					2	
		Wahane Gulch population:									
2	2221	Select genetic stock to use in augmenting population.	2	DLNR*	2			1	1		
				FWE	2			1	1		
2	2222	Identify areas to augment population.	1	DLNR*	3			3			
				FWE	1			1			
2	2223	Propagate genetically suitable plants.	10	DLNR*	30			10	10	10	
				FWE	30			10	10	10	
2	2224	Fence areas to contain expanded population.	C	FWE*	15					15	
				DLNR	10					10	
2	2225	Control alien weeds within expanded exclosures.	C	DLNR*	2					2	
				FWE	1					1	
2	2226	Control predation and disease.	C	DLNR*	1					1	
				FWE	1					1	
2	2227	Ensure fire protection plan extends to expanded population.	1	DLNR*	1					1	
				FWE	1					1	
2	2228	Transplant into expanded exclosures.	4	DLNR*	5					5	
				FWE	1					1	
		Puhielelu Ridge population:									
2	2231	Select genetic stock to use in augmenting population.	2	DLNR*	2			1	1		
				FWE	2			1	1		

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	152	Develop methods to control introduced insects.	10	DLNR* FWE	30 15			10 5	10 5	10 5	
2	153	Develop methods to control rusts and fungus.	10	DLNR* FWE	15 6			5 2	5 2	5 2	
2	154	Develop methods to control rats.	5	DLNR* FWE	9 3			3 1	3 1	3 1	
2	155	Develop methods to control introduced birds.	10	DLNR* FWE	30 15			10 5	10 5	10 5	
2	156	Develop methods to control alien weeds.	10	DLNR* FWE	15 15			5 5	5 5	5 5	
	NEED 2 (CONDUCT RESEARCH ON LIMITING FACTORS)				423	0	0	141	141	141	
2	21	Determine augmentation/ reintroduction techniques.	10	DLNR* FWE	30 15			10 5	10 5	10 5	
	Kanepuu population:										
2	2211	Select genetic stock to use in augmenting population.	2	DLNR* FWE	2 2			1 1	1 1		
2	2212	Identify areas to augment population.	1	DLNR* FWE TNCH	3 1 1			3 1 1			
2	2213	Propagate genetically suitable plants.	10	DLNR* FWE	30 30			10 10	10 10	10 10	
2	2214	Fence areas to contain expanded population.	C	FWE* DLNR TNCH	15 10 5					15 10 5	
2	2215	Control alien weeds within expanded exclosures.	C	DLNR* FWE TNCH	2 1 1					2 1 1	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	2247	Ensure fire protection plan extends to expanded population.	1	DLNR* FWE	1 1					1 1	
2	2248	Transplant into expanded exclosures.	4	DLNR* FWE	5 1					5 1	
		Puu Kuua population:									
2	2251	Select genetic stock to use in augmenting population.	2	DLNR* FWE	2 2			1 1	1 1		
2	2252	Identify areas to augment population.	1	DLNR* FWE	3 1			3 1			
2	2253	Propagate genetically suitable plants.	10	DLNR* FWE	30 30			10 10	10 10	10 10	
2	2254	Fence areas to contain expanded population.	C	FWE* DLNR	15 10					15 10	
2	2255	Control alien weeds within expanded exclosures.	C	DLNR* FWE	2 1					2 1	
2	2256	Control predation and disease.	C	DLNR* FWE	1 1					1 1	
2	2257	Ensure fire protection plan extends to expanded population.	1	DLNR* FWE	1 1					1 1	
2	2258	Transplant into expanded exclosures.	4	DLNR* FWE	5 1					5 1	
		Nanakuli population:									
2	2261	Select genetic stock to use in augmenting population.	2	DLNR* FWE	2 2			1 1	1 1		
2	2262	Identify areas to augment population.	1	DLNR* FWE	3 1			3 1			

