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THE PLANT GENUS *HIBISCADELPHUS* IN HAWAI'I

A History, Analysis of Problems, and a Management Plan for Trees in Hawaii Volcanoes National Park

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ABSTRACT

The history of the genus *Hibiscadelphus* is presented illustrating the problem of planting *H. hualalaiensis* close to *H. giffardianus* in Kīpuka Puaulu. Although *H. giffardianus* is extinct in the wild, it is still cultivated in the type locality. In order to preserve what remains of the gene pool of this very rare species, four management actions are proposed: Removal of the second generation hybrids; propagation and removal of the F_1 hybrids; propagation and removal of all *H. hualalaiensis* trees; and propagation and cultivation of *H. giffardianus*.

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A HISTORY

The endemic Hawaiian plant genus Hibiscadelphus (Family Malvaceae) was named in 1911 by Joseph F. Rock to recognize three tree species discovered by him which were related to the genus Hibiscus. Rock (1911, 1913) noted that flowers of the new species resembled Hibiscus blossoms except that they were tubular in shape and curved at maturity. In addition, Rock noted that calyxes of the new species appeared to be deciduous (shedding; absent on seed pods), and that the seed pods were woody capsules, unlike Hibiscus.

Based on these morphological differences, Rock (1911) established the genus name Hibiscadelphus, meaning "brother of Hibiscus," for the three species. Collectively, the species were given the Hawaiian vernacular name "hau kuahiwi" meaning "upland or mountain hau" because of the resemblance of Hibiscadelphus trees to the common lowland hau, Hibiscus tiliaceus L.

The type species (first named species of a new genus) is Hibiscadelphus giffardianus Rock, named in honor of Rock's friend W. M. Giffard who has introduced many varieties of Hibiscus into Hawai'i. Giffard's home in Volcano, adjacent to Hawaii Volcanoes National Park, was to play an important role in later years in saving the species from extinction (Degener 1932; Bryan 1938; Fagerlund 1944).

Rock and Giffard collected type specimens of H. giffardianus from the only tree in existence at that time. The tree was located in Kīpuka Puaulu (Bird Park), now a part of Hawaii Volcanoes National Park. Rock discovered the lone tree in 1910. It later died in 1930 but not before seeds were planted in Giffard's garden at Volcano to save the species. The subsequent history of the species, which was reduced to a single tree on two additional occasions, is given by Degener (1932), Bryan (1938), Fagerlund (1944), and summarized by Baker and Allen (1977). Today, 11 mature trees of H. giffardianus are known to exist, seven of which are in Kīpuka Puaulu.

The second species discovered by Rock (also represented by a single tree) was H. wilderianus, found on the southern slopes of Haleakalā, Maui. Rock (1911) named the species in honor of another friend, G. P. Wilder, who like Giffard had also grown and developed varieties of Hibiscus. The species is now believed to be extinct, although Bishop and Herbst (1973) suggest that H. wilderianus may have been a variant of H. giffardianus, in which case only the variant is extinct.

The third of Rock's new species was H. hualalaiensis, first seen in 1909 on the slopes of Mt. Hualālai in the forest of Waihou (presently the Pu'uwa'awa'a Ranch) in North Kona, Hawai'i (Rock 1911). The species was known from only about a "dozen"

wild trees, which number has been reduced now to two because of the pressures from cattle grazing and loss of habitat, and depredations by rats. However, a number of trees of this species grows under cultivation in arboreta and in Kīpuka Puaulu where 12 seedlings were planted in the early 1950's. Ten or 11 now survive as mature trees but they have caused problems by hybridizing with H. giffardianus (Baker & Allen 1976a, 1976b, 1977; Carr & Baker 1977).

Prior to the time of Rock's collections in the early 1900's another species of Hibiscadelphus had been discovered unknowingly by William Hillebrand. It was collected from the arid slopes above Kawaihae, Hawai'i, sometime between 1851 and 1871. Hillebrand also recognized the similarity of his specimens to Hibiscus and labeled his specimens "Hibiscus section bombycinus." However, Hillebrand never published his name and the specimens eventually wound up in the herbarium of the Bernice P. Bishop Museum, Honolulu. There, Charles N. Forbes (1920) recognized the specimens for what they were and he described the Kawaihae species as Hibiscadelphus bombycinus. Forbes separated the new species from its closely allied congener H. hualalaiensis on the basis of having strap-shaped (broader) involucral bracts and smaller leaves.

No other collections of H. bombycinus have ever been made, and because of the destruction of much of the native vegetation in the region around Kawaihae by cattle grazing and wildfire the species may be extinct.

