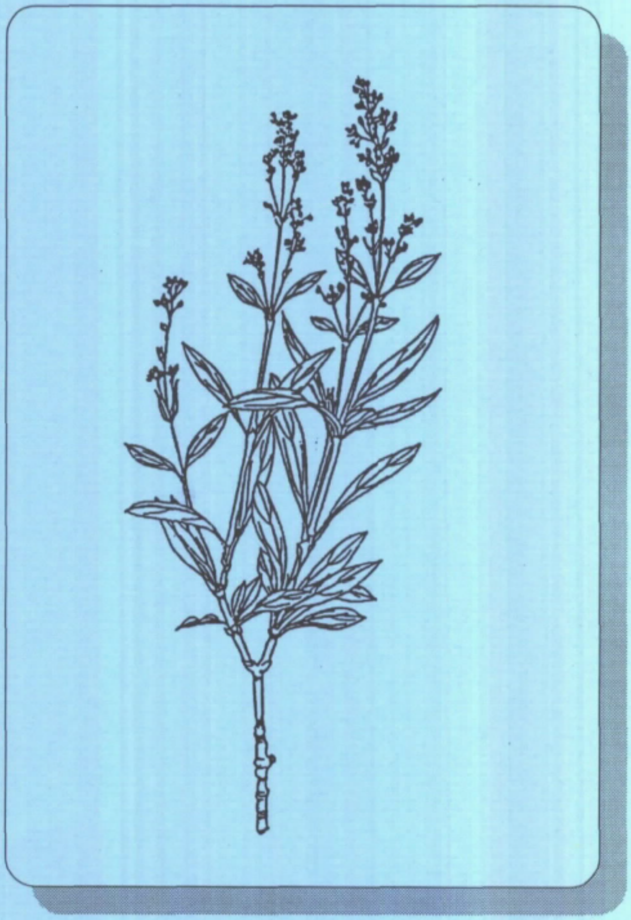
RECOVERY PLAN FOR *SCHIEDEA ADAMANTIS*

FEBRUARY, 1994



U.S. Fish and Wildlife Service, Pacific Region

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RECOVERY PLAN FOR

SCHIEDEA ADAMANTIS

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

Approved: Don Weathers DON WEATHERS
Acting Regional Director

Date: 2/2/94

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THIS IS THE COMPLETED RECOVERY PLAN FOR Schiedea adamantis. 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.

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ACKNOWLEDGEMENTS

This recovery plan for Schiedea adamantis was prepared by Ann K. Sakai, Department of Ecology and Evolutionary Biology, University of California-Irvine. Modifications have been made by the U.S. Fish and Wildlife Service.

EXECUTIVE SUMMARY OF THE RECOVERY PLAN FOR SCHIEDEA ADAMANTIS

Current Species Status: *Schiedea adamantis*, a small shrub of the Caryophyllaceae family, is federally listed as endangered. Currently, only one population exists on the Diamond Head Crater in Honolulu, Hawai'i. The last population estimate, based on field work conducted in 1990, was 244 plants.

Habitat Requirements and Limiting Factors: Habitat requirements for *Schiedea adamantis* can only be inferred by observing the one site on which it currently exists. This site is located on the Diamond Head crater, a palagonite tuff cone which has a substrate consisting of consolidated volcanic ash with pockets of loose, shallow soil interspersed along a steep, well-drained slope. An average annual rainfall of 60 centimeters (23 inches) falls in intense storms, mostly between November and March. Because the population was not discovered until 1955, limiting factors for this plant are unclear. However, because *S. adamantis* occurs in one of the few areas of the crater undisturbed by construction, it is believed that disturbance and loss of habitat caused by construction and use of military and other federal facilities on Diamond Head as well as invasion by alien plants, are among the limiting factors. Current known threats include fire, competition from alien plants, and disturbance by users of a nearby hiking trail. Another threat may be a lack of genetic diversity caused by increased levels of selfing due to loss of native pollinators. Because only one population of this species is currently in existence, its extinction is threatened by a single catastrophic event.

Recovery Objectives: Downlist to threatened status.

Recovery Criteria: To downlist this species to threatened status, the current population should be increased to at least 500 reproductive plants and two additional populations of at least 500 reproductive plants each should be established. All populations should be naturally-reproducing and should have remained at these numbers for a minimum of ten years.

Actions Needed:
1. Secure and manage existing population.
2. Conduct studies necessary to better manage the species.
3. Establish new populations.
4. Validate recovery objectives.

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

Year	Need 1	Need 2	Need 3	Need 4	Total
1994	48.5	0.0	0.0	0.0	48.5
1995	38.0	36.0	0.0	0.0	74.0
1996	42.0	45.0	0.0	0.0	87.0
1997	14.0	29.0	7.0	0.0	50.0
1998	17.0	8.0	9.75	0.0	34.75
1999	6.0	8.0	7.25	4.0	25.25
2000	3.0	0.0	6.0	5.0	14.0
2001	3.0	0.0	6.0	0.0	9.0
2002	3.0	0.0	6.0	0.0	9.0
2003	3.0	0.0	2.0	0.0	5.0
2004	3.0	0.0	2.0	0.0	5.0
2005	3.0	0.0	2.0	0.0	5.0
2006	3.0	0.0	2.0	0.0	5.0
2007	3.0	0.0	2.0	0.0	5.0
2008	0.0	0.0	2.0	0.0	2.0
2009	0.0	0.0	2.0	0.0	2.0
2010	0.0	0.0	2.0	0.0	2.0
2011	0.0	0.0	2.0	0.0	2.0
Total	189.5	126.0	60.0	9.0	384.5

Date of Recovery: Downlisting to Threatened should initiate in 2011, if recovery criteria are met.

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PART I. INTRODUCTION

BRIEF OVERVIEW

The genus Schiedea (Caryophyllaceae, the carnation or pink family) is the sixth largest endemic plant genus of the Hawaiian Islands (Wagner et al. 1990). Comprised of 24 species, it is an excellent example of evolutionary processes resulting in the diversification and adaptive radiation that have occurred within many Hawaiian groups. Schiedea species include rainforest vines, small shrubs, and slightly woody herbs. The genus also has a great diversity of floral types, making it a model for the study of breeding systems and in particular the evolution of dioecy (separate male and female plants).

Unfortunately, the genus Schiedea is also an example of the rapid rate of extinction of native plants of Hawai'i. Two Schiedea species are extinct, and two previously considered extinct were recently re-discovered. Five species are listed as endangered, three species are proposed for the federal list of threatened or endangered species, and five species are candidates for listing but not enough information is available to determine if listing is warranted. Most other Schiedea species occur in only a few small populations.

Schiedea adamantis St. John is a small shrub known only from one population on the dry slopes of Diamond Head Crater in Honolulu, Hawai'i. It has survived in the midst of this urban area largely because access is limited by proximity to Federal Aviation Administration (FAA) facilities. Although this urban location has protected the species from browsing by feral and domestic livestock, and its location and topography have protected it from development for agriculture, it remains threatened by fire, competition from alien plants, and users of a hiking trail immediately adjacent to the population.

Schiedea adamantis was federally listed as endangered on February 17, 1984 (49 FR 6099-6102), with the listing becoming effective on March 19, 1984. This listing purposefully did not include the designation of critical habitat for the species because the one known locality is very accessible and it was believed that publicizing its specific location may result in greater damage to the population (49 FR 6099-6102).