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	2232	Identify areas to augment population.	1	DLNR* FWE	3 1			3 1			
2	2233	Propagate genetically suitable plants.	10	DLNR* FWE	30 30			10 10	10 10	10 10	
2	2234	Fence areas to contain expanded population.	C	FWE* DLNR	15 10					15 10	
2	2235	Control alien weeds within expanded exclosures.	C	DLNR* FWE	2 1					2 1	
2	2236	Control predation and disease.	C	DLNR* FWE	1 1					1 1	
2	2237	Ensure fire protection plan extends to expanded population.	1	DLNR* FWE	1 1					1 1	
2	2238	Transplant into expanded exclosures.	4	DLNR* FWE	5 1					5 1	
	Mahana population:										
2	2241	Select genetic stock to use in augmenting population.	2	DLNR* FWE	2 2			1 1	1 1		
2	2242	Identify areas to augment population.	1	DLNR* FWE	3 1			3 1			
2	2243	Propagate genetically suitable plants.	10	DLNR* FWE	30 30			10 10	10 10	10 10	
2	2244	Fence areas to contain expanded population.	C	FWE* DLNR	15 10					15 10	
2	2245	Control alien weeds within expanded exclosures.	C	DLNR* FWE	2 1					2 1	
2	2246	Control predation and disease.	C	DLNR* FWE	1 1					1 1	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	332	Map, tag & monitor transplanted plants.	C	DLNR* FWE	7 5					7 5	
		Puu Kuua population & cultivars:									
2	341	Map, tag & monitor wild plants.	C	DLNR* FWE	2 2			1 1	0.5 0.5	0.5 0.5	
2	342	Map, tag & monitor transplanted plants.	C	DLNR* FWE	7 5					7 5	
		Nanakuli population & cultivars:									
2	351	Map, tag & monitor wild plants.	C	DLNR* FWE	4 3			2 1	1 1	1 1	
2	352	Map, tag & monitor transplanted plants.	C	DLNR* FWE	7 5					7 5	
		Mahana population & cultivars:									
2	361	Map, tag & monitor wild plants.	C	DLNR* FWE	2 2			1 1	0.5 0.5	0.5 0.5	
2	362	Map, tag & monitor transplanted plants.	C	DLNR* FWE	7 5					7 5	
		NEED 3 (INCREASE NUMBERS AND MONITOR)			834	0	0	204	161	469	
		Oahu:									
2	411	Identify one reintroduction site on Oahu.	1	DLNR* FWE	10 10			10 10			
2	412	Secure site identified in Task #411.	2	FWE* DLNR	4 4				2 2	2 2	
2	413	Select genetic stock to use in reintroduction efforts.	1	DLNR* FWE	1 1			1 1			

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	2263	Propagate genetically suitable plants.	10	DLNR*	30			10	10	10	
				FWE	30			10	10	10	
2	2264	Fence areas to contain expanded population.	C	FWE*	15					15	
				DLNR	10					10	
2	2265	Control alien weeds within expanded exclosures.	C	DLNR*	2					2	
				FWE	1					1	
2	2266	Control predation and disease.	C	DLNR*	1					1	
				FWE	1					1	
2	2267	Ensure fire protection plan extends to expanded population.	1	DLNR*	1					1	
				FWE	1					1	
2	2268	Transplant into expanded exclosures.	4	DLNR*	5					5	
				FWE	1					1	
		Kanepuu population & cultivars:									
2	311	Map, tag & monitor wild plants.	C	DLNR*	9			5	2	2	
				FWE	9			5	2	2	
				TNCH	9			5	2	2	
2	312	Map, tag & monitor transplanted plants.	C	DLNR*	7					7	
				FWE	5					5	
				TNCH	10					10	
		Wahane Gulch population & cultivars:									
2	321	Map, tag & monitor wild plants.	C	DLNR*	4			2	1	1	
				FWE	4			2	1	1	
2	322	Map, tag & monitor transplanted plants.	C	DLNR*	7					7	
				FWE	5					5	
		Puhielelu Ridge population & cultivars:									
2	331	Map, tag & monitor wild plants.	C	DLNR*	5			3	1	1	
				FWE	5			3	1	1	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	427	Ensure fire protection plan extends to reintroduced populations.	1	DLNR* FWE	1 1					1 1	
2	428	Reintroduce plants into reintroduction sites.	4	DLNR* FWE	5 1					5 1	
2	429	Monitor reintroduction.	C	DLNR* FWE	5 5					5 5	
	Hawaii:										
2	431	Identify three reintro-duction sites on Hawaii.	1	DLNR* FWE	10 10			10 10			
2	432	Secure sites identified in Task #431.	2	FWE* DLNR	10 10				5 5	5 5	
2	433	Select genetic stock to use in reintro-duction efforts.	1	DLNR* FWE	1 1			1 1			
2	434	Fence areas to contain reintroduced populations.	C	DLNR* FWE	20 30					20 30	
2	435	Control alien weeds.	C	DLNR* FWE	2 2					2 2	
2	436	Control predation & disease.	C	DLNR* FWE	1 1					1 1	
2	437	Ensure fire protection plan extends to reintroduced populations.	1	DLNR* FWE	1 1					1 1	
2	438	Reintroduce plants into reintroduction sites.	4	DLNR* FWE	5 1					5 1	
2	439	Monitor reintroduction.	C	DLNR* FWE	5 5					5 5	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
2	414	Fence area to contain reintroduced population.	C	DLNR* FWE	10 15					10 15	
2	415	Control alien weeds.	C	DLNR* FWE	2 2					2 2	
2	416	Control predation & disease.	C	DLNR* FWE	1 1					1 1	
2	417	Ensure fire protection plan extends to reintroduced population.	1	DLNR* FWE	1 1					1 1	
2	418	Reintroduce plants into reintroduction site.	4	DLNR* FWE	5 1					5 1	
2	419	Monitor reintroduction.	C	DLNR* FWE	5 5					5 5	
	Molokai:										
2	421	Identify two reintroduction sites on Molokai.	1	DLNR* FWE	10 10			10 10			
2	422	Secure sites identified in Task #421.	2	FWE* DLNR	8 8				4 4	4 4	
2	423	Select genetic stock to use in reintroduction efforts.	1	DLNR* FWE	1 1			1 1			
2	424	Fence areas to contain reintroduced populations.	C	DLNR* FWE	15 25					15 25	
2	425	Control alien weeds.	C	DLNR* FWE	2 2					2 2	
2	426	Control predation & disease.	C	DLNR* FWE	1 1					1 1	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
3	52	Determine the number of individuals needed to ensure the long-term survival of each population.	3	FWE* DLNR	0 0						
3	53	Determine germination requirements & identity, distribution & status of pollen vectors.	20	FWE* DLNR FWS-RES	10 5 3					10 5 3	
3	54	Determine breeding system & susceptibility to inbreeding depression.	20	FWE* DLNR FWS-RES	5 5 1					5 5 1	
3	55	Determine if human-induced changes in climate will affect populations.	20	FWS-RES* FWE DLNR	5 1 1					5 1 1	
	NEED 5 (VALIDATE RECOVERY OBJECTIVES)				36	0	0	0	0	36	
	TOTAL COST				2170	8	14.25	691.75	425.5	1030.5	