No new species of Hibiscadelphus were discovered until Bishop and Herbst (1973) found a new taxon growing in the lower reaches of Waimea Canyon, Kaua'i, in 1972. They named it H. distans because of the geographic isolation from the other species on Maui and Hawai'i, and because the fruit morphology stands apart from all other known Hibiscadelphus. Hibiscadelphus distans is known from only six wild trees although others are growing under cultivation in arboreta.

In 1973, Baker and Allen discovered a hybrid Hibiscadelphus in Hawaii Volcanoes National Park while analyzing rat damage to flowers and noting differences in flower morphology on various trees. The hybrids between H. giffardianus and H. hualalaiensis were named H. x puakuahiwi Baker and Allen (Baker & Allen 1976a). A history of the hybrid origin brought about by planting geographically isolated (allopatric) species in close proximity to one another is given by Baker and Allen (1977). There are 40 hybrid trees (Appendix I) growing in Hawaii Volcanoes National Park and about an equal number in gardens and arboreta throughout the world.

In summary, two taxa--H. wilderianus and H. bombycinus--are believed to be extinct. Hibiscadelphus hualalaiensis is known from only two wild trees and H. distans is known from six. Several of both species, however, grow under cultivation. Hibiscadelphus giffardianus is extinct in the wild but 11 trees grow under cultivation, seven of which are in Kīpuka Puaulu. The

hybrid species, H. x puakuahiwi, had its origin in Kīpuka Puaulu but is grown elsewhere in gardens and arboreta. There are about 80 hybrid trees of which half are growing in Hawaii Volcanoes National Park.

The genus Hibiscadelphus, therefore, is a complex of extremely rare and already extinct species. It is considered one of the world's rarest groups of trees. The very rare type species, H. giffardianus, is endemic to Hawaii Volcanoes National Park. The other taxa planted in the Park present natural resource management personnel with a complexity of management problems and decisions.

ANALYSIS OF PROBLEMS

PROBLEM 1--The National Park Service, alone, is responsible for the care and perpetuation of the extremely rare H. giffardianus in its native habitat. Hibiscadelphus giffardianus is a species that has been on the brink of extinction three times already, and it is, perhaps, that fact alone which makes it unique among all rare species. The historical range of H. giffardianus is restricted to a small area of forest comprising only about 83 ha (200 acres). Because of this restricted historical range and local adaptation, the species should not be grown in any other habitat within the Park.

Yet, the confinement of H. giffardianus to a single kīpuka is like the proverbial "eggs in one basket." Herein arises a question of concern. Should the National Park Service maintain all the trees in a single area, considering the consequences of wildfire or other natural disasters through the entire kīpuka, with a possible loss of seven of the world's 11 trees, or should trees be propagated in other areas of the Park?

Alternative 1.--Do nothing. To do nothing leaves the seven trees to the whims of chance and natural catastrophe. Because of a known poor history of natural reproduction the trees are quite likely to eventually die out.

Alternative 2.--Maintain the existing trees in their same few numbers but replace them one by one with greenhouse propagated specimens as the older trees die. Since the species was first known from only a single tree, and because rarity and confinement to small isolated areas is not uncommon in the Hawaiian flora, this strategy would represent an attempt to increase the likelihood of survival without extending the range or increasing the present number of trees.

Alternative 3.--Propagate a number of additional trees in Kīpuka Puaulu to help ensure species survival in the event that one or more of the existing trees is lost due to a natural catastrophe such as fire, windstorm, or disease. The number might be increased two to several times the present number of seven.

Alternative 4.--Propagate additional trees in other similar habitats such as in Kīpuka Kī. This strategy would be legitimate, perhaps, since Kīpuka Kī was probably once part of the same forest contiguous with Kīpuka Puaulu prior to the time the Mauna Loa lava flows bisected the forest. This alternative would double the chances for survival of the trees if a wildfire burned through only one or the other of the two kīpukas.

PROBLEM 2--In the early 1950's, 12 seedlings of the allopatric H. hualalaiensis were transplanted into Kīpuka Puaulu as one effort to save the species from extinction by cattle depredations on the Pu'uwa'awa'a Ranch. Ten or 11 of the original 12 trees still survive. The eleventh tree may be a natural seedling which has reached maturity, and the twelfth appears to be a first generation (F_1) hybrid with H. giffardianus rather than one of the original 12. Nevertheless, the presence of any of this species in close proximity to H. giffardianus perpetuates a continuing hybridization problem.

