

within historic range, and (4) research on species biology and ecology (Service 1994, 1995, 1996, 1997, 1998a, 1998b, 1998c, 1999). Thus, the long-term recovery of these species is dependent upon the protection of existing population sites and potentially suitable unoccupied habitat within their historic range.

The overall recovery goal stated in the recovery plans for each of these species includes the establishment of 8 to 10 populations with a minimum of 100 mature, reproducing individuals per population for long-lived perennials; 300 mature, reproducing individuals per population for short-lived perennials; and 500 mature, reproducing individuals per population for annuals. There are some specific exceptions to this general recovery goal of 8 to 10 populations for species that are believed to be very narrowly distributed on a single island and the proposed critical habitat designations reflect this exception for these species. For example, the recovery goals for *Cyanea undulata*, *Dubautia pauciflora*, *Hesperomannia lydgatei*, *Labordia lydgatei*, and *Viola helenae* are five populations for each species with 250 individuals in each population. The numbers of individuals and populations for these five species are based on our current understanding of these species and our current understanding of the unique biological characteristics of Wahiawa Bog. These numbers should provide for the maintenance of the majority of the genetic diversity of each species, and assurances that a single catastrophic event will not destroy all members of a species (Service 1994). To be considered recovered, the populations of a multi-island species should be distributed among the islands of its known historic range (Service 1994, 1995, 1996, 1997, 1998a, 1998b, 1998c, 1999). A population, for the purposes of this discussion and as defined in the recovery plans for these species, is a unit in which the individuals could be regularly cross-pollinated and influenced by same small-scale events (such as landslides), and which contains a minimum of 100, 300, or 500 mature, reproducing individuals, depending on whether the species is a long-lived perennial, short-lived perennial, or annual.

By adopting the specific recovery objectives enumerated above, the adverse effects of genetic inbreeding and random environmental events and catastrophes, such as landslides, hurricanes, or tsunamis, that could destroy a large percentage of a species at any one time may be reduced (Menges 1990; Podolsky 2001). These

recovery objectives were initially developed by the HPPRCC and are found in all of the recovery plans for these species. While they are expected to be further refined as more information on the population biology of each species becomes available, the justification for these objectives is found in the current conservation biology literature addressing the conservation of rare and endangered plants and animals (Beissinger and Westphal 1998; Burgman *et al.* 2001; Falk *et al.* 1996; Ginzburg *et al.* 1990; Hendrix and Kyhl 2000; Kariava and Wennergren 1995; Luijten *et al.* 2000; Meffe and Carroll 1996; Menges 1990; Murphy *et al.* 1990; Podolsky 2001; Quintana-Ascencio and Menges 1996; Taylor 1995; Tear *et al.* 1995; Wolf and Harrison 2001). The overall goal of recovery in the short-term is a successful population that can carry on basic life-history processes, such as establishment, reproduction, and dispersal, at a level where the probability of extinction is low. In the long-term, the species and its populations should be at a reduced risk of extinction and be adaptable to environmental change through evolution and migration.

Many aspects of species life history are typically considered to determine guidelines for species' interim stability and recovery, including longevity, breeding system, growth form, fecundity, ramet (a plant that is an independent member of a clone) production, survivorship, seed longevity, environmental variation, and successional stage of the habitat. Hawaiian species are poorly studied, and the only one of these characteristics that can be uniformly applied to all Hawaiian plant species is longevity (*i.e.*, long-lived perennial, short-lived perennial, and annual). In general, long-lived woody perennial species would be expected to be viable at population levels of 50 to 250 individuals per population, while short-lived perennial species would be viable at population levels of 1,500 to 2,500 individuals or more per population. These population numbers were refined for Hawaiian plant species by the HPPRCC (1994) due to the restricted distribution of suitable habitat typical of Hawaiian plants and the likelihood of smaller genetic diversity of several species that evolved from one single introduction. For recovery of Hawaiian plants, the HPPRCC recommended a general recovery guideline of 100 mature, reproducing individuals per population for long-lived perennial species, 300 mature, reproducing individuals per population for short-lived perennial

species, and 500 mature, reproducing individuals per population for annual species.

The HPPRCC also recommended the conservation and establishment of 8 to 10 populations to address the numerous risks to the long-term survival and conservation of Hawaiian plant species. Although absent the detailed information inherent to the types of population variability analysis models described above (Burgman *et al.* 2001), this approach employs two widely recognized and scientifically accepted goals for promoting viable populations of listed species—(1) Creation or maintenance of multiple populations so that a single or series of catastrophic events cannot destroy the entire listed species (Luijten *et al.* 2000; Menges 1990; Quintana-Ascencio and Menges 1996); and (2) increasing the size of each population in the respective critical habitat units to a level where the threats of genetic, demographic, and normal environmental uncertainties are diminished (Hendrix and Kyhl 2000; Luijten *et al.* 2000; Meffe and Carroll 1996; Podolsky 2001; Service 1997; Tear *et al.* 1995; Wolf and Harrison 2001). In general, the larger the number of populations and the larger the size of each population, the lower the probability of extinction (Meffe and Carroll 1996; Raup 1991). This basic conservation principle of redundancy applies to Hawaiian plant species. By maintaining 8 to 10 viable populations in several critical habitat units, the threats represented by a fluctuating environment are alleviated, and the species has a greater likelihood of achieving long-term survival and recovery. Conversely, loss of one or more of the plant populations within any critical habitat unit could result in an increase in the risk that the entire listed species may not survive and recover.

Due to the reduced size of suitable habitat areas for these Hawaiian plant species, they are now more susceptible to the variations and weather fluctuations affecting quality and quantity of available habitat, as well as direct pressure from hundreds of species of nonnative plants and animals. Establishing and conserving 8 to 10 viable populations on one or more islands within the historic range of the species will provide each species with a reasonable expectation of persistence and eventual recovery, even with the high potential that one or more of these populations will be eliminated by normal or random adverse events, such as the hurricanes that occurred in 1982 and 1992 on Kauai, fires, and nonnative plant invasions (HPPRCC 1994; Luijten