RECOVERY PLAN IMPLEMENTATION SCHEDULE FOR HAWAIIAN GARDENIA (THRU 1996)

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000) FY 1992	FY 1993	FY 1994	FY 1995	FY 1996	Comments
	Maui:										
2	441	Identify three reintroduction sites on Maui.	1	DLNR* FWE	10 10			10 10			
2	442	Secure sites identified in Task #441.	2	FWE* DLNR	10 10				5 5	5 5	
2	443	Select genetic stock to use in reintroduction efforts.	1	DLNR* FWE	1 1			1 1			
2	444	Fence areas to contain reintroduced populations.	C	DLNR* FWE	20 30					20 30	
2	445	Control alien weeds.	C	DLNR* FWE	2 2					2 2	
2	446	Control predation & disease.	C	DLNR* FWE	1 1					1 1	
2	447	Ensure fire protection plan extends to reintroduced populations.	1	DLNR* FWE	1 1					1 1	
2	448	Reintroduce plants into reintroduction sites.	4	DLNR* FWE	5 1					5 1	
2	449	Monitor reintroduction.	C	DLNR* FWE	5 5					5 5	
	NEED 4 (REESTABLISH IN FORMER RANGE)				413	0	0	88	32	293	
3	51	Determine the number of populations needed to ensure survival over the next 200 years.	3	FWE* DLNR	0 0						

APPENDIX B

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APPENDIX A

References to Gardenia brighamii locations

ISLAND	RECOVERY POPULATIONS	HAWAII HERITAGE PROGRAM ELEMENT OCCURRENCE *
Oahu	Puu Kuua	.014
	Nanakuli	.001
	Nuuanu	.019
	Makaleha	.002
Maui	Olowalu Valley	.003
Hawaii	Puuwaawaa, North Kona	.005 & .017
	Puu Koihala	.021
Molokai	Mahana	.004
Lanai	Kanepuu	.006 & .011 & .027 & .018
	Wahane Gulch	.026 & .022
	Puhielelu Ridge	.008 & .025 & .028
	Kaiholena Valley	.024
	Mahana	.009
	Paomai	.010
	Kaena	.008

* Element occurrences are used to identify a single locality for a species. In this instance, several adjacent localities form a single population.

APPENDIX B

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