Alternative 1.--Do nothing. To do nothing would allow the trees to continue to hybridize. The end result would be a hybrid swarm and the extinction of H. giffardianus as the parent trees die.

Alternative 2.--Leave the H. hualalaiensis in place but bag and hand pollinate flowers of H. giffardianus to get pure seed, or make cuttings, in order to propagate the endemic species.

Alternative 3.--Remove the H. hualalaiensis. This approach, however, could present the following problem.

PROBLEM 2A--The H. hualalaiensis trees in Kīpuka Puaulu represent about half the world's population of mature trees. If the Kīpuka Puaulu trees are removed--even with the most precautionary care to save them--they could fail. Can the National Park Service risk losing half the world's known population of this species?

Alternative 1.--Do nothing. To do nothing would risk losing the trees--if not propagated--since natural reproduction is low and the trees probably will die anyway.

Alternative 2.--If a decision is made not to save them, then cut the trees down and poison the stumps and roots to prevent suckers resprouting. This approach immediately eliminates the hybridization problem, assuming the hybrid trees would also be destroyed or removed.

Alternative 3.--Prune the trees heavily, ball the roots with burlap, and transplant to other areas of suitable habitat outside the Park apart from any other Hibiscadelphus trees. A consideration would be to wait until enough seedlings of this species are established elsewhere before attempts are made to move the trees from Kīpuka Puaulu. The more trees of this species that grow

elsewhere the less critical it becomes if the Park trees die as a consequence of their removal.

PROBLEM 3--There are 40 hybrid H. x puakuahiwi trees within Hawaii Volcanoes National Park. Sixteen are growing in Kīpuka Puaulu; 19 are growing in Kīpuka Kī; and 5 are growing at the 'Āinahou Ranch house. Since hybridization of the trees was the result of planting the allopatric H. hualalaiensis in Kīpuka Puaulu, they have no natural place in a native park ecosystem.

Alternative 1.--Do nothing. To do nothing will result in a flourish of second (F_2) and third (F_3) generation trees with backcrossing with the parent species and an eventual swamping of the original parental genotypes. The swamping is a consequence of the hybrid vigor already demonstrated by the comparatively large number of hybrid plants compared with the parental plants.

Alternative 2.--Remove the hybrids from Kīpuka Puaulu so that they cannot backcross with the parent H. giffardianus. This strategy still would leave hybrids in Kīpuka Kī and at the 'Āinahou Ranch house where there are no trees of the parent species.

Alternative 3.--Remove all hybrid trees from both kīpukas and the 'Āinahou Ranch house.

Alternative 4.--Remove the five hybrid trees from the 'Āinahou Ranch house since the 'Āinahou area is not a habitat for Hibiscadelphus, but leave the hybrid trees in the two kīpukas. Cut the kīpuka trees to stump level and graft with scions of H. giffardianus (Leonhardt 1978). Hybrid and parent trees are probably graft compatible and it might be possible to grow parent species on hybrid stumps. A potential problem would be hybrid sucker growth from the bases of the trunks.

PROBLEM 3A--Of the 40 hybrids growing in Hawaii Volcanoes National Park there are only two known F_1 hybrid trees--both growing in Kīpuka Kī--although a tree growing in Kīpuka Puaulu is suspected of being an F_1 hybrid also. The two (or three) F_1 trees are in themselves some of the world's rarest trees. Of the two known F hybrid trees growing in Kīpuka Kī, one labeled KK-HX-1 is the designated type tree for the hybrid from which the holotype (the originally describd herbarium specimen) was collected and on which the hybrid description was based. A question, therefore, arises--can the National Park Service morally or legally destroy a type tree? Dr. Harold St. John (pers. comm.) thinks not.

Alternative 1.--Do nothing. Leave both F_1 trees. To do nothing would perpetuate the hybrid problem.

Alternative 2.--Leave the two F_1 trees but keep all F_2 generation growth cropped out from beneath the trees. It is probable that the F_1 trees in Kīpuka Kī are too far removed from

parent trees in Kīpuka Puaulu to present a problem of backcrossing.

Alternative 3.--Cut down the one non-type F_1 tree, and all existing F_2 and F_3 trees in Kīpuka Kī. Leave only the one type tree, and remove all new hybrid seedlings.

Alternative 4.--With all precautionary care, prune the type tree, wrap the roots with burlap, and transplant the tree to an arboretum. Or, make cuttings of the F_1 type, transplant the cuttings to several arboreta, and be sure all are well-established before the type tree is cut down or an attempt is made to transplant the type tree and in case the transplant fails. At least the cuttings would preserve the genotype. (Growing seeds of the F_1 tree to propagate others will not work because the parents are not true breeding species. Seedlings will be F_2 trees which are genetically quite different trees).