TAXONOMY

Schiedea adamantis (Caryophyllaceae family) was first collected by C. Lamoureux and E. T. Ozaki in 1955 and was described as a valid new species in 1970 (St. John 1970). It has been collected several times since then, with specimens at several herbaria (BISH, HAW, PTBG, RSA, and US). The Hawaiian name for the genus is ma'oli'oli, although the species is sometimes referred to as the Diamond Head Schiedea because of its locality. Wagner et al. (1990) mention its phenotypic similarity to S. salicaria (endemic to Maui) and S. ligustrina (endemic to the Waianae Mountains of Oahu). More recent phylogenetic studies based on morphological characters suggest that S. adamantis is most closely related to S. ligustrina and S. salicaria as well as S. haleakalensis and S. lydgatei, (Weller, Wagner, and Sakai, unpublished data).

SPECIES DESCRIPTION

Schiedea adamantis is a branching, brittle shrub 30 - 80 centimeters (11.8 - 31.5 inches) tall (Figure 1). The leaves are opposite, 1.5 - 3 centimeters (0.6 - 1.2 inches) long and 0.4 - 1.2 centimeters (0.2 - 0.5 inches) wide (Wagner et al. 1990). Plants grow actively and flower during the rainy season (December - April), and are dormant during the dry summer months (Sakai and Weller, unpublished observation). The plants have clusters of small flowers, with one to several inflorescences. The flowers have green to yellowish sepals about 3 millimeters (0.1 inches) long, no petals, and small nectaries. Individual plants have either perfect flowers (hermaphroditic, with both functional stamens and carpels), or pistillate flowers (female, with only functional carpels but no functional stamens). The fruits are small brown capsules containing an average of 10-12 tiny brown seeds. Further technical descriptions are given in the Manual of the Flowering Plants of Hawai'i (Wagner et al. 1990).

HISTORIC RANGE AND POPULATION STATUS

The genus Schiedea and the closely related genus Alsinidendron are found only in the Hawaiian Islands and are probably derived from a single ancestor (Wagner et al. 1990). The number of species, the biogeography of the group with a distribution centered on older islands (Weller et al. 1990), and the lack of closely related relatives suggests an early origin of the group in Hawai'i. Schiedea adamantis is known only from one locality on the Diamond Head Crater. The land on which it occurs is owned by the State of Hawai'i and managed by the Division of State Parks, under the direction of the Department of Land and Natural Resources. The low electrophoretic variability in this species suggests either that the population was founded by one or only a few individuals, or that the population has undergone a severe population bottleneck.

There is little available evidence of land use on Diamond Head before 1906, when the federal government acquired the land for military use (Takeuchi 1980). Extensive fortifications were constructed within the crater and along the rim until 1945. In 1950, the crater was occupied by the Hawaii National Guard and FAA. Public access was permitted in 1968.

Schiedea adamantis was not discovered until 1955, well after development of FAA facilities on the northeast rim and military emplacements along the southern and western ridge summits. It is unclear what impact this construction had on the distribution of

Figure 1. Habit of Schiedea adamantis. From Wagner, Herbst, and Sohmer 1990.

the species, although the current population is found in one of the few areas of the crater that is undisturbed by construction. (Use of the FAA facilities will be discontinued by the year 2000 and the structures demolished and removed). The dominant plant cover on this area of Diamond Head Crater has probably consisted of alien species for several decades. The historic impact of these alien species on S. adamantis, although unclear, is probably substantial. These aliens have undoubtedly changed the shade, nutrient status, and moisture conditions of the site, and increased the potential for more severe fires on the slopes. The dominant shrub at the site is koa haole (Leucaena leucocephala (Lam.) de Wit), an alien species first collected on O'ahu or Kaua'i in 1837 (Wagner et al. 1990).

Based on herbarium records, the population size of Schiedea adamantis has grown from an estimated 67 plants in November 1978 (Obata and Palmer 409, BISH), to a March 1990 count of 244 individuals that had flowered at least once in the previous three years (see below) (Sakai and Weller, unpublished data). In February 1979, there were 78 plants, of which 26 were at least 0.3 meters (1 foot) in height, with the population occupying 55 square meters (600 square feet) (Takeuchi 1980). Twenty-three flowering plants were reported in January 1985 (Takeuchi 1919, BISH); and 84 mature plants (40 female, 44 hermaphroditic), and 150-200 seedlings and juvenile plants were present in March, 1987 (Perlman, Obata, and Weller 5450, BISH).

CURRENT RANGE AND POPULATION STATUS

Although several botanists (S. Perlman, J. Obata, S. Weller, A. Sakai) searched for other localities on the slopes of Diamond Head in 1987, Schiedea adamantis has been found only in the original locality. Charles Lamoureux, who discovered the original population in 1955, is also unaware of any other populations (University of Hawaii, personal communication 1991). Given the extensive urbanization surrounding Diamond Head, the dominance of alien vegetation, and the lack of similar remaining habitat elsewhere on southeast O'ahu, it seems unlikely that other populations exist.

The most recent information on population status was obtained from field work conducted during the 1989-1990 flowering season (Sakai and Weller, unpublished data). The population occurred in an area approximately 11 meters (36 feet) by 22 meters (72 feet). The total population size of flowering plants was 244, including all plants that had flowered at least once during the previous three years. During this three-year period, a mean of 40.6% of the flowering plants were strictly female; the remainder of the flowering plants had hermaphroditic flowers. Seedlings, juveniles, and flowering plants were most abundant in the top five meters of the locality closest to the crater rim. The density of plants decreased down the slope away from the rim.

LIFE HISTORY

According to field and green house observations by Sakai and Weller (unpublished data), flowering of Schiedea adamantis occurs during the winter and appears to be induced by local rainfall. A plant may flower over several days and sometimes weeks, although a given flower is receptive for only 2-3 days. If rainfall is abundant, the flowering season for the population as a whole may extend over several months.

No native pollinators have been observed visiting the small yellow-green flowers (Weller et al. 1990). The most common visitor to Schiedea adamantis was Simosyrphus grandicornis (Macquart), an introduced syrphid fly. Occasional visits by Allograpta exotica (Wiedemann), another introduced syrphid species, were also noted. Flies were equally likely to land on females and hermaphrodites and the length of the foraging bouts were similar for the two sexes. Flies may have been feeding on the pollen, but they did not appear to be foraging for nectar. It is unclear whether the flies served as effective pollinators.

Although Lipochaeta lobata (Gaud.) DC. var. lobata (Asteraceae) was also flowering and intermingled with the Schiedea; flies were more likely to land on and remain on Lipochaeta than S. adamantis.

Based on greenhouse studies using controlled crosses, hermaphroditic plants are capable of selfing. Preliminary studies indicate inbreeding depression in Schiedea adamantis, as shown by a reduced number of seeds per capsule for selfed hermaphrodites compared to outcrossed hermaphrodites (Weller and Sakai 1990). Other Schiedea species show strong inbreeding depression at many stages of their life history, including reduced numbers of seeds per capsule, biomass, flowering and survival rates, and poorer performance of progeny resulting from selfing (Sakai et al. 1989). Natural rates of selfing in the field are unknown. Many of the electrophoretic markers often used to detect outcrossing rates are monomorphic in S. adamantis, and cannot be used.

Sex expression in Schiedea (including Schiedea adamantis) is under nuclear control (Weller and Sakai 1991). Interspecific crosses have produced segregation patterns of females, males, and hermaphrodites consistent with nuclear control of male sterility. The nuclear gene controlling expression of the male (or hermaphroditic) sex in Schiedea is dominant; females are homozygous recessives. Other species of Schiedea are gynodioecious, subdioecious, and dioecious, supporting the view that gynodioecy (females and hermaphrodites) in S. adamantis is likely to represent an early stage in the evolution of dioecy.

According to Sakai and Weller (unpublished data), observations of females and hermaphrodites revealed similar numbers of flowers per inflorescence (a mean of 40-70 depending on year) and numbers of inflorescences (a mean of 11-19 depending on year). However, females had more capsules per inflorescence than hermaphrodites, and fewer but larger viable seeds with higher germination rates (Sakai and Weller, unpublished data). As a result, females produced far more seeds per plant on an annual basis than hermaphrodites.

Fruits mature approximately 3 weeks after pollination. The dry capsules open on the plants and seeds are dispersed by wind and gravity. Seeds apparently do not germinate immediately but require a 6-9 month dormancy. Seeds are shed in the early spring, lie dormant during the dry summer, and germinate with the onset of the following rainy season. Surveys of seedling density in December 1988, showed a mean of 7-8 seedlings within a 20 x 20 centimeter area at the base of each large plant surveyed (plants with >10 inflorescences, N=36). These surveys were conducted near the top of the crater rim, where the population density of Schiedea was greatest. Seedling survival was not followed, but mortality was undoubtedly high, especially with drier conditions (Sakai and Weller, unpublished data).

Plants are perennial and can live for several years. Over a two year period (1988-1990), 17 of 211 (8%) marked flowering plants died; most of these were small plants (Sakai and Weller, unpublished data).

HABITAT DESCRIPTION

According to MacDonald et al. (1986), Diamond Head is a palagonite tuff cone of the post-erosional Honolulu Volcanic Series and consists largely of once vitric ash and lapilli altered to palagonite. It also contains occasional blocks of Koolau basalt and fragments of coral limestone from the underlying reef. At the site of Schiedea adamantis, the substrate is "consolidated volcanic ash with shallow pockets of loose soil interspersed along a steep, but stable, slope" (Takeuchi 1980). There are rock outcrops over more than a quarter of the surface, on well-drained slopes. The soil is very shallow with a moderate, persistent litter layer (Takeuchi 1980).

Average annual rainfall is about 600 millimeters (23 inches) per year, with the vast majority of the precipitation occurring between November and March (Giambelluca et al. 1986). Given the steep slope, shallow soil, and short buyt intense storms, there is little retention of moisture in the soil. The desiccating effects of the strong prevailing tradewinds make this site dry throughout the year and, in combination with the summer drought and intense solar radiation, cause exceptional water stress for the plants during the summer season.

The one known locality of *Schiedea adamantis* can be roughly divided into three areas which differ in topography, density and sex ratios, and species composition (Sakai and Weller, unpublished data). The top area includes about 11 meters (36 feet) across the rim of the crater where *Schiedea* first occurs and extends down the outside rim about five meters (16.4 feet). This area is quite rocky and the dominant vegetation is *Schiedea*. The middle area includes the next seven meters (23 feet) down the slope and is characterized by a much higher density of koa haole. The low area covers the next ten meters down the slope and includes the *Schiedea* furthest down the slope, about one third to halfway way down the side of the crater. This area has a low density of *Schiedea* and is very rocky with little soil development.

In 1990, the dominant cover at the site consisted of the alien koa haole, as well as small native shrubs of *Schiedea adamantis*, *Lipochaeta lobata* (Gaud.) DC (Asteraceae), *Sida fallax* Walp. (Malvaceae), and *Eragrostis variabilis* (Gaud.) Steud. (Poaceae, a native grass) (Sakai and Weller, unpublished data). Takeuchi (1980) also reported that *S. adamantis* was found in frequent association with *Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult. (an indigenous or Polynesian-introduced grass), *Sonchus oleraceus* L. and *Emilia sonchifolia* (L.) DC (*E. javanica*) (both alien composites), and *Chamaecrista nictitans* (L.) Moench (*Cassia leschenaultiana*) (an alien legume).

Spatial distribution of *Schiedea adamantis* suggests a negative association with koa haole (*Leucaena leucocephala*) distribution. *Schiedea* occurs at the highest density near the top of the rim, with percent cover of *Schiedea* (25%) and numbers of flowering, juvenile, and seedling *Schiedea* all being much higher in the top area than in the middle area. The top area, relative to the middle, also has more cover of *Eragrostis variabilis* (16% vs 6%), but is characterized by less cover of live *Leucaena* (7% vs. 31%) and fewer dead *Leucaena* ramets. Percent cover of *Sida* (12-13%) and *Lipochaeta* (18-21%) are similar in the two areas. The low area has the lowest density of *Schiedea* but cover of plants was not quantified due to the steepness of the slope.

The increase in numbers of *Schiedea adamantis* seedlings, juveniles, and flowering adults between 1984 and 1990 is coincident with the defoliation and dieback in koa haole caused by the Caribbean psyllid insect (*Heteropsylla cubana*) first observed in Hawai'i in 1984 (Wagner et al. 1990). Several of the plants first flowering in 1989-90 were on the periphery of the population in areas that had been covered with koa haole. As noted above, the number of *Schiedea* plants is highest in the top area where the density of dead koa haole and percent cover of koa haole are much lower, and where the soil is more rocky than the middle area. *Eragrostis variabilis*, an endemic grass that occurs in open and exposed areas, shows patterns similar to *Schiedea*. Although koa haole is a nitrogen-fixer and thus able to grow in poor soils, it may be that *Schiedea* can grow in poorer soil conditions than koa haole. In better soil conditions koa haole may be the better competitor, largely excluding the *Schiedea* as well as the *Eragrostis*. Competition may be especially intense because of the limited number of shallow soil pockets in the area. By March 1990, the koa haole appeared to be increasing in cover again, most likely with an increasing detrimental effect on the *Schiedea* population. In 1980, Derral Herbst also noted the increasing encroachment of exotics into areas of *Schiedea*, and Takeuchi (1980) suggested that this might result in the competitive displacement of *Schiedea*. With the increase in koa haole, this is again a possibility.

Females and hermaphrodites show sex-related differences in spatial distribution within the population. Females are significantly over-represented in the middle area, an area with better soil and moisture conditions than the top or bottom areas, although competition from koa haole probably decreases the overall density of Schiedea relative to the top area. Within the top area, seedling density near flowering female plants is not significantly different than seedling density near hermaphrodites. Because of the high density of flowering Schiedea in the top area, however, seedlings counted around one plant may have come from several maternal sources (Sakai and Weller, unpublished data).

REASON FOR DECLINE AND CURRENT THREATS

Because Schiedea adamantis is known only from one small population, any one of several threats could easily eradicate the species.

(1) Fire. It is presumed that fires did not play a part in maintaining this habitat and that native plants in this area, including Schiedea adamantis, are not adapted to respond after fires. Because of the dense cover of live and dead koa haole, the area is now highly susceptible to fire, especially during the summer when all the accumulated litter and vegetation in the area is dry. Fires are likely to be much more intense and spread more 2rapidly than would have occurred in the native vegetation. The presence of a hiking trail immediately adjacent to the population poses an immediate danger of fires from careless hikers or deliberate vandalism. Given the very strong winds blowing up the outer slope, a fire hazard is posed by homes and businesses surrounding the crater as well as a public lookout with large numbers of visitors at its outer base. Public picnic areas within the crater pose an additional fire hazard. Even a very small brush fire could exterminate the entire population within a few minutes. There are no means to prevent fires such as fire breaks or fire watches in the immediate area, although the FAA towers are in the general area, and there are no means to control fires quickly should they occur.

(2) Alien vegetation. Koa haole dominates the area in and around the Schiedea adamantis site and, as stated above, the presence of koa haole increases the danger of fire. Also noted earlier, there is a negative association between live koa haole and Schiedea. Where koa haole has died back, plants of Schiedea are beginning to grow more vigorously. The interaction of soil conditions and competitive abilities of Schiedea and koa haole are not clear.

(3) Hiking trail. The hiking trail at the top of the crater rim immediately adjacent to the population impacts Schiedea adamantis in several ways. In addition to the danger of fire mentioned above, there has already been serious disturbance of the fragile substrate from hikers in the area. The trail has no doubt restricted expansion of the population on the crater rim to some extent because of compaction of soil and trampling of plants. In addition, damage has occurred within the site from people wandering through the population, causing erosion and compaction, and trampling large plants and especially seedling and juvenile Schiedea.

(4) Lack of native pollinators. Disruption of the native insect fauna may have brought about significant changes in the population structure of Schiedea adamantis. In particular, if native pollinators are now absent, levels of selfing may have increased in the population. Changes in the levels of selfing may have long-term consequences on the genetic diversity within the population.

(5) Climatic changes. Extended drought over a several-year period, whether because of normal variation in weather patterns or because of long-term climatic changes such as global warming, could result in high mortality and extinction of Schiedea adamantis in spite of its being adapted to dry lowland conditions. Seedlings are very vulnerable to desiccation, and adults may also suffer high mortality with a sequence of dry years.

Prolonged winter rainstorms could also have a severe negative effect on population size. Given the steep slopes and human disturbance of soil within the site, erosion could be severe. The rate of turnover of plants in the population is unknown. The 8% mortality of flowering adults noted over a two-year period requires a high recruitment of juveniles to flowering adults to maintain the population.

(6) Thrips. No widescale damage by insects was evident in the natural population through 1989-90 (Weller and Sakai, unpublished data). Under greenhouse conditions, however, thrips present naturally in some *Schiedea globosa* populations are capable of attacking all species of *Schiedea*, including *S. adamantis*. These thrips spread the spotted-wilt virus which causes the leaves to curl and the inflorescences to abort before setting seed, and may cause the death of the plants. Inadvertent introduction of insects through re-introduction of *S. adamantis* from greenhouse cuttings or plants could be disastrous.

(7) Grazing and browsing. There is no obvious damage of *Schiedea adamantis* from browsing or grazing of large herbivores. In coastal *S. globosa* populations, there is evidence of herbivory on inflorescences, possibly due to rats. In 1989-90, there was a large resident population of apparently feral cats within the crater which may have reduced any potential damage to *S. adamantis* by rats. Potential granivores include ground-feeding birds such as doves.

CONSERVATION EFFORTS

(1) Federal actions. The U. S. Fish and Wildlife Service listed *Schiedea adamantis* as an endangered species in February, 1984 (49 FR 6099-6102). The decision was based principally on a status report from 1980 (Takeuchi 1980). Listing did not include

critical habitat because the one known locality was accessible and easily destroyed (49 FR 6099-6102).

(2) State of Hawai'i actions. Schiedea adamantis is also listed as endangered by the State of Hawai'i, and the Diamond Head area is under several land use limitations imposed by the City and County of Honolulu as well as the State of Hawai'i (Takeuchi 1980). At present, there are no botanists on the staff of the Division of State Parks. With the addition of such a position, more aggressive management of the Schiedea site may be possible (Wayne Sousa, Hawaii Division of State Parks, personal communication 1991).

(3) Cultivation. Research has shown that Schiedea adamantis can be grown from seeds or cuttings (Weller and Sakai, unpublished data), although cuttings are difficult to establish. Cuttings root best if they are taken from actively growing stems, dipped in rooting hormone, and placed in a mist bench with heating pads beneath. Roots should form within 4-6 weeks, although rooting may take longer.

Plants are more easily grown from seeds. Seeds should be collected when ripe (dark brown and full shape), before the capsules dehisce and disperse the seeds. The majority of seeds exhibit an innate dormancy of 6-9 months when stored at room temperature. About one-third to one-half of the seeds can be germinated when scattered over a mixture of potting soil, peat, and small perlite with slow-release fertilizer followed by a very light dusting of potting medium over the soil. Pots should be kept evenly moist until germination occurs. Seedlings are extremely susceptible to fungus gnats, which can be controlled using oxymyl. Germination of seeds from females tends to be higher than that of seeds from hermaphrodites. Seeds lose viability rapidly after about 9 months. Waimea Arboretum (O'ahu), the National Tropical Botanical Garden (Hawaiian Plant Conservation Center, Kaua'i), and the University of

California-Irvine have germinated seeds. Seeds can be produced easily through artificial crossing programs under greenhouse conditions. Plants under greenhouse conditions can be grown from seed to flower in about four months. Plants require heavy fertilization, careful attention to watering to avoid both desiccation and overwatering, and aggressive insect pest control.

Micropropagation is an alternative method of cultivation that the Lyon Arboretum has found to be successful with *Schiedea kaalae* and *Silene perlmanii*, both also of the Caryophyllaceae family (C. Lamoureux, University of Hawaii, personal communication 1993). Utilizing this method, it is possible to grow seedlings *in vitro* from either immature or mature seeds and, when the seedlings reach a certain stage, to induce them to clone by changing to an appropriate medium. Thus, genetic diversity can be retained by growing as many seedlines as are available and, at the same time, numerous individuals can be produced quickly by cloning each seedline. Young plants are transferred from flasks or tubes of medium to pots of soil mixture in the certified greenhouse. This method and its associated costs may be investigated for cultivation of *Schiedea adamantis*.

Because of the problems of viruses spread by thrips, any exchange of plants between greenhouses or outplanting into the field should be limited to seed if possible. If absolutely necessary, plants from a certified greenhouse may be outplanted to establish new populations but under no circumstances should they be outplanted to the original population.

Schiedea adamantis does not co-occur with other *Schiedea*, so no hybridization occurs in nature. In the greenhouse, *S. adamantis* can be crossed easily with other *Schiedea* and *Alsinidendron* species (Weller and Sakai 1991).

PART II. RECOVERY

OBJECTIVE

The objective of this recovery plan is to secure and expand the current population of Schiedea adamantis sufficiently first to downlist the species from endangered to threatened status, and then to remove the species from the federal list of threatened and endangered plants. Greater knowledge of the life history and breeding system of Schiedea adamantis is necessary to achieve this objective. Until such information is available, however, several steps can be taken to ensure the continued existence of this species with maintenance of current genetic diversity. Within the current population, protection from fires, removal of koa haole, and maintenance of plants within all of the current habitat, given the spatial segregation of the sexes, is essential. Given the vulnerability of this population, however, additional populations must be established to allow for survival of the species.

The number of populations and population sizes necessary to downlist or remove this species from the federal list should be re-evaluated depending on the data from the analyses recommended in this recovery plan.

Downlisting to Threatened Status

To downlist this species to threatened status, the current population should be increased to at least 500 reproductive plants and two more populations of at least 500 reproductive plants should be established. This would approximately double the size of the existing population making it less susceptible to threats such as trampling, and make the species less vulnerable to extinction due to catastrophic event by establishing additional populations. All populations should be naturally-reproducing as indicated by the presence of varied age classes ranging from seedlings to mature, reproducing adults, and should remain at these numbers for a minimum of ten years.

Delisting

As a preliminary target to delist Schiedea adamantis, at least five populations should be established, each with a minimum 10-year average of at least 500 reproductive plants. Again, the populations should include seedlings, juveniles, and adults with an age distribution allowing for a stationary if not growing population size.

NARRATIVE

1. Manage existing population of Schiedea adamantis.

Given the vulnerability of the natural Schiedea adamantis population, it is important to proceed simultaneously on controlling the threat of fire, invasion by alien plants, and impact of human disturbance, and it is essential that seed banks and specimen plants be maintained.

Field work at the site should only be conducted by persons extremely familiar with the site and with Schiedea adamantis, since juveniles and seedlings are very inconspicuous and adult plants are extremely brittle. Great care should be taken to avoid further degradation of the habitat through erosion and trampling of plants while trying to restore the population.

11. Reduce the risk of catastrophic fire.

Fire poses the greatest threat to quick and complete extinction of Schiedea adamantis. A single small fire that burns for only a few minutes could easily exterminate the species. At present there is no effective way to quickly stop the spread of a fire. There is also little or no awareness of the presence of this endangered species by either the agencies most likely to first spot a fire or the persons from agencies most likely to fight a fire.

111. Improve fire prevention and control.

Steps toward fire prevention and control should be taken in consultation and cooperation with the Honolulu Fire Department. All measures deemed appropriate should then be taken.

1111. Prevent fire from reaching population.

Takeuchi (1980) recommended a firebreak to prevent the spread of fire by strong winds that generally blow up the slope from urban areas at the outer base of Diamond Head Crater to the Schiedea adamantis site. A traditional bulldozed firebreak around the area, while it might prevent the spread of fire, would call attention to the area and may cause problems with erosion. It would also ruin the aesthetic of the area which is important to the surrounding community. An alternative to a traditional fire break might be the use of fire-resistant plants at the base of the crater (Derral Herbst, U. S. Fish and Wildlife, personal communication 1992). Care should be taken to ensure that these plants occur in a dense enough and wide enough band so that a fire cannot jump it, and that these plants are able to survive with the minimal level of care that will be provided in order that they do not turn into more standing dead fuel. These plants also should not be capable of becoming naturalized and spreading on the crater slopes.

1112. Reduce fuel load.

Dead brush from the earlier dieback of koa haole remains in and around the *Schiedea adamantis* population. Careful removal of dead koa haole from the areas surrounding the population would help to prevent severe burns in the area. Such removal is unlikely to cause any negative impact on the population, as long as the area with the *S. adamantis* population is avoided by untrained personnel.

1113. Consider alternative fire control methods.

In an earlier status report, Takeuchi (1980) recommended reactivation of abandoned water tanks on the rim of Diamond Head Crater for fire control. However, because these tanks are located on the seaward rim by the lighthouse on the opposite side of the crater rim from the *Schiedea adamantis* site, they may not be especially appropriate for fires near this site (W. Sousa, personal communication 1991).

These and other nearby sources of water for fire control should be explored and suggestions for immediate fire control should be solicited from the Honolulu Fire Department and State Division of Forestry and Wildlife. For instance, nearby water pipes might be tapped to install an appropriate sprinkler system around the population.

112. Develop a fire response and suppression plan.

A fire response and suppression plan should be developed in conjunction with the Federal Aviation Administration, Hawai'i National Guard, Diamond Head State Park, City and County of Honolulu Fire Department, and State Division of Forestry and Wildlife. The plan should place the sites of the *Schiedea adamantis* population among the priority areas for protection, and should address how to access the population with fire fighting equipment. A map of the location of the population should be provided to these agencies so that the population is not damaged if fires are in the general vicinity and in case of construction or other changes in the surrounding area.

12. Assess the effect of koa haole on Schiedea adamantis, and develop means of control for koa haole.

Although koa haole died back in this area in the mid 1980s due to an introduced psyllid, it appeared to be recovering in 1989. It now appears that the Schiedea adamantis population is decreasing in size because of koa haole at its perimeter. It is necessary to determine whether this observation is correct, and to identify the positive and negative effects of removing koa haole.

If removal of koa haole is necessary, studies are needed to determine the best way to remove koa haole with the least damage to Schiedea adamantis and its habitat. Agencies with experience in dealing with noxious alien plants should be consulted, including the State of Hawai'i Department of Natural Resources, the State of Hawai'i Department of Agriculture, the U. S. Forest Service, and the National Park Service.

121. Determine the effect of koa haole on Schiedea adamantis via experimental studies.

Because the interactions of Schiedea adamantis and koa haole may involve both edaphic and climatic conditions, and because many of the important interactions occur with mature, established koa haole, greenhouse experiments may not yield meaningful results. Small field experiments at the study site may be more appropriate. Until the best way to remove koa haole is determined, removal of koa haole for these test plots should be accomplished by careful cutting.

Several small replicate plots are required because of the small size of microhabitats (i.e., soil pockets) and the elevational segregation of the sexes of Schiedea adamantis as well as of koa haole. If possible given the size of the population, six replicate 1 x 1 meter plots for each of the following four conditions should be chosen:

a.) good soil (soil pocket), with initial high density of S. adamantis, low density of koa haole;

b.) good soil, with initial low density of S. adamantis, high density of koa haole;
c.) poor soil (rocky outcrops), with initial high density of S. adamantis, low density of koa haole;
d.) poor soil, with initial low density of S. adamantis, high density of koa haole.

Three replicate plots for each of these conditions should have koa haole removed, and three replicate plots for each treatment should serve as controls, with no removal of koa haole. Control plots should be paired as closely as possible with the treatment plots for plant density, elevation, and edaphic conditions. This design would result in twelve plots with koa haole removed and twelve control plots.

All plots should be surveyed before removal of koa haole for the density and percent cover of Schiedea adamantis, koa haole, and any other species before treatment. Surveys should be done during the early winter when seedling S. adamantis can be observed.

These plots should be maintained for at least two years and resurveyed annually in the early spring when Schiedea adamantis seedlings are evident. Treatment plots should be cleared of koa haole at that time or more often if sprouting occurs. Methods of removal may be changed based on results from the following section.

Results can be used to determine whether Schiedea adamantis increases with the removal of koa haole, and whether detrimental effects, such as the invasion by alien grasses, occur in the cleared areas. Because of the dry site conditions and because invasion by grasses has not occurred with the natural dieback of koa haole in the past, such a negative effect seems unlikely. Results should be interpreted with care, since there is a great deal of variation in annual rainfall patterns which may not be included in only a two year study.

122. Determine the most effective way to remove koa haole without negatively affecting Schiedea adamantis.

Because of the potential negative effects of the removal of koa haole on Schiedea adamantis (increased erosion, invasion by alien grasses, increased desiccation, etc.), test plots to remove koa haole should be established first outside of the S. adamantis population and, after preliminary results are known, additional plots may be established within the study population for the most promising treatments.

1221. Determine removal techniques outside of the Schiedea adamantis population.

At least three small (2 x 2 meter) replicate plots for each of three treatments to kill koa haole should be established on Diamond Head Crater well away from the Schiedea adamantis population to initially test the effectiveness of the treatments on the koa haole. Removal treatments that should be investigated include: cutting, systemic herbicide (painted, not sprayed), and biological control. Removal of other alien species, including those that may establish themselves following the removal of kao haole, should also be addressed in these plots.

Cutting, one of the simplest ways to remove koa haole, should be done at the beginning of the growing season. Potential negative side effects of cutting are increased erosion and compaction of the soil, and, if this treatment is chosen for use within the Schiedea adamantis sites, increased likelihood of damage to S. adamantis by branches of koa haole that are not removed carefully. In addition, incomplete removal of koa haole may result in greater resprouting and regrowth of the remaining plant parts. If regrowth occurs and if testing of herbicides shows no damage to S. adamantis, koa haole stumps could be painted with an EPA-approved systemic herbicide. Girdling of koa haole stems, followed by removal of dead material may also be effective, although this would necessitate multiple visits to the site with the potential to cause greater erosion and compaction.

EPA-approved herbicides should be applied to koa haole in test plots, not at the Schiedea adamantis site. Application techniques, such as injection, should specifically target the koa haole or other invasive alien species and avoid other native plants. Applications of the herbicide in dosages that might be leached or spilled into the environment should be applied to test plants in the greenhouse or a garden plot of S. adamantis before any application is made at the field site. S. adamantis plants should be monitored throughout their life cycle, with the effects of herbicide at the seed, seedling, juvenile, and adult stages noted.

Further research into the literature is necessary to determine if biological control is possible.

1222. Test removal treatment within the Schiedea adamantis population.

After the effects on koa haole are known from task #1221, additional plots should be established within the Schiedea adamantis population. Three replicate plots (2 x 2 meters) of the most effective treatment should be studied over at least one year to determine if koa haole can be safely and effectively removed without disrupting S. adamantis. Treatments for these plots should continue for two years to try to anticipate more long term effects.

123. Remove remaining koa haole.

The amount and method of removal should be determined by the results of Tasks #121 and 122.

13. Control human activities near Schiedea adamantis.

The hiking trail which passes through the top of the Schiedea adamantis site is not commonly used by tourists or other State Park visitors. It is very difficult to walk around the rim to the S. adamantis site from the more popular seaward rim, and travel up the paved access road near the site is presently controlled by the FAA. The site has been visited only infrequently by a few hikers from around the rim or botanists who have either received permission to use the FAA access road or hiked up the outer edge of the crater. Most local botanists are well aware of the federal listing of the species and fragile nature of the environment. Agencies such as the FAA, National Guard, and State Parks should be encouraged to continue to limit and to monitor hiker access to the population.

The level of current access seems to have prevented major disturbance to the population, although some erosion within the site is evident. While posting signs about the plants or publicizing the presence of endangered plants in the area is believed to increase the chance of vandalism, clear posting of the area as restricted may prevent inadvertent entry. All personnel with access to present and future Schiedea adamantis sites should be aware of the presence and endangered status of the population.

It should be noted that the FAA plans to discontinue use of the facilities on the Diamond Head crater by the year 2000, at which time its structures will be demolished and removed. Care should be taken to ensure that these activities do not affect current or new populations, and that the site continues to be protected.

Any plans to increase trail usage or other increased disturbance in the vicinity of the present and any future Schiedea adamantis sites should not be permitted.

14. Back-up current population with scientifically managed germ plasm reserves, including seed banks and plants in cultivation.

Because there is only one natural population of this species, it is necessary to create a back-up genetic reserve.

Seeds have already been distributed to the National Tropical Botanical Garden (NTBG, Hawaiian Plant Conservation Center, Kaua'i), Waimea Arboretum (O'ahu), and the University of California-Irvine (UCI). Seeds should also be distributed to institutions and individuals located in habitats more similar to the native habitat of Schiedea adamantis.

Initial seed collections should be established from as many genotypes as possible and should be taken separately for each plant (with the sex of the maternal plant noted). Collection should be coordinated with the annual survey (see task #21), but also take place throughout the fruiting season, with care to minimize damage from trampling, erosion, or overcollecting.

Known requirements for seed dormancy, storage, and propagation are described in the Conservation Efforts section of this report. Seed viability at room temperature is extremely low after 9 months. Other methods of storage need to be tested, including refrigeration and cryopreservation. Seeds should be either collected annually in the field or produced each year from controlled crosses of plants in cultivation until adequate seed storage procedures are developed.

Research should include more detailed study of the viability of seeds in storage. If large numbers of mass-collected seeds are available from the field or greenhouse (produced during the normal fruiting season), a study to investigate viability and germination should be conducted. Beginning immediately after harvest, and once a month for the next twelve months, twenty seeds should be examined for viability with tetrazolium blue. In addition, ten small pots with five seeds each should be planted to determine percent germination of seeds of that age since harvest.

Although propagation has been successful, alternative methods of propagation may be investigated (see Conservation Efforts section). However, as long as the established population continues to produce abundant seed, no introduction of greenhouse-grown Schiedea adamantis should be permitted to this population because of the possibility of introducing new pests and diseases into the population. It should be noted that S. adamantis is very susceptible to rotting from overwatering or poorly drained soil.

2. Conduct studies necessary to enhance the population.

Because of the need for immediate action with this population, control of koa haole and other management actions should be taken at the same time as studies of the basic biology of the population.

Earlier studies (Sakai and Weller, unpublished data) suggest that there is considerable spatial variation within the site by sex, size of plants, habitat, etc. Further studies should continue to monitor these plants and their size, reproduction, and survivorship through time. With continued surveys, the effect of more long term climatic changes (e.g. a several year drought, changes in air quality, increasing radiation) should become evident and provide information for appropriate mitigation procedures.

21. Conduct annual survey of the current population.

An annual survey should be conducted when plants are in flower and seedlings are evident. New plants larger than first year seedlings should be mapped, the sex, number of inflorescences, number of ramets, mortality of marked plants, and any damage from diseases, insects, and large herbivores should be noted.

211. Map and record location and microhabitat of Schiedea adamantis and its competitors.

The population should be mapped and the demography of the population should be followed for at least five years to gather sufficient data to determine changes in population size and project viable population sizes. Using previous information on marked plants in this population if possible (Sakai and Weller, unpublished data), individual Schiedea adamantis should be mapped to the nearest ten centimeters (four inches). For each plant, the microhabitat (soil, bare rock, or other appropriate categories), the species within a ten centimeter (four inch) radius of the plant, the sex of the plant (female or hermaphrodite), and the size of the plant (number of ramets) should be recorded. The presence or absence of S. adamantis seedlings within a ten centimeter (four inch) radius should also be noted.

Because the soil is so thin and the plants are so brittle, great care should be taken to gather as much information as possible with as little movement as possible through the population. Initial mapping should be conducted during the first annual survey, and mapping of new individuals should occur during subsequent surveys.

212. Monitor for damage by diseases, insects, other herbivores, humans and alien plant species.

In 1989, there did not appear to be any major diseases or herbivores affecting the population (Sakai and Weller, unpublished data). If traffic to the area increases with implementation of recovery plans, there is a greater likelihood of introduction of diseases, herbivores, and alien species into the habitat.

2121. Determine damage to Schiedea adamantis.

During the annual survey, each plant should be inspected for damaged leaves or newly missing inflorescences or branches. Samples of damaged leaves or stems should be collected from marked plants to determine the cause of damage.

Also during this survey, a species list for the area should be made. Any small new alien plants should be weeded out immediately before they become well established. The locality of the new aliens should be noted in case additional work to weed out successive cohorts of seedlings is necessary.

As long as the natural population continues to produce abundant seed, no introduction of greenhouse-grown Schiedea should be permitted, because of the possibility of introducing new pests and diseases into the population.

2122. Control damage, if necessary.

If leaf damage is identified, action should be taken to stop the damage as soon as possible. Any fungicides or insecticides to be used should be EPA-approved, and first tested on potted plants in the greenhouse with similar dosages to those used in the field on plants at similar stages of growth.

Rodents may chew off inflorescences of other species of Schiedea (Stephen Weller, Department of Ecology and Evolutionary Biology, University of California-Irvine, personal communication, 1992). If this occurs in the natural population, rat bait or continued tolerance of the cat population in the crater may be the simplest solution, although should be considered with caution.

213. Collect seed of Schiedea adamantis.

Mature seeds should be collected as available during the survey and identified by capsule by maternal plant for use in outcrossing rates, measures of genetic variance, *ex situ* propagation, and for new populations. Because seeds mature at different times both within and among plants, such a method of seed collection should not significantly affect the seed production of the population.

22. Study breeding systems of the population.

Knowledge of the breeding system of this gynodioecious species is critical to understand since the breeding system may limit the successful establishment of new populations and continued existence of the present population.

221. Determine pollinators.

The native insect fauna of Hawaii has been severely disrupted (Howarth 1990) and the native pollinators of *Schiedea adamantis* may now be extinct or absent in their locality. Non-native insects may now be pollinating *S. adamantis*, and patterns of gene flow may have changed extensively with this change in pollinators. In order to establish successful new populations, pollinator relationships need to be understood.

Observations should be made throughout the day and night to determine the insect visitors, if any, and whether they are effective pollinators. Specimens of potential pollinators should be identified and examined for Schiedea adamantis pollen.

Pollinator flight distances should be recorded if possible.

Plants should be caged to determine if they can set seed without insect pollination (either because of wind or self-fertilization in the case of hermaphrodites).

222. Investigate seed production of females and hermaphrodites.

Seeds collected during the annual survey can be used to compare female and hermaphroditic plants in seeds per capsule. Combined with previous data (Sakai and Weller, unpublished data), these data can be used to estimate total average genetic contributions of female and hermaphroditic plants in the population.

223. Determine genetic variability within the population, outcrossing rates, and population substructure.

Identification of genetic variability and estimation of outcrossing rates within the population need to be determined.

Preliminary data (Sakai and Weller, unpublished data), based on starch gel electrophoretic results, indicate that genetic variability within the population is low and that the population probably experienced a tight genetic bottleneck. Additional data are needed to quantify the variability. Outcrossing rates for hermaphrodites and females also need to be determined. Preliminary results (Sakai and Weller, unpublished data) indicate that there may be substantial variation in outcrossing rates among individuals. A study of inbreeding depression in this group (Sakai, Weller, and Chen, unpublished data), in combination with the outcrossing rates, should reveal the importance of selfing within the population.

Various molecular techniques are presently being developed which may be more sensitive than starch gel electrophoresis. Alternative techniques should be evaluated and genetic research continued with the most appropriate technique.

23. Investigate germination and establishment techniques for restoration.

Data from both the field and the greenhouse should be used to investigate germination and establishment of Schiedea adamantis. Information on the microhabitat of seedlings from the field surveys should be used to guide the choice of initial greenhouse conditions.

Greenhouse experiments should be conducted to determine the range of tolerance of growing conditions of Schiedea adamantis using soil found in likely spots for establishing new populations as well as various soils found within the present site. Because female and hermaphroditic plants appear to be spatially segregated in the field, experiments should start with seeds from controlled crosses with known expected ratios of females and hermaphrodites to determine whether there are sex-related differential effects of germination, survival, etc. Plants should be raised until flowering.

Methods for the highest success rate in transplanting older female and hermaphroditic plants should be investigated. If possible, an experimental design, controlling for edaphic conditions as well as the effects of koa haole (whether from competition or because of nitrogen fixation) should also be set up.

3. Expand current population and establish new populations of Schiedea adamantis.

This species remains vulnerable as long as it is represented by one population. Additional populations must be established to consider downlisting. If by the time this is undertaken the original population is not expanding, efforts should be made to expand this population.

31. Expand current population of Schiedea adamantis.

Because the nearly four-fold increase in population size of Schiedea adamantis between 1978 and 1990 is attributed to a die-back of koa haole, it is hoped that controlling this alien shrub will allow even greater increase in numbers of the sole current population. If, however, this population is not expanding at a sufficient rate after the current threats are controlled, efforts should be made to expand the population via seed during the beginning of the subsequent rainy season.

32. Establish minimum of two new populations.

A single population, no matter how vigorous, remains vulnerable to extinction from a catastrophic event. Therefore, new sites must be established.

321. Identify sites.

The extensive urbanization around Diamond Head makes it difficult to know the former range of this species. Potential new sites should be chosen, keeping in mind edaphic and climatic requirements of *Schiedea adamantis* as well as the ability to protect the new site from development or other disturbances. It may be possible to establish *S. adamantis* at additional sites on Diamond Head Crater, although new sites should be far enough away from the existing population and eachother so that an impact on one population is unlikely affect another. Clearly, differences in volcanic composition and soil development, as well as exposure to salt spray, solar radiation, and variation in rainfall patterns around the rim need to be taken into consideration.

Carolyn Corn (personal communication 1991) suggested that a rocky ridge in Kaimuki near the freeway may also provide suitable habitat. Other sites with suitable edaphic and climatic conditions need to be explored.

322. Secure sites identified in task #321.

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

323. Control threats to new sites.

Threats to each population should be identified and controlled. Control measures may include, but are not limited to: fencing of new populations to exclude herbivores and prevent trampling by humans; control of alien plant competitors, particularly koa haole, utilizing the techniques established in task #12; construction of fire breaks (whether created by bulldozing or planting of fire resistant plants); and reduction of fuel load for brush fires. Fire emergency plans should be developed for each site.

324. Establish new populations.

Protocol used for establishment of new populations will depend upon the site. Out-planting of adults taken from the current population and seeds collected during the annual survey or from greenhouse plants may have greatest success if planted at the beginning of the rainy season. If absolutely necessary, plants from a certified greenhouse may be outplanted to establish new populations (but under no circumstances should they be outplanted to the original population because of potential spread of disease or insects). Supplemental watering will most likely need to be provided initially. A range of genotypes, with both females and hermaphrodites, should be used to start the population. New populations should be maintained until they are able to survive without human intervention.

33. Monitor all populations.

Annual monitoring of all populations (and more frequent initial monitoring of new populations) for general health of plants, identification of potential threats to the plants, inspection of fencing etc. should start with establishment and continue until downlisting is warranted.

4. Validate Recovery Objectives.

Data on population sex ratios, locations of individuals and spatial segregation of the sexes, mortality, and plant sizes collected by Sakai and Weller (unpublished data) and in subsequent annual surveys should be combined with data on genetic variability and genetic substructure of the population to validate the recovery objectives of this plan.

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

It is necessary to know whether the projected five populations are adequate to safeguard against catastrophic events over the next 200 years.

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

It is necessary to determine the number of individuals needed to ensure the long-term survival of each population.

43. <u>Revise recovery objectives.</u>

Recovery objectives should be revised if new information suggests that the current objectives are inadequate.

LITERATURE CITED

Giambelluca, T. W., M. A. Nullet, and T. A. Schroeder. 1986. Rainfall atlas of Hawai'i. Report R76. State of Hawaii. Department of Land and Natural Resources. Division of Water and Land Development. Honolulu, Hawaii.

Howarth, F. G. 1990. Hawaiian terrestrial arthropods: an overview. Bishop Museum Occasional Papers 30: 4-6.

Macdonald, G. A., A. T. Abbott, and F. L. Peterson. 1986. Volcanoes in the sea; The geology of Hawaii. Second edition. University of Hawaii Press, Honolulu.

St. John, H. 1970. The 'staminodia' of the genus Schiedea (Caryophyllaceae) and three new Hawaiian species. Pacific Science 4: 45-54.

Sakai, A. K., K. Karoly, and S. G. Weller. 1989. Inbreeding depression in Schiedea globosa and S. salicaria (Caryophyllaceae), subdioecious and gynodioecious Hawaiian species. American Journal of Botany 76: 437-444.

Takeuchi, W. 1980. Status report on Schiedea adamantis (Caryophyllaceae). 5 August 1980. For U.S. Fish and Wildlife Service.

Wagner, W. L., D. R. Herbst, and S. H. Sohmer. 1990. Manual of the flowering plants of Hawai'i. University of Hawaii Press and Bishop Museum (Special Publication 83), Honolulu.

Weller, S. G. and A. K. Sakai. 1990. Evolution of dioecy in the endemic Hawaiian Caryophyllaceae. Plant Species Biology 5: 83-95.

Weller, S. G. and A. K. Sakai. 1991. The genetic basis of male sterility in Schiedea (Caryophyllaceae), an endemic Hawaiian genus. Heredity 67: 65-73.

Weller, S. G., A. K. Sakai, W. L. Wagner, and D. R. Herbst. 1990. Evolution of dioecy in Schiedea (Caryophyllaceae: Alsinoideae) in the Hawaiian Islands: Biogeographical and ecological factors. Systematic Botany 15: 66-76.

PART III. IMPLEMENTATION SCHEDULE

The Implementation Schedule that follows outlines actions and estimated cost for the recovery program for *Schiedea adamantis*, 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, 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 population, and increase the population size and numbers. 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

DHSP	-	Diamond Head State Park
DLNR	-	Hawai'i Department of Land and Natural Resources
ES	-	Fish and Wildlife Service, Ecological Services, Honolulu
FAA	-	Federal Aviation Administration
HFD	-	Honolulu Fire Department
RES	-	Fish and Wildlife Service, Research Division

Key to Other Codes Used in Implementation Schedule

C	-	Continuous
O	-	Ongoing (already begun as of writing of plan)

Recovery Plan Implementation Schedule for Schiedea adamantis

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000s) FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
Need 1 (Manage existing population)										
1	1111	Prevent fire from reaching population.	5	DLNR*	24	10	5	5	2	2
				ES	11	5	2	2	1	1
1	1112	Reduce fuel load.	6	DLNR*	16	5	5	2	2	2
				ES	7	2	2	1	1	1
1	1113	Consider alternative fire control methods.	1	DLNR*	0.5	0.5				
				ES	0.5	0.5				
				HFD	0.5	0.5				
1	112	Develop fire response plan.	1	DLNR*	1	1				
				ES	0					
				HFD	0					
				FAA	0					
				DHSP	0					
1	121	Determine effect of koa haole on Schiedea.	3	DLNR	3	1	1	1		
				ES	6	2	2	2		
				RES*	15	5	5	5		
1	1221	Determine removal techniques outside of population.	3	DLNR	3	1	1	1		
				ES	6	2	2	2		
				RES*	15	5	5	5		
1	1222	Test removal techniques within population.	3	DLNR	3			1	1	1
				ES	6			2	2	2
				RES*	15			5	5	5
1	123	Remove living koa haole.	10	DLNR*	2					2
				ES	1					1
1	13	Control human activities near Schiedea.	C	DHSP*	0					
				DLNR	0					
1	14	Back-up current population.	3	DLNR*	9	3	3	3		
				ES	15	5	5	5		
		Need 1 (Manage existing population)			159.5	48.5	38	42	14	17

Recovery Plan Implementation Schedule for Schiedea adamantis

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURA-TION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000s) FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
Need 2 (Conduct studies to enhance population)										
2	211	Map and record location, habitat and competitors.	5	DLNR*	4		1	1	1	1
				ES	14		5	3	3	3
2	2121	Determine damage.	5	DLNR*	4		1	1	1	1
				ES	4		1	1	1	1
2	2122	Control damage if necessary.	3	DLNR*	12		4	4	4	
				ES	3		1	1	1	
2	213	Collect Schiedea seed.	5	DLNR*	4		1	1	1	1
				ES	4		1	1	1	1
2	221	Determine pollinators.	2	DLNR	2		1	1		
				ES	4		2	2		
				RES*	10		5	5		
2	222	Investigate seed production of females and hermaphrodites.	2	DLNR	2		1	1		
				ES	2		1	1		
				RES*	2		1	1		
2	223	Determine genetic variability of Schiedea population.	2	DLNR	2			1	1	
				ES*	15			10	5	
2	23	Investigate germination and establishment techniques.	3	DLNR	9		3	3	3	
				ES	3		1	1	1	
				RES*	18		6	6	6	
		Need 2 (Conduct studies to enhance population)			118	0	36	45	29	8
Need 3 (Establish new populations)										
2	31	Expand current population.	2	DLNR*	10				5	5
				ES	4				2	2
2	321	Identify sites for new populations.	1	DLNR*	1					1
				ES	0.5					0.5

Recovery Plan Implementation Schedule for Schiedea adamantis

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION (YRS)	RESPONSIBLE PARTY	TOTAL COST	COST ESTIMATES ($1,000s) FY 1994	FY 1995	FY 1996	FY 1997	FY 1998
2	322	Secure sites.	2	DLNR	0.25					0.25
				ES*	1					1
2	323	Control threats to new populations.	10	DLNR	0					
				ES*	0					
2	324	Establish new populations.	4	DLNR*	0					
				ES	0					
2	33	Monitor new populations.	C	DLNR*	0					
				ES	0					
		Need 3 (Establish new populations)			16.75	0	0	0	7	9.75
Need 4 (Validate recovery objectives)										
3	41	Determine number of populations needed.	2	DLNR*	0					
				ES	0					
3	42	Determine number of individuals needed.	2	DLNR*	0					
				ES	0					
3	43	Revise recovery objectives.	1	ES	0					
		Need 4 (Validate recovery objectives)			0	0	0	0	0	0
	TOTAL COST				294.25	48.5	74	87	50	34.75

IV. APPENDIX A - Reviewers of Draft Recovery Plan

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