PROBLEM 4.--There are a number of adverse, alien influences which hinder natural reproduction of the endemic H. giffardianus. Rats eat bark, buds, flowers, nectar, and seed pods. It is believed that house mice, and rats, eat seed upon the ground. It is also believed that seedlings cannot germinate through substrate growths of dense, non-native grasses.

Alternative 1.--Do nothing. Let the trees "tough-it-out" as best as they can. To do nothing would probably mean the eventual loss of all H. giffardianus.

Alternative 2.--Hand propagate all future reproduction of H. giffardianus. The rationale is that man caused the reproductive problems by introducing rodents and grasses, and therefore man should now help to cultivate and propagate the species.

Alternative 3.--Continue the Park's present efforts to propagate and cultivate the species but also aid in natural reproduction by systematically poisoning and trapping rodents from around the trees, and by keeping non-native grasses cleared away.

A MANAGEMENT PLAN

Based on the above discussions of the problems of Hibiscadelphus trees in Hawaii Volcanoes National Park, and in consideration of the alternative actions, the following Management Plan has been designed to perpetuate the rare, endemic H. giffardianus.

1. Removal of the second generation hybrids

Remove all of the second generation (F_2) hybrid trees. Either cut down and poison the stumps to prevent sucker growth, or consider the option of permitting private citizens who are

concerned about destroying rare trees (although they are hybrid in origin) to transplant the trees into private gardens or arboreta.

2. Propagation and removal of first generation hybrids

A. Prune the non-type F_1 tree labeled KK-HX-2 down to the trunks and stumps of its major limbs. Ball the roots and wrap in burlap, then transplant the tree to a suitable garden or arboretum.

B. Make a number of air-layerings (cuttings) of the type F_1 tree labeled KK-HX-1. Ball the roots and wrap in burlap, then transplant the cuttings to suitable gardens, arboreta, or nature reserves.

C. After a number of the type F_1 transplants are well-established, prune KK-HX-1. Ball the roots and wrap in burlap, then transplant to a suitable arboretum where this type tree can be protected. Be sure that the F_1 transplants are well-established from cuttings before the type F_1 tree is removed in the event of a failure in transplanting the latter.

> Management actions 1 and 2 remove all hybrids from the Park. Action 2 makes every effort to ensure that the type F_1 tree, or a cutting from it, preserves the genotype.

3. Propagation and removal of H. hualalaiensis trees

A. Bag buds and hand pollinate flowers on the first and second days following opening in order to get pure seeds. Cross-pollinate with pollen from various trees to help retain the genetic variability of the species.

B. Also, make cuttings from each of the H. hualalaiensis trees as an additional method of ensuring reproduction and retention of genetic variability from the trees. When seedlings and cuttings are well-established transplant them to selected arboreta, gardens, and nature reserves, keeping in mind the preferred dryland habitat of the species.

C. When a number of saplings of young trees are well-established elsewhere prune all of the H. hualalaiensis trees in Kipuka Puaulu down to lower trunks and stumps of the major limbs. Ball the roots and wrap in burlap, then transplant the trees to selected arboreta, gardens, and nature reserves.

> Management Action 3 removes all of the H. hualalaiensis from the Park but insures that a number of young trees are well-established prior to removing the old adult trees.

4. Propagation and cultivation of H. giffardianus

A. Continue Park efforts to propagate H. giffardianus from pure seed by bagging and hand pollinating flowers, and by air-layering. Continue to hand pollinate so long as any hybrid or H. hualalaiensis trees remain in Kīpuka Puaulu. Cross-pollinate with pollen from various trees to help maintain genetic variability.

B. Plant well-established saplings back into Kīpuka Puaulu away from trails. Trees near trails get broken down by collectors of herbarium specimens and vegetative material for propagation.

C. In consideration of the probability that Kīpuka Kī was once an area of forest contiguous with Kīpuka Puaulu, and that H. giffardianus was extant in both areas, plant a number of saplings in both the upper and lower portions of Kīpuka Kī but out of sight of the road.

D. Place rat traps in a one-hectare grid of five rows of five traps each (25 traps) spaced 16 m apart and centered around a tree or group of trees. Bait with peanut butter. Run the traps initially for a period of at least two weeks or until no additional rats are caught to clear the area. At least eight to 10 rats should be expected to be caught. Retrap the same grids at least five days consecutively about every two months to get rid of reinvading rats. Put out warfarin stations to help control rats which may be trap shy and for control of house mice. One station per grid, centered at the base of a tree or trees should be sufficient.

E. Keep grass cleared from beneath mature trees. As a first step, use the herbicide Round-up which is highly selective for grasses, then physically remove reinvading grass as it appears. Continued use of Round-up may kill out germinating or sprouting Hibiscadelphus seeds; when physically removing grass watch for seedlings.

> Management Action 4 ensures perpetuation of the rare, endemic, H. giffardianus by propagation, cultivation, and control of factors limiting to natural reproduction.

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APPENDIX I

Locations of *Hibiscadelphus giffardianus* in Hawai'i

Island of Hawai'i

Seven trees are located in Kīpuka Puaulu in Hawaii Volcanoes National Park.

Maui

Three trees are located in the Pu'umāhoe (Fleming or Vodtrock) Arboretum.

O'ahu

One tree is located in the Wahiawā Arboretum.

The latter two islands are sources of seeds or cuttings in the event of a loss of the seven trees in Hawaii Volcanoes National Park.

Locations of *Hibiscadelphus* species in Hawaii Volcanoes National Park

All of the *H. giffardianus* trees growing in the Park are located in Kīpuka Puaulu (trees growing outside the Park are listed above). Each tree is tagged with an aluminum label with the designation KP (for Kīpuka Puaulu) followed by HG (for *H. giffardianus*) followed by the individual tree number, such as KP-HG-1 through KP-HG-7.

All of the Park's *H. hualalaiensis* trees are located also in Kīpuka Puaulu. Trees of this species are labeled KP-HH- followed by individual tree numbers. The 11 trees are in two groups of six and five trees, respectively. Part of the latter group is a sixth tree that appears to be a natural F_1 hybrid. This tree is untagged.

There are 16 F_2 *H. x puakuahiwi* trees in Kīpuka Puaulu. Eight are loosely grouped in one area and eight are solitary in distribution. All hybrid trees in Kīpuka Puaulu are labeled KP-HX-F2- followed by individual tree numbers.

There are two F_1 and 17 F_2 *H. x puakuahiwi* trees in Kīpuka Kī. Both F_1 trees have a number of untagged F_3 trees beneath their canopies. The F_1 trees are labeled KK-HX-1 and KK-HX-2. The F_2 trees are labeled KK-HX-F2- followed by individual tree numbers. Five of the "F_2" trees are unnumbered. Tags on these trees indicate they are possible backcrosses with a parent *H. hualalaiensis* tree which once grew in the same spot as the five hybrids (a falling limb from a large *Sapindus* tree broke down and killed the *H. hualalaiensis* tree in about 1974). In

such case these five hybrid trees would actually be F_1 backcrosses. Nevertheless, while their origin is uncertain, they are hybrid trees.

No F_3 trees in Kīpuka Kī are labeled because it is not certain if they are actually F_3 trees or are F_2 in origin. All grow beneath the canopies of the F_1 trees, and what might be F_3 trees are growing also under the canopies of F_2 trees.

There are five F_2 hybrids at the 'Āinahou Ranch house labeled AR-HX-F2-1 through -5. Other aluminum labels on these trees give a Boy Scout Troop number which planted the trees.

A KEY TO HIBISCADELPHUS SPECIES

1. Involucral bracts free or connate only at the bases.

    2. Longest bracts usually less than 3 mm long; found in the wild only on Mt. Hualalai on island of Hawaii, and elsewhere in the State under cultivation including Kipuka Puaulu in Hawaii Volcanoes National Park . . . . . H. hualalaiensis

    2. Longest bracts usually more than 3 mm.

        3. Longest bracts usually more than 20 mm long; now extinct in the wild in Kipuka Puaulu but is grown under cultivation back in Kipuka Puaulu and elsewhere in the islands including Maui and Oahu . . . . . H. giffardianus

        3. Longest bracts usually less than 20 mm.

            4. Leaves usually 8 cm wide or less; found originally in the wild on western slopes of Kohala Mountains above Kawaihae, but now believed to be extinct . . . . . H. bombycinus

            4. Leaves usually 8 cm wide or more.

                5. Calyx apex in bud prolonged into a beak (see Fig. 1, D & E; Baker & Allen 1977); found under cultivation in various localities in Hawaii including Hawaii Volcanoes . . . . . H. x puakuahiwi

                5. Calyx apex in bud not prolonged into a beak; found originally on Maui on Haleakala but now believed to be extinct . . . . . H. wilderianus

1. Involucral bracts connate through 1/3 their length; found in wild only on Kauai, but elsewhere under cultivation . . . . . H